CANADA

DEPARTMENT OF MINES

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

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

MEMOIR 166

Geology and Ore Deposits of Rouyn-Harricanaw Region, Quebec

BY

H. C. Cooke, W. F. James, and J. B. Mawdsley

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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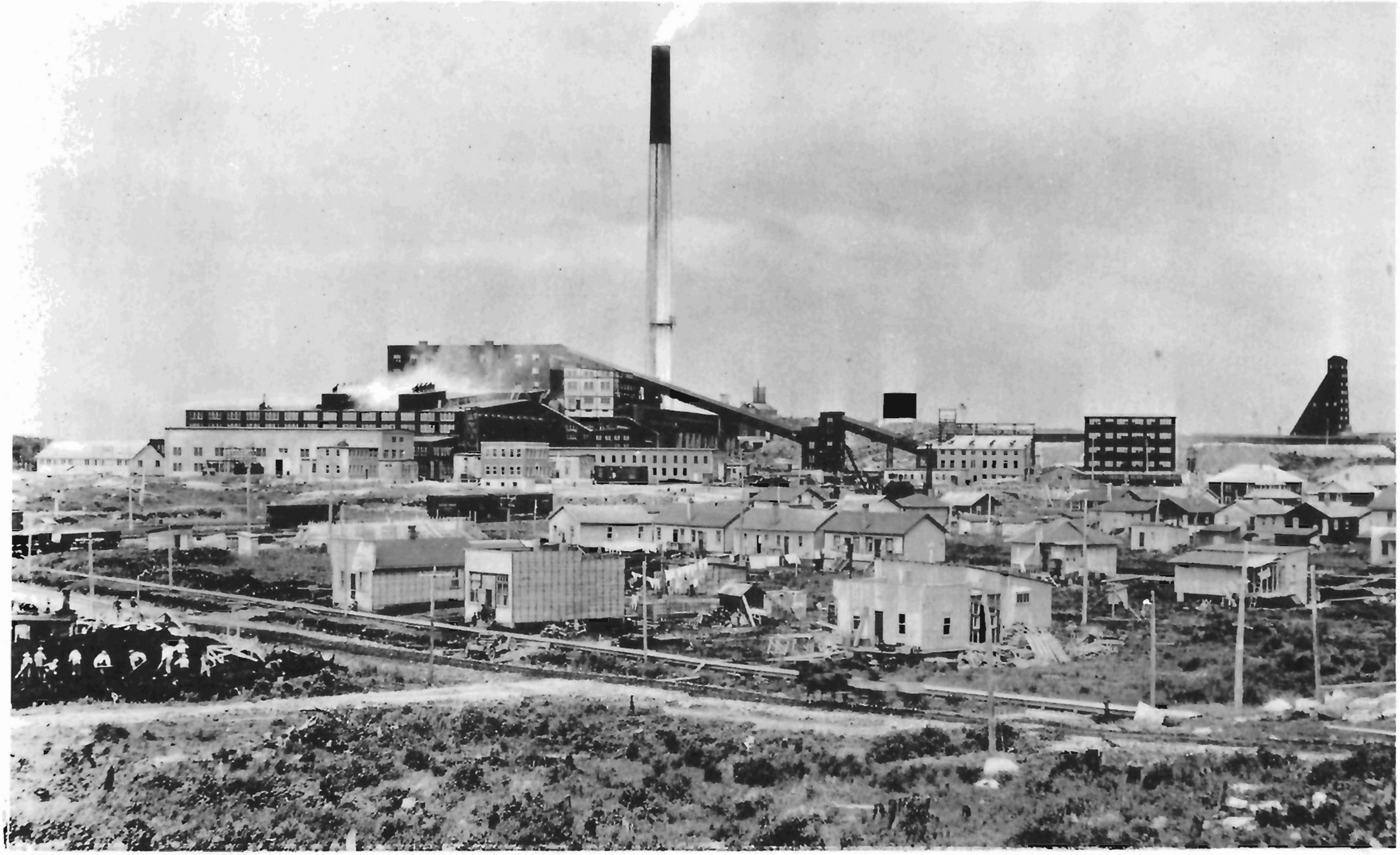

Horne mine and smelter.

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PREFACE

This report brings together and co-ordinates the results of a study that has been in progress for nine years, of an area in western Quebec. In this work several officers of the Geological Survey have been engaged, and their results have been published individually when completed. Additional examinations have, also, been made, the results of which have not yet been published. In the main, the different observers have been in complete accord as to the facts noted; but as information has accumulated, some changes of viewpoint have been inevitable, and render a re-statement of conclusions desirable. Furthermore, so many reports and articles have appeared that it becomes difficult for a reader to acquaint himself with the general situation, more particularly as some of the publications are out of print. In this report, therefore, a full re-statement of all facts obtained by all observers has been attempted.

The recent workers whose results are herein summarized include the authors of this report, B. S. Buffam, H. C. Gunning, and W. Gerrie. Their individual fields of work have been as follows.

H. C. Cooke, in 1922, mapped Opasatika area; in 1927, he mapped an area of some 90 square miles west and southwest of lake Dufault; in 1929, he mapped the Dufault granodiorite, the Clericy granodiorite, and other parts of Clericy and Kinojevis map-areas. Several seasons and parts of others, between 1922 and 1929, were devoted to the examination of various mines and prospects.

W. F. James mapped Duparquet area in 1922, and Rouyn area in 1923. In 1927 he revised part of the mapping of Duparquet area, and examined the Robb-Montbray, Coniagas, Eplett-Metcalfe, and other prospects in that area.

W. F. James and J. B. Mawdsley, in 1924-26, mapped Clericy, Kinojevis, Fournière, La Motte, Dubuisson, and Fiedmont areas, and examined such prospects as were under development at the time of mapping.

B. S. Buffam, in 1925-6, mapped Palmarolle and O'Brien areas, and the northeastern corner of Duparquet area.

H. C. Gunning, in 1925, revised the mapping of the northern edge of Opasatika area, and studied the mass of syenite porphyry in Beauchastel township.

W. Gerrie, in 1926, made a detailed study of the property of the Molybdenite Reduction Company, in LaCorne township.

All the workers have contributed information to each section of the report. No attempt has been made to indicate which of the authors wrote each section, because although a section may have been written by one author, and perhaps the bulk of the information in that section may have been supplied by him, nevertheless his material has always been supplemented by facts collected by the other joint authors.

Geology and Ore Deposits of Rouyn-Harricanaw Region, Quebec

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

The following report describes a district in Quebec lying just east of the Ontario boundary and, for the most part, south of the Canadian National railway. Reconnaissance of it began in 1872 with a traverse of Abitibi district by McOuat, and from then on a number of such examinations were made. From 1910 to 1915, during construction of the Canadian National railway, more detailed work was carried on by M. E. Wilson, J. A. Bancroft, W. J. Wilson, and T. L. Tanton, but most of this work was confined to the main water routes, and little of the country inland was examined. In 1922 the Geological Survey commenced a program of mapping on a scale of 1 mile to 1 inch, with the object of showing the geology in detail, and the location and extent of the outcrops. Since that time the Survey has maintained several parties in the region, so that now about 4,000 square miles of territory between the interprovincial boundary and Bell river have been mapped in detail, and the more important mining properties have been studied.

Geologic study in the region has kept pace, approximately, with the mining development. Late in 1922 discoveries of promising mineral occurrences attracted numerous prospectors to Rouyn area, and since that time a continuous succession of discoveries has gradually enlarged the area of interest to include the whole mapped district. Some of the occurrences have become proved mines, and others, less advanced, have been shown to merit further expenditure to prove their value. The success of these ventures has greatly stimulated the growth of the whole district. Two railways have been built into Rouyn district, from Taschereau on the north and from Kirkland Lake on the west; a fairly good summer road has been run from Makamik on the north to Angliers on the south, as well as numerous roads of poorer grade; and many other developments are in progress.

It is the purpose of this report to gather together all the information now known concerning this new mining district of western Quebec. The report is accompanied by a map on a scale of 4 miles to 1 inch. The information shown is compiled from maps on a scale of 1 mile to 1 inch, published in the Summary Reports of the Geological Survey, and from information still unpublished. Many details of topography and geology found on the larger-scale maps have been omitted.

Throughout the several field seasons the writers were greatly helped in their work by individuals, mining companies, and assistants, acknowledgments to whom have been made in the Summary Reports for the various years.

LOCATION AND AREA

The area under discussion extends from the interprovincial boundary to west longitude 77° 30′, and from north latitude 48° to 48° 45′. The area includes approximately 4,000 square miles. It has been divided for purposes of detailed mapping into ten map-areas. The four southernmost, named from west to east, are Opasatika, Kinojevis, Fournière, and Dubuisson. The adjoining tier on the north comprises Duparquet, Clericy, La Motte, and Fiedmont map-areas. North of the Duparquet and Clericy map-areas lie Palmarolle and O'Brien map-areas. Geological maps on a scale of 1 mile to 1 inch are available of Opasatika, Kinojevis, Fournière, Duparquet, Clericy, La Motte, Fiedmont, and Dubuisson map-areas.

MEANS OF ACCESS

Early travellers entered the district by way of Ottawa river, following the old established route of the Indians and traders to lake Abitibi by way of Opasatika and Dasserat lakes. The construction of the Temiskaming and Northern Ontario railway opened an alternative canoe route by way of Larder and Raven lakes; and, later, the Canadian National railways provided a convenient means of access to the northern part of the district. More recently a branch of the Canadian National railways has been constructed from Taschereau to Rouyn, and a branch of the Nipissing Central railway now connects Swastika and Rouyn. Great advances have also been made in the construction of roads, many of which are now suitable for automobile traffic. Although most of these are concentrated in the farming areas near the Canadian National railway, others have been built particularly to serve the mining districts. The most important is the provincial road that permits travel from Ville Marie and other places on lake Timiskaming to Makamik on the Canadian National railway.

WATER ROUTES

The area is well provided with water routes by which one may approach within a few miles of any locality. Several years ago all travel proceeded by these routes, but the new railways and highways have greatly lessened the volume of water traffic, and the water routes are now used chiefly by prospectors and others who require to reach the less accessible localities. Portages on the routes have been greatly improved of late years by the Forest Protection service of the province of Quebec.

The northwestern part of the area is traversed by La Reine, La Sarre, and Lois rivers. Large motor boats may conveniently be used on the two first-mentioned streams from the Canadian National railway to lake Abitibi, and from the lake up Duparquet river as far as Danseur portage. Above this point, large canoes fitted with outboard motors may be used to advantage.

From lake Duparquet, Magusi river provides a good route westward to the Ontario boundary. Eastward to lake Dufresnoy, the route is by way of a chain of shallow lakes and connecting streams. Several short portages are necessary and, in time of low water, canoeing is somewhat difficult.

South from Duparquet, Smoky river may be easily followed to a rapid about 4 miles south of the lake, and is navigable as far as Flavrian lake, but the upper part is obstructed by numerous rapids and beaver dams. Farther west, along the south shore of lake Duparquet, Kanasuta river enters. This river gives easy access to lake Dasserat and only four short portages have to be crossed. The other streams flowing into lake Duparquet are not navigable, being obstructed at frequent intervals by log jams and beaver dams.

From Dasserat lake, Kwaskwinadaga river is a convenient route to Labyrinth lake and the neighbouring parts of Ontario. A wide stream, also, leads to Arnoux lake, and at the southeast corner of lake Dasserat a navigable stream connects with lake Ogima on the Abitibi canoe route. None of the other streams flowing into lake Dasserat are suitable for canoeing, nor are those joining Kanasuta river.

Norman river, flowing into Arnoux lake, can be ascended to lake Norman and, in the early part of the season, as far as lake Daudin. O'Sullivan's line crosses Norman river and serves as a trail to the difficultly accessible parts of Duprat and Beauchastel townships. Another trail begins at a cabin about a mile from the mouth of a creek flowing into the southeast part of Arnoux lake, and runs northeast in Boischatel township.

The southeastern part of Duparquet area may be reached from lake Dufresnoy by way of Sills lake and lake Dufault, or from the Kinojevis River and Lake Osisko route from the south.

The southwestern part of the area, Opasatika area, may be reached from Quinze lake by a chain of rivers and lakes, leading through Barrière lake to lake Opasatika, whence a portage route may be followed to Washusk lake which drains into Ogima lake. A diversion of water across the former height of land now causes these lakes to drain southward and, if permitted to continue, will eventually divert all the drainage of Dasserat lake in the same direction. Another canoe route on which the portages are rather long leads from Barrière lake through lakes Albee and Evain to Kekeko lake, a part of the Kinojevis route.

Clericy and Kinojevis map-areas may be reached from either of the railways entering Rouyn district. Rouyn and Clericy stations are convenient points at which to begin canoe travel. Kinojevis river is the important route of these map-areas. It may be reached from Quinze lake by way of Ottawa river with only one portage around Sturgeon rapids, a few miles above lake Expanse. Its whole length from Ottawa river to Kewagama lake may be traversed in times of high water with but five portages. A tributary, Villemontel river, provides a good route to a point within 4 miles of Villemontel station on the Canadian National railways, and a good road connects the landing on the river with the village.

Montanier and Surimau townships, which are the most difficult of access in the region, may be best approached from Kinojevis river, from Darlens river, a tributary of the Ottawa, or by trail from Piché lake, Fournière township. Kewagama lake is reached either from Villemontel by way of Kinojevis river, or from Harricanaw river by Kewagama portage. The portage, 2 miles in length, is equipped with a track and motor lorry.

The eastern areas are drained by Harricanaw river, the largest stream in the region. Small steamboats can be operated on it for a distance of about 70 miles above Amos, and in past years a fairly regular service has been maintained. Boats for private use may also be chartered without difficulty at Amos. The headwaters of Harricanaw river are suitable for canoes as far as Lamy lake, Sabourin township, and into the southwest corner of Courville township.

Natagagan river in Fiedmont township used to be suitable for canoeing, and was an excellent route from the railroad north to Bell river. In recent years, however, it has been used for driving timber, and in consequence is much obstructed by log jams and deadheads for about 10 miles below Barraute.

ROADS

A system of roads built under the direction of the provincial government is gradually being extended to cover the arable sections of the country, and also to afford access to the mining districts. The roads are of a character suitable to a sparsely settled region, ordinary dirt roads, in places faced with gravel wherever a cheap local supply is available. They are usually well ditched and graded, and are excellent in dry weather. In the spring and autumn, however, when there is much rain, the surfaces are deeply covered with wet and slippery clay rendering them impassable to all but horse-drawn vehicles.

In addition to these better-class roads, two poorer grades occur. The first, which may be called bush roads, is made by merely clearing away the trees and stumps sufficiently to make a track whereby teams may travel. No attempt is made to ditch, grade, or surface these roads, except that where they cross swamps a " corduroy " of logs is laid down. Except in the driest weather, therefore, these roads are usually deep in mud where they cross soil-covered areas; and they are always exceedingly rough where the ground is stony.

The second class, the winter roads, cannot be used for summer travel. They are made merely by clearing away the trees from the proposed roadway; and where possible they usually follow lakes, quiet streams, or open swamps to avoid unnecessary cutting and to obtain flat gradients. The heavy snows of the region cover the logs, stumps, and underbrush, giving a good surface for teaming. Such roads are much used when the expense of making a summer road is not justified, as in lumbering operations and for bringing supplies into areas to be prospected on a large scale. Even where mining operations are relatively far advanced these roads are much used for bringing in the heavier food supplies, machinery, and so on, as the cost of teaming on the snow surfaces is low.

A trunk road parallels the Canadian National railway across the north end of the region under discussion, from the interprovincial boundary as far as Senneterre on Bell river. From this, roads run north and south for distances of 5 to 10 miles, distances representing the maximum extension, at present, of farming operations. In a few places, such as along Harricanaw river, the roads may run as much as 20 miles from the railway, serving farms that were first taken up on these good waterways.

A second trunk road has been recently opened from Makamik on the Canadian National railway via Rouyn to Angliers, the terminus of the branch of the Canadian Pacific railway along the east side of lake Timiskaming. This road has been graded and gravelled over all of this distance. Between Makamik and Rouyn the road is fairly straight and runs almost due north and south. From Rouyn it runs somewhat south of west for about 12 miles, almost to Renaud lake, then turns almost directly south again, passing east of Opasatika lake. A branch, which has been cleared but not yet ditched or graded, runs south from Rouyn around the south side of Pelletier lake, across the head of Kekeko lake, and along the south side of Kekeko hills to join the main road again near Olier lake. From this trunk road short stretches of ordinary road run off to serve various mining properties.

Between Lake Fortune mine and the interprovincial boundary at Cheminis the existing road was originally built as a bush road for hauling supplies into Lake Fortune mine; and the western part, which lies on high ground, can still be used. Several miles of the eastern part is in poor shape, but was used in 1927 for hauling supplies for construction of the Nipissing Central railway.

The block of country east of Rouyn for about 30 miles has as yet no roads, except for a short stretch leading from Rouyn to Rouyn lake, where the water route from Angliers ends. This block is bounded on the north by the wide, rough barrier of Abijevis hills, through which no road has yet been driven.

The first road east of the hills is short, leading from Villemontel to the head of navigation on Villemontel river 4 miles away. A rough continuation of this road runs south across Villemontel township to Kinojevis river, and was formerly continued as a winter road as far as the molybdenite deposits on Indian peninsula, Kewagama lake. The latter section has not been used for some years, and is probably overgrown with brushwood.

A fairly good road runs down the west side of Harricanaw river for 20 miles from Amos to Malartic lake. In the autumn of 1928 the Quebec government began an extension of it, to reach the Malartic property in

Fournière township. The extension is now fully cleared, necessary bridges are built, and it is to be properly ditched and gravelled throughout its entire length. A winter road branches off from it, and leads to the O'Brien and Thompson-Cadillac properties on the western side of Cadillac township.

East of Amos the usual farm roads run for 4 or 5 miles from the railway, and render access easy to the northern edge of the mapped area. Other than these only two need be mentioned. A winter road starts at the end of a farm road on the west side of Fiedmont lake, runs southwest across the northwest corner of Senneville township into Varsan, crosses Harricanaw river, and ends at the Stabell mine. A branch of it strikes off in Senneville township and runs southeast 3 miles to a sawmill at the north end of Blouin lake. The second road is a bush road from the south end of Blouin lake to the Clark property about 4 miles to the southeast. A trail connects the end of this road with Bourlamaque river, 5 miles to the east.

RAILWAYS

All parts of the region under discussion are now readily accessible from a railway line. The Canadian National railway, constructed 1910 to 1915, runs through the northern part in a direction slightly north of west, crossing the navigable streams which almost all run north and south. The traveller wishing to reach any desired point within the district may, therefore, leave the railway at the nearest river crossing, and reach his objective in not more than two days of canoe travel.

Additional railway service is provided to the western section where the mining operations have warranted construction. A branch of the Canadian National railway, known as the Rouyn Mines railway, was run in 1925 from Taschereau to Rouyn, a distance of 44 miles. A spur line connects the Waite-Ackerman-Montgomery property with the main line, and another spur to the Amulet mine is under construction. Daily trains make connexions at Taschereau with the through trains on the main line of the Canadian National.

In 1926 the Nipissing Central railway, a subsidiary of the Temiskaming and Northern Ontario railway, was extended from Cheminis village on the interprovincial boundary to the town of Rouyn. Daily trains now run between Swastika and Rouyn, so that the traveller may leave Toronto or Montreal on the usual evening train, and arrive in Rouyn in less than 24 hours.

FIELD WORK

One of the earliest traverses of this region made by a geologist was a trip by Walter McOuat, in 1872, along the canoe route from lake Timiskaming to lake Abitibi, by way of Opasatika and Dasserat lakes. No further reconnaissance of the region was undertaken until 1901, although

Robert Bell in 1887 and 1895 explored Grand lake Victoria and Bell river, lying just to the east. In 1901 J. F. E. Johnston mapped La Sarre river, Makamik lake, Lois lake and river, Kinojevis river, and the canoe route from lake Duparquet to Dufresnoy lake. In 1904 W. A. Parks made a trip through Dasserat and Labyrinth lakes. During the summers of 1906 and 1907 W. J. Wilson investigated the geology along the waterways and survey lines adjacent to the projected location of the National Transcontinental railway. In the same years J. Obalski, superintendent of the Quebec Department of Mines, made some reconnaissance trips through the region. In 1909 T. L. Walker examined the molybdenite occurrences near Kewagama lake, for his report on the molybdenum ores of Canada. M. E. Wilson spent the three seasons of 1908, 1910, and 1911, and part of the season of 1909, in making a general reconnaissance of the whole area between the interprovincial boundary and Kewagama lake, and published a detailed report accompanied by a map on a scale of 4 miles to 1 inch. In 1911 and 1912 J. A. Bancroft mapped the geology around Kewagama lake and the headwaters of Harricanaw river, and supplemented his reports with a map on a scale of 4 miles to 1 inch. In 1914 and 1915 T. L. Tanton mapped the Harricanaw-Turgeon basin from latitude 50 degrees to the National Transcontinental railway. This mapping included practically all of the Palmarolle and O'Brien map-areas.

The more detailed study of the area began in 1922 when H. C. Cooke and W. F. James mapped in detail, on a scale of 1 mile to 1 inch, the greater part of Opasatika and Duparquet map-areas. In the following year W. F. James and Robert Harvie continued this mapping into Kinojevis and Clericy areas, and H. C. Cooke made a detailed study of mineral discoveries from lake Demontigny to the interprovincial boundary. In 1924 W. F. James and J. B. Mawdsley completed the mapping of Clericy and Kinojevis areas. In the same year Wright and Segsworth, working independently of the Survey, described the Timiskaming sediments in Destor township. In 1925 James and Mawdsley mapped the La Motte and Fournière areas, and examined certain mineral deposits in Desmeloizes and Trécesson townships; B. S. Buffam mapped the northern end of Duparquet area, which was left unfinished in 1922, and carried the mapping eastward through Destor and Aiguebelle townships. H. C. Gunning completed the mapping of the northern end of Opasatika area, left unfinished in 1922; and H. C. Cooke studied in detail certain mining properties in Dasserat, Beauchastel, Rouyn, Dufresnoy, and Duprat townships. In 1926 James and Mawdsley mapped Fiedmont and Dubuisson areas, B. S. Buffam Palmarolle and O'Brien areas, and Cooke covered the central part of Duparquet area, which had been unmapped up to this time, and revised the detailed mapping of eastern Duprat, the southwestern quarter of Dufresnoy, and the northwestern quarter of Rouyn townships. In 1927 W. F. James revised the mapping of the rest of Duparquet area, and examined in detail the mineral discoveries in it; H. C. Cooke studied the Aldermac and Horne mines, together with some of the smaller properties near Rouyn.

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LUMBERING

The timber of the region is still of importance. Spruce, the mainstay of the pulpwood industry, is the most valuable wood, but white, red, and Banksian pine, cedar, balsam, and birch also occur and are used to a minor extent.

Stands of white pine are relatively few. Some excellent timber of this kind was noted on Dasserat, Duparquet, and Kewagama lakes, but no heavy growth of white pine occurs north of Grand lake Victoria. Red pine is more common. Some excellent red pine was observed in the southern townships of the area and in Joanne township. The Banksian or jack-pine flourishes throughout the region wherever there are sand-plains. Spruce is also widely distributed. It attains a large size on the clay-covered areas, but owing to the coldness of the soil it grows very slowly, and requires about 30 years to become large enough even for pulpwood. It also grows in the swamps, but the individuals remain small. Cedar occurs on the shores of many lakes and in swamps in the upland areas. Some of the trees attain a fair diameter at the butt, but taper rapidly and are commonly decayed in the centre. The value of the cedar in the region is small. Balsam is common, particularly in the western parts of the region. Near the Ontario boundary it has suffered greatly from the ravages of the spruce bud worm. It was observed that the damage caused by this pest diminishes eastward, and that east of the Harricanaw the balsams had suffered comparatively little. When attacked by this worm the trees soon die and are blown down, thus constituting a serious obstruction to travel. A dense growth of small shrubs such as raspberry springs up among the fallen trees, rendering passage through them still more difficult.

Birch frequents the higher ridges, and also occurs, along with poplar, wherever the normal evergreen forest has been destroyed by fire or by lumbering. The poplar and birch appear to be a necessary protection to the slower-growing spruce or pine, as the latter spring up beneath their shade and later displace them. Tamarack or larch used to be common but was almost all killed by the larch sawfly, which swept over the region in 1893 and later years. A new growth of tamarack has sprung up, however, and should be of economic importance in a few years. A few red and sugar maples were noted in the southern townships, but these trees are not found in numbers north of Grand lake Victoria. Ordinary poplar and Balm of Gilead or rough-barked poplar form large groves on the clay areas along many streams.

A very heavy undergrowth of small shrubs is found everywhere on the clays, and makes travel exceedingly difficult. Scrub maple, hazel, alder, raspberry, and labrador tea are the more common shrubs.

Most of the timber of the district is used for wood pulp. Much of it is cut by colonists while clearing their lands, and either hauled over the roads or floated downstream to the railway where it is peeled and shipped to the pulp companies. The cutting of jack-pine for railway ties is also carried on, but as an industry is not of the same importance as the cutting of pulpwood.

During recent years, since the development of mining, there has been an increase of lumbering on the timber limits, partly because of the growth of the local market and partly because the fire hazard has risen rapidly with the increase of population. Extensive operations were commenced in 1923 near the banks of Kinojevis river and are being extended each year farther from the river. About 1924 operations were begun in the upper waters of the Harricanaw, and have since been extended into the country about Kewagama lake. About 1925 lumbering began south of lake Abitibi, and will probably be continued for some years to come.

Although most of the timber, as stated, is used for pulp, a certain proportion is converted into lumber. Most of this is absorbed locally for building purposes, but a little is shipped. The lumber is apt to be small and of rather poor quality, and most of that shipped is said to be used in the manufacture of crates, boxes, and other articles requiring cheap grades of wood.

The country between the Ontario boundary and Kewagama lake has been the scene of several serious fires that destroyed large amounts of timber. Large areas in Montbray township were fire-swept prior to 1920, and the northern part of the same township has suffered severely from fire since that year. Areas north and west of Rouyn have been stripped of their timber since 1923, and also large tracts in the vicinity of Kewagama lake.

The Quebec government has made a serious effort to lower the fire hazard. Rangers, under the supervision of inspectors, are posted at strategic points throughout the district. A permit system serves as some check on the identity and movements of travellers. Propaganda by means of advertising and signs posted in conspicuous places has been instituted to inculcate in settlers and travellers the necessity of preventing fire. The use of fire in clearing new land, a very common cause of forest fires, is allowed only on receipt of a permit from a fire ranger, and this is granted only when the danger of spreading is at a minimum. Fire-fighting apparatus is in use, but it is realized that the employment of such means is of less importance than prevention. Airplanes have been employed both as regular patrols and for locating suspected fires and transporting fire-fighting equipment to them.

The importance of the lumber industry in this newly settled district is perhaps not thoroughly appreciated. In addition to supplying the requirements of the paper industry it provides settlers with an immediate income while they are clearing their lands and the returns from agriculture are necessarily small. Settlers can also work on the timber limits in the winter, when other remunerative work is scarce, and thus add to their income. The industry also provides a convenient and moderately cheap local supply of lumber, very necessary in a district where the construction of many buildings is in progress. The conservation of this valuable asset is worthy of serious effort.

FARMING

Settlement in Abitibi region began with the construction of the Quebec-Cochrane section of the Canadian National railway in 1912, and is still in progress. Settlers of several types are entering the country, but the most important class, numerically and otherwise, is the farmer. The settled area begins at Senneterre on Bell river and extends to the interprovincial boundary, a distance of more than 100 miles. Small villages have grown up where the railway crosses the larger waterways and in some of the better-developed farming areas. The villages on the waterways are the centres of a rather extensive pulpwood industry, and, in many cases, support small sawmills that produce lumber for local consumption. The first settlers, of course, located near the railway except where navigable rivers provided routes to good farming areas farther away. Road-building during the last few years has extended the settled areas farther and farther from the railway.

A vigorous colonization program has long been part of the policy of the provincial government, and is in large part responsible for the rapid settlement of the district. The colonists are drawn from the more crowded farming sections in the older parts of the province, and, in some instances, from the cities. A few foreign settlers have also been brought in. Most of the people have had some farming experience and are well suited by training and temperament for the work of pioneers. Under the government policy land is sold to the settlers at very low prices and on long terms. In return for a deed to his farm the settler clears it of bush, brings it under cultivation, and pays a small instalment annually on the price. Settlement is controlled by opening new districts for colonization as means of access become available, and as the older districts become more developed. This control prevents isolation of settlers and taking up unsuitable land. The pulpwood cut during the process of clearing is an important source of revenue to the colonists, many of whom have very little capital. Construction of government roads also provides work for them during the early critical years of settlement.

A large part of the area is suitable for farming. It is estimated that more than 60 per cent of many townships is underlain by arable land, and in some townships the proportion may be even higher. Much land that is at present too wet for farming may be easily reclaimed by drainage, or in many cases simply by clearing away the thick vegetation. A large proportion of the soil is rather heavy clay, but all gradations exist between such clay and pure sand. The soil is very sandy in the eastern sections particularly, as around Fiedmont lake. The Canadian National railway between Senneterre and La Reine traverses a wide area of very good soil.

The district suffers from several disadvantages, chiefly late frosts, that not infrequently destroy the crops. September frosts, also, sometimes damage unharvested crops. In some years a heavy frost occurs in the middle of the summer. It is quite a widespread opinion that the danger from frosts will be lessened as larger areas of the country are cleared and drained. Although no accurate data are available to prove the truth of this idea, it is said to have been found correct in Lake St. John district, as development proceeded. It seems reasonable to believe that with the removal of forest growth, the heavy snow will be melted more quickly in the spring, and the ground be brought to a higher temperature sooner than at present.

Although most of the crops grown farther south will also probably be grown in Abitibi district, certain selected crops will undoubtedly prove the most profitable. The Federal Government maintains an experimental farm at La Ferme, a few miles west of Amos. Much experimental work has already been done, and some valuable results already obtained. The development of hardy varieties of various plants will be of the greatest importance to the district. At present the hardy root crops and certain of the cereals are the principal ones grown to advantage. Hay is almost everywhere an excellent crop, but freight charges to such centres as Montreal and Quebec are too great for it to be shipped at a profit. It, therefore, seems better to concentrate on developing herds and to ship meat and dairy products on which the freight charges will be relatively less.

The general increase in the population and the growth of mining centres should provide a much larger local market for agricultural produce than has been available in past years. A better organization among the farmers or the establishment of a system of marketing would probably be of advantage.

WATERPOWER

A number of small waterpowers are available within the area, but none has yet been developed. The power used in the mining districts is brought from Quinze river. Some of the small powers may be worth developing for local uses when population increases sufficiently to justify the expense of doing so.

The power sites available within the area and estimates of the amount of power they will develop are set forth in the following table prepared by the Dominion Water Power and Reclamation Service.

Water Resources Inventory

Location of rapid or fall	Head (Feet)	Area above site (Sq. miles)	Fstimated flow (Cubic feet per second)		24-hour H.P. at 80% efficiency	
			Ordinary minimum	Ordinary six-month	Ordinary minimum flow	Ordinary six-month flow
Harricanaw river:						
Town of Amos	3·3	1,400	420	1,120	126	336
2½ miles below Amos	2·5	1,410	423	1,128	96	256
8 miles below Amos	4·3	1,480	444	1,184	174	463
3 miles below Obalski lake	4·8	1,580	474	1,264	207	552
NOTE.—Estimates of other waterpowers on Harricanaw river to its mouth may be obtained from the Dominion Water Power and Reclamation Service. Many of these powers are large.						
Piché creek, 2½ miles below Piché lake	15	100	30	80	41	110
Bourlamaque river, near south boundary Bourlamaque tp	40	83	24	66	87	240
Bourlamaque river, 17½ miles above Blouin lake	30	190	57	152	155	415
Bourlamaque river, 16½ miles above Blouin lake	9	193	57	154	47	126
Bourlamaque river, 16 miles above Blouin lake	5	194	58	155	26	70
Bourlamaque river, 14¾ miles above Blouin lake	14	203	61	164	78	209
Bourlamaque river, 14¼ miles above Blouin lake	4	209	63	167	23	60
Bourlamaque river, 14 miles above Blouin lake	9	213	64	170	52	140
Dufault creek:						
4 miles above mouth	8	87	22	56	16	40
3½ " "	12	90	23	58	25	63
3 " "	30	93	24	60	65	164
2½ " "	10	95	24	62	22	56
1½ " "	12	100	26	65	28	71
Creek from Olier lake:						
1 mile from Opasatika lake	33	32	8	21	24	63
Kinojevis river:						
1st rapid below Kewagama lake, Preissac tp	9	410	106	266	87	218
2nd rapid below Kewagama lake, Preissac tp	5	420	109	273	50	124

Water Resources Inventory—Continued

Location of rapid or fall	Head (Feet)	Area above site (Sq. miles)	Estimated flow (Cubic feet per second) Ordinary minimum	Ordinary six-month	24-hour H.P. at 80% efficiency Ordinary minimum flow	Ordinary six-month flow
Kinojevis river—Continued						
3rd rapid below Kewagama lake, Villemontel tp	6	435	113	283	62	154
Flat rapid, Manneville tp	4	625	162	406	59	148
Cascade rapid, Manneville tp	26	650	169	422	406	997
Clayhill rapid, Clericy tp	18	755	196	490	320	800
Chute 1 mile below Clayhill rapid	2	770	200	500	36	90
Windfall rapid, Clericy station, Rouyn Mines ry	7	795	206	516	131	328
Rapid, SE. corner Dufresnoy township	2	970	252	630	46	115
Abitibi river and tributaries:						
Abitibi river, 1½ miles below Duparquet lake	5	645	193	516	88	235
Kanasuta river, 1 mile below Dasserat lake	35	175	52	140	165	445
Kanasuta river, 7 miles below Dasserat lake	6	205	61	164	33	90
La Sarre river, 19 miles above mouth	4	523	157	418	57	152
La Sarre river, 16 miles above mouth	24	541	162	433	353	945
La Sarre river, 12½ miles above mouth	10	583	175	466	160	424
La Sarre river, 11½ miles above mouth	8	585	175	468	127	350
Lois river, 12 miles above mouth	35	84	25	67	80	213
Lois river, 9 miles above mouth	6	107	31	85	17	46
Lois river, 8 miles above mouth	32	113	34	90	99	262

FAUNA

The animals of the district are of the same varieties as in the other northern parts of Ontario and Quebec. Moose, deer, and caribou are the largest. Moose are much less abundant now than in 1922, partly because they have been frightened away by the larger numbers of people in the district, and partly because great numbers have been killed. They are still important as a source of food for the Indians; each autumn, also, they attract many hunters to the country. Red deer are comparatively few, and were less numerous than the moose even before the influx of prospectors and settlers. Caribou are probably merely occasional visitors. They may come from long distances and pass through parts of the district periodically. In the autumn of 1923 a herd of about a dozen was reported near Rouyn lake.

The fur-bearers are not numerous, and appear to be suffering rapid depletion. Trapping supports a few Indian families, and some white trappers operate sporadically. Beaver were at one time very numerous, but not now. The reason for their decrease is undoubtedly wholesale slaughter. Red foxes are still plentiful, chiefly in the sandy areas. Otter, mink, marten, and fisher are trapped, but are not particularly abundant. Lynx and wolf are reported, but seldom seen. Black bears are not uncommon, and appear to have increased since the burning of large areas of forest, in 1923-24, gave rise to great blueberry districts. Muskrats are numerous in the sluggish streams. A few skunks occur, and smaller animals, such as weasels, rabbits, squirrels, and chipmunks, abound.

Gulls, tern, black duck, and saw-bill duck frequent the larger streams and lakes. Bitterns live around the marshy borders, and ravens and loons are fairly common. Partridge were numerous a few years ago, but have shown a remarkable decrease since 1925, probably owing to a succession of cold, wet springs. Smaller birds of many varieties are known, but on the whole their numbers are much less than farther south. It is probable that the bird population will increase with the growth of settlement.

Fishing constitutes a very small industry. Some commercial fishing has been carried on intermittently on Kewagama lake and the upper waters of Harricanaw river, chiefly for export. Some fishing has been done in Abitibi and Duparquet lakes, and, also, on Dasserat lake since the completion of the Nipissing Central railway to Rouyn. Whitefish and sturgeon are principally sought, though pike and pickerel are also available in moderate quantity.

As most of the lakes lie in clay basins, their muddy waters are not suitable for the finer varieties of fish. Thus, while pike and pickerel abound, trout are almost absent, except in the few sandy or rocky lakes. Trout of large size may be caught in Trout or Clarice lake on the Ontario boundary, and in lakes Eileen (La Haie) and Abijevis (Sault) in Abijevis hills. Smaller brook trout are said to occur in a small stream draining from Abijevis hills into Kinojevis river, near the centre of Manneville township. A few small-mouthed black bass occur in Dasserat lake, in Duparquet lake, and in Opasatika lake.

CHAPTER II

TOPOGRAPHY

GENERAL PHYSIOGRAPHIC HISTORY

A general understanding of the recent history of the Canadian Shield, of which Rouyn-Harricanaw region is a small part, is essential to a proper study of its topography; the events of this history are, therefore, briefly stated, although lack of space forbids a full discussion of the evidence on which the conclusions are based.

It has been proved by many different writers that the Canadian Shield is an ancient peneplain; that is to say, that it has been reduced by erosion to a comparatively uniform level. There is evidence that this took place for the first time very early in the Precambrian era, before the deposition of the Cobalt series; later, after the Keweenawan folding and the elevation of the Killarnean mountain ranges along the north shore of what is now lake Huron, the process was renewed, and early in the Palæozoic the country was once more reduced to a low plain. It is probable that the process of elevation followed by long-continued erosion was repeated at least twice more during geologic history. However this may be, it is reasonably certain that in late Tertiary time, just prior to the last Ice age, the Canadian Shield was a high plateau, standing approximately 600 feet higher above the sea than at the present time. Hudson bay at that time did not exist as a body of water, but was a broad, low plain through which great rivers flowed to Hudson strait. On the uplands east and west of this central plain the great glaciers of the Quaternary period formed and grew, attaining finally, according to Coleman, thicknesses of about half a mile near the margins in Gaspe and northern Labrador, but which must have been much greater near the centres of the sheets. The weight of the enormous masses of ice depressed the land surface about 1,200 feet; so that toward the end of the Ice age the general level of the country was about 600 feet lower than at present. As the ice melted the land gradually rose, continuing thereafter until it attained the present height. No satisfactory evidence of uplift within recent times has been found; so that it is probable a condition of equilibrium has now been reached that will endure for a considerable period of geologic time.

The legacy of the ice-sheets is of the profoundest importance to Canada. It has modified and will continue to modify the course of its social and economic development. The ice-sheets in their advance scraped from the surface the deep covering of soil and weathered rock, the accumulation of previous ages of weathering, and carried these products completely away, to dump them in southern Ontario and the northern part of the United States, in the Atlantic ocean, and on the Great Plains. For this good soil the ice-sheets substituted the present thin and patchy covering made up chiefly of boulders, gravel, and sand. Thus they ruined the agricultural possibilities of somewhat more than half of Canada; possibilities that can never return until the slow lapse of ages once more crumbles the gravel, the boulders, and the rock surfaces to a deep loam. However, this disaster brought its compensations. The removal of the soils laid bare clean rock surfaces, which can be readily examined for the occurrence of mineral. It thus contributed to the discovery of the country's mines, an asset whose value is but now beginning to be appreciated. Again, the deposits of the glaciers completely disorganized the original drainage, filling many of the former river valleys and forcing the water to find new channels to the sea. The result is the network of lakes united by short lengths of stream in which quiet stretches alternate with rapids or falls, that now covers the whole of northern Canada, and that renders comparatively accessible any part the traveller may wish to reach. From the earliest times this geographical peculiarity has been the controlling influence in the exploration and development of the country.

The great post-glacial lake beds are likewise an inheritance from the Ice age. They are made up of the fine clays and silts deposited in lakes ponded between the retreating ice front and a divide. Many such lake deposits, great and small, are found throughout the Canadian Shield and near its borders. The two most important are the rich alluvial plain of southern Manitoba and the great "clay belt" of northern Ontario and Quebec that covers the greater part of the particular area discussed in this report.

About the same time as the lake beds were laid down, corresponding sediments were being deposited in the sea. It will be recalled that the land surface was still depressed some 600 feet below its present elevation; so that surfaces now up to 600 feet above sea-level were then bays and estuaries of salt water. In such localities the glacial streams deposited their load of silt and clay, forming beds afterwards laid bare by the elevation of the land. The rich clay lands of the lower St. Lawrence, lower Ottawa, and lower Gatineau rivers were formed in this way; so, too, were the great areas of clay land surrounding the southwest side of Hudson bay and running up the valleys of the great rivers; so, too, were the fertile farming lands around lake St. John. The series of bench-like terraces that give Montreal its peculiar configuration were likewise formed at this time, each terrace representing a period of standstill in the gradual uplifting of the surface.

LOCAL TOPOGRAPHY

As already stated, the greater part of the Rouyn-Harricanaw region is overlain with lacustrine clays. They form a surface that in wooded areas seems perfectly flat, but which, where clearing has exposed longer reaches to view, is seen to be gently rolling. Here and there through the clayey blanket project the larger irregularities of the surface on which the clay was deposited. Some of these knobs and ridges consist of loose materials dropped by the ice-sheet in its retreat—terminal moraine, eskers, kames, and the like—and these are usually low and of comparatively small size. The remainder are rock, partly covered with morainal materials. They vary in size from small, low outcrops barely projecting above the clay to ranges of hills miles in length and rising hundreds of feet above the general level. The hilly areas are generally known as the rocky uplands, and the low remainder is referred to as the clay belt.

ROCKY UPLANDS

The rocky uplands are largely concentrated toward the western end of the area. Toward the eastern end the proportion of hilly country is very much smaller. Indeed, in the Fiedmont and Dubuisson map-areas the total area of exposed rock is probably less than 5 per cent of the whole.

Geologically there is a close relationship between the proportion of exposed rock and the nature of that rock. The Cobalt series, outcropping in the western end of the area, is very resistant to erosion, and practically all the area underlain by it stands high. Most of the loftiest hills of the region are concentrated within the small area of Cobalt series; mount Cheminis, which rises 900 feet above the general level, Swinging hills, and Kekeko hills, both with about 700 feet of relief, are all parts of this range; the average level, though less lofty, is nevertheless great enough to form a striking feature of the normally flat landscape.

Other rocks that tend to form upland areas are the Timiskaming conglomerates, the granites, the dykes of later gabbro, and the rhyolite lavas. For the most part these rocks do not form ridges either so high or so continuous as the Cobalt series. Their tendency rather, as will later be brought out, is to form elevations rising to some 200 feet above the level of the clays; and the elevated parts are usually of no great size, but sink within a mile or two to the general level. Thus the areas underlain by these rocks may contain a large proportion of outcrop, but these outcrops are neither so large nor so continuous as within the areas of Cobalt series.

Exception may perhaps be made in the case of some of the areas of Keewatin rocks, certain hilly parts of which are both large and lofty. The most outstanding example is afforded by Abijevis hills, which extend for some 20 miles through Destor, Aiguebelle, and Manneville townships, and whose height approaches closely that of Swinging hills.

The Timiskaming greywackes, which underlie a great part of the southern half of the region, have been very readily eroded, and on them the clay plain is most perfectly developed. Over great areas one may walk without finding more than three or four low outcrops daily; in other places, none at all. The basic volcanics of the Keewatin in the eastern part of the district appear almost equally susceptible to erosion, as knobs of rock, though perhaps more numerous than on the greywackes, are still few and far between.

In addition to the ranges mentioned, other prominent hills in the region are Tenendo hills in the northern part of Montbray township and Smoky hills in central Duprat township.

From these hills and ridges a number of conclusions may be drawn as to the course of the more recent geologic history of the region. The prominent ridge of Cobalt series, that extends from Pelletier creek to the interprovincial boundary, preserves a general accordance of summit levels that gives it the appearance of a level-crested ridge, in spite of the fact that in places streams have cut deep valleys into and across it. The beds composing it are not flat-lying, but dip 10 to 25 degrees. The level crest cannot, therefore, be due to original bedding, but must be due to peneplanation; in other words, the ridge is almost the sole remnant of a former peneplain.[1] The maximum elevations on it, as determined by M. E. Wilson, from aneroid observations, are 1,680 feet on Kekeko hills, and 1,600 feet on Swinging hills. It is interesting to note, also, in this connexion, that Wilson gives the maximum elevation of Abijevis hills, 35 miles to the northeast, as 1,650 feet. Abijevis hills are composed, not of the Cobalt series, but of resistant Keewatin volcanics. The general accordance of the summit level of Abijevis hills with those of Kekeko and Swinging hills is striking, and tends to confirm the conclusion as to the existence of a former peneplain which, if reconstructed, would now lie between 1,600 and 1,700 feet above sea-level.

At a lower elevation there is another set of ridges and uplands characterized by flat tops and a general accordance of summit levels. This set includes the ridge formed by the diabase dyke traced for 17 miles from McLaren creek past Kekeko lake; the ridges of granite and Timiskaming lava between Opasatika lake and McLaren lake and creek, and west of McLaren lake and Atikameg bay; the ridges of Timiskaming conglomerate south of Pelletier lake; and many others. These may be seen from points of vantage to have a general equality of level. Their heights were not accurately measured, but are estimated at 200 to 250 feet above lake Opasatika, which, according to the Ottawa River Regulation survey, is 869 feet above sea-level. The general level of the ridges described is, therefore, in the neighbourhood of 1,100 feet. These level-crested ridges and flat-topped uplands, composed of rocks so different in character as granite, diabase, and folded conglomerate, suggest a second nearly perfect period of base-levelling.

Finally, a great part of the district has been eroded to a still lower level, and now is approximately 900 feet above sea-level. These lower areas are covered with flat-lying, thin-bedded clays and silts formed at the bottoms of large post-Glacial lakes. The nature of the underlying rock surface, however, inferred from observation of outcrops along lake shores, in stream valleys, etc., is rugged on a small scale, but plain-like on a large scale, with a relief which, for the most part, probably does not exceed 50 feet. These areas of low elevation are, of course, most widely developed on the least resistant rocks, the schistose greywackes of the Timiskaming series. Farther to the north there are similar rather flat areas of low relief developed on the Keewatin volcanics; but, as the volcanics are much more resistant to erosion, the areas of lowest elevation are neither as large nor

[1] Peneplain, literally, almost plain; a large land area of nearly plain-like surface, which has been levelled by erosion.

as low as they are on the greywacke. The relief of the lowest surface on the Keewatin areas is also greater than on the areas of greywacke, probably 100 to 150 feet. The lowest erosion surface, therefore, appears to be merely a surface carved out of the second peneplain above mentioned, after uplift had taken place. It cannot have been formed by peneplanation, since the greywackes and lavas are not reduced to a general level.

Opasatika district thus apparently affords evidence of two distinct periods of peneplanation. The only remnants of the first peneplain are the long ridge of Cobalt series in the northern part of the district, and Abijevis hills 35 miles to the northeast. If reconstructed, it would lie 1,600 to 1,700 feet above sea-level. This peneplain may possibly be the remnant of the Cretaceous peneplain that covered the greater part of the land surface of North America and was uplifted at the end of the Cretaceous period. At about 1,100 feet above sea-level a large series of level-crested ridges and flat surfaces of nearly equal elevation appear to represent the remains of a second peneplain that may correspond to the Pliocene peneplain of the Appalachian region. Since the uplift of the Pliocene plain, erosion has removed from 50 to 250 feet of the softer rocks. The effect has been most pronounced on the easily eroded mica schists, on which a surface of, roughly, 900 feet average elevation has been produced, with a relief of perhaps not more than 50 feet.

The topographic history, therefore, appears to have commenced with a long period of erosion that reduced the area almost to sea-level, forming the peneplain of which Abijevis, Kekeko, and Swinging hills are now almost the only remnants. This peneplain was then uplifted to a height of 500 to 600 feet above sea-level. A general continental uplift of about this amount occurred at the end of the Cretaceous, after peneplanation, and the uplift in Opasatika area is, therefore, assumed to be of this age. The land surface seems then to have remained stationary long enough for the bulk of it to be again reduced to sea-level, forming a second peneplain, which for similar reasons, is supposed to have been uplifted during the Pliocene to a level some 600 feet or more above the present surface. After the last uplift erosion began to cut away the second peneplain, and had removed about 200 feet of the softest rocks when glaciation occurred.

CLAY BELT

The clay belt, as already stated, is a gently rolling plain of deposition that covers almost all of the area under discussion except the rocky uplands protruding through it. The clays are not of great thickness, as a rule less than 25 feet; and the general level thus corresponds closely to the level of the rock surface beneath.

The following table of elevations within the clay belt has been compiled mainly from levels along the railways, and from levels determined by the Ottawa River Storage Branch of the Public Works Department (Upper Ottawa Regulation survey). Those marked with an asterisk are aneroid determinations by M. E. Wilson. The railway levels are Geodetic Survey precise levels, given to the nearest foot.

Clay Belt Elevations

	Feet
Height of land, C.N.ry., east of Monet station	1,493
Forget, rail at station	1,136
Migiskan river, water July 28, 1923, 1,060; rail	1,098
Migiskan, rail at station	1,099
Bell river, high water, 1,000; low water, 987; bed, 976; rail	1,023
Senneterre	1,027
Goulet	1,023
Coffee	1,091
Uniacke	1,058
Barraute	1,024
Natagan river, high water, 997; low, 988; bed	963
Natagan	1,075
Fisher	1,122
Summit between Fisher and Amos	1,126
Landrienne	1,049
Amos	997
Harricanaw river, high, 972; low, 965; bed, 942; rail	997
La Ferme	1,049
Villemontel	1,046
Summit between Villemontel and Launay	1,073
Launay	1,067
Taschereau	1,015
Robertson lake, high, 1,005; low, 998; rail, at narrows	1,011
Bellefeuille river, high, 992; low, 988; bed, 978; rail	1,019
Authier	1,005
Lois river, water, June 11, 1923, 915; rail	933
Makamik	933
Hatherly	945
Colomburg	931
La Sarre	880
La Sarre river, high, 869; low, 864; rail	882
Dupuy	943
La Reine	908
Okikodosik river, high, 871; low, 869; rail	903
Abitibi lake, high, 880; low	865
C.N.ry., at Ontario-Quebec boundary	903
Geodetic Survey plug, Rouyn	1,029·3
Summit of hill at Horne mine, Rouyn	1,081
Osisko lake, level, August 26, 1927	948
Hébécourt lake	890
Duparquet lake	885
Summit between Duparquet and Dufresnoy lakes	950*
Dufresnoy lake	907*
Dasserat lake	913*
Opasatika lake	867
Barrière lake	867
Albee lake, Evain lake, and Kekeko lake	877*
Dufault lake	966
Renaud lake	921
Lois lake	995
Rouyn lake	877
Kinojevis lake	876
Kinojevis river, at junction with Ottawa river	875
Kewagama lake, Newagama lake	958
Malartic lake, Malartic township, low water	965
De Montigny and Lemoine lakes	967
Blouin lake	968
Nipissing Central Railway	
Cheminis station	1,017
Bridge over Bear creek, rail	1,018·6
Ontario-Quebec boundary, north crossing	1,044
" " centre "	1,071
" " south "	1,071
Dasserat, west switch, 1,039; east switch	1,037
Trestle, 41·6 miles from Swastika, rail	919

Clay Belt Elevations—Continued

	Feet
Nipissing Central Railway—Continued	
Highway crossing, 43·9 miles from Swastika	920
Lake Fortune, west switch, 931; east switch	926·5
Lake Fortune, water, June, 1929, 921; rail on trestle	926·5
Highway crossing, 46·5 miles from Swastika	935
Highway crossing, 48·4 miles from Swastika	989
Aldermac	972
Trestle, 50·15 miles from Swastika, rail	988
Trestle, 53·0 miles from Swastika, rail	938
Highway crossing, 53·2 miles from Swastika	951
Highway crossing, 54·4 miles from Swastika	955
Beauchastel, west switch, 989; east switch	999
Highway crossing, 56·3 miles from Swastika	976
Rouyn station, rail	962·4
Noranda station	990·6
Rouyn Mines Railway	
Noranda station, rail	977·7
Trestle, 40·7 miles from Taschereau, rail	994
Lake Dufault, water, July 11, 1929	966
Trestle, 40·1 miles from Taschereau, rail	986
" 39·2 " " " "	973
" 38·8 " " " "	975
" 37·4 " " " "	981
Waite trestle, 36·8 miles from Taschereau, rail	981
Lake Dufault siding, south switch	973
Trestle, 34·7 miles from Taschereau, rail	986
Dufresnoy siding, south switch	891
Clericy station, rail	919
Destor siding, north switch	903
Destor creek, water-level, July 15, 1929	889
Destor creek, rail on trestle	906
Trestle, 20·9 miles from Taschereau, rail	912
" 20·1 " " " "	915
" 18·2 " " " "	924
" 17·0 " " " "	947
Bassignac siding, south switch	954
Trestle, 14·5 miles from Taschereau, rail	970
Trestle, 10·5 miles from Taschereau, rail	1,015
Lois siding, south switch	1,029
Trestle, 4·8 miles from Taschereau, rail	1,002
Trestle, 2·0 miles from Taschereau, rail	1,015
Junction switch, Taschereau	1,015·5

Analysis of these figures brings out the fact that the district has a pronounced slope toward the west. The height of land between the St. Lawrence and James Bay waters winds across the region in a general east and west direction. From the point where the Canadian National railway crosses the height of land east of Monet station (a point about 100 miles east of the east boundary of the region under discussion), to the height of land between Opasatika and Dasserat lakes, is 175 miles due west. The elevation of the height of land near Monet is 1,493 feet; that south of Dasserat lake is 915 feet. In 175 miles, therefore, the height of land falls 578 feet, corresponding to an average westward slope of 3·3 feet a mile. If the known elevation of the height of land be taken at shorter intervals, the westward slope thus determined is found to vary but slightly from the above figure.

Even better evidence as to the westward slope is found in the westward courses of many streams. Migiskan river, to the east of the district, the upper Ottawa both east and west of Grand lake Victoria, and Kinojevis river, all pursue long west or southwest courses before finally turning north or south.

Lying as it does astride the height of land, the district has very little slope either north or south. On the east, Harricanaw river crosses from south to north with practically no change of level, although a little current is present in some parts. In the centre, the greater part of the district forms a trough in which the drainage runs to Kinojevis river in the middle. The latter, after a long westward course, turns south and somewhat east to join the Ottawa; and this course has the singular result of making the stream at a point only 8 miles from its mouth, pass less than $1\frac{1}{2}$ miles from its source in lake Gendron, a small pond south of lake Vaudray. Even in the extreme west end of the district there is little north or south gradient. There is a rapid drop of 44 feet from the height of land to Opasatika lake, but Opasatika and Barrière lakes stretch more than 20 miles to the south without change of level. To the north the land falls away more gradually toward Abitibi lake, a total fall of 48 feet in 36 miles, or only 1·3 feet a mile.

CHAPTER III

KEEWATIN SERIES

GENERAL STATEMENT

Rouyn-Harricanaw area has a general similarity to the remainder of the Canadian Shield in that the primary subdivision of the rocks is a dual one. There are two main groups of formations separated by the very great unconformity found everywhere between rocks of the Huronian and pre-Huronian eras. This unconformity represents a lapse of time so great that, during the interval, erosion was able to remove thicknesses of the older rocks estimated at 3 to 5 miles. The younger group, the Huronian formations, is represented in this area by the Cobalt series, which forms a forked ridge with an area of perhaps 50 square miles near the Ontario boundary. The older group, on the other hand, includes a large variety of rock types, almost all of which are widely distributed. Two great series of surficial rocks fall into this group, together with many intrusives. The younger is known as the Timiskaming series; it consists predominantly of sediments, but locally contains masses of lava. The older, or Keewatin series, is composed largely of lavas with minor amounts of sedimentary material. The igneous rocks intruding the surficial formations are of great variety, and will be discussed fully in the detailed section of this report.

Table of Formations

Quaternary	Post-Glacial	Clays, silts, sands
	Glacial	Boulder clay; stony and gravelly morainic deposits
Keweenawan(?)	Nipissing diabase	Dykes
Huronian	Cobalt series	Conglomerate, greywacke, arkose, argillite
	(Great unconformity)	
Pre-Huronian	Intrusives	Basaltic dykes Later gabbro Altered peridotites Granitic intrusives—granite, granodiorite, augite syenite, porphyritic syenite, grey and red syenite porphyry Quartz diorite (older gabbro) (Post-Timiskaming folding) Diorite porphyry Amphibolite
	Timiskaming series	Conglomerate, greywacke, lavas
	(Probable unconformity)	
	Keewatin series	Basalts, andesites, dacites, rhyolites, tuffs, and metamorphosed sediments

The Keewatin series in this part of Quebec is composed essentially of volcanics with, in places, a sedimentary member apparently younger than the volcanics. The series was formerly termed the Abitibi volcanics by M. E. Wilson, during his reconnaissance work of 1908-11, because of doubt as to its proper correlation. Since that time the area between the interprovincial boundary and Kirkland Lake, Porcupine, Cobalt, and Sudbury has been mapped, leaving no room for doubt that the Abitibi volcanics are of the same age as the rocks termed Keewatin in northern Ontario. The name Keewatin is accordingly applied to them now in Quebec as well.

The Keewatin series occupies practically all of Duparquet, Clericy, La Motte, Fiedmont, Palmarolle, and O'Brien map-areas, together with the adjacent quarter or third of the southern tier of map-areas, except where it is broken by bodies of granite or other intrusive rock. The sediments believed to be of Keewatin age form several narrow bands in Palmarolle and O'Brien map-areas, and underlie parts of the La Motte and Fiedmont map-areas. Smaller bodies of sediments have been found in many other places throughout the region, generally interbanded with lavas.

LAVAS

The lavas are of many varieties, and of acid, intermediate, and basic composition. A volume might easily be written in description of them, but so detailed a description has no place in this report. It will be sufficient to describe the more outstanding types that are found in almost all localities.

The volcanics are unusually well-preserved for purposes of study. In many other localities they are described as severely mashed and converted into schists, completely recrystallized by intrusion of granite masses, or altered by other means beyond the possibility of effective study. This is not the case here. The flows are not mashed, except along fault-planes or flow margins where movement between flows has taken place during folding. Otherwise the flows are massive and unsheared, with all their original textures and structures undisturbed. In composition they have suffered more, through the action of solutions or vapours penetrating the pores of the rocks and converting original into secondary minerals. This action has not destroyed the original textures and structures, however; the characteristic flow textures, pillow structures, and bedding planes are still retained, and are easily detected on the weathered surfaces. Even the original grain is not completely destroyed, but is preserved well enough to be brought out by the slight weathering of post-Glacial time; so that the examination of clean, weathered surfaces commonly affords more information as to the original texture and composition than can be obtained even from the study of thin sections with the microscope. It is a very curious fact that rocks that are seen under the microscope to be composed of a tangled mat of leaf-like chlorite, kaolin, epidote, and other secondary minerals, weather so as to show clearly the outlines of the original augite or hornblende and feldspar of which they were once composed; so that the nature, size, and relative proportions of these original minerals can readily be estimated. Were it not for this peculiarity it would be impossible to form any conception, with certainty, of the composition and nature of the bulk of the Keewatin volcanics.

The composition of the lava seems to have determined, to some extent at least, the degree of its alteration. The basalts and andesites have commonly, though not invariably, been changed to aggregates of chlorite and carbonates, and have consequently acquired the dark greenish colour that suggested the field name "greenstones." Still, in spite of this, enough residuals of the original minerals are to be found by microscopic examination to render possible a determination of the original composition; besides which the weathered surfaces also enable the original composition to be pretty accurately inferred. The more acid types have suffered much less alteration than the basic. The dacites and trachytes, though commonly rather badly altered to mixtures of sericite and carbonate, are nevertheless found fresh and hard in many more instances than the basic lavas. Their alteration seems in fact to be rather spotty, so that although parts of a flow may be badly altered, other parts of the same flow are comparatively fresh. The rhyolites are still fresher, and in places occur almost entirely unaltered. Consequently the clear, ringing sound resulting when a slab of rhyolite is struck by the hammer is in sharp contrast with the dull thud of a blow on other varieties of lava.

Nomenclature

On account of their alteration it is very difficult to classify and name the lavas with accuracy. It is common to speak of basalt, andesite, dacite, and trachyte, but in many instances a rock classified by one observer under one of these headings would be placed by another in a different division. Again, a really precise classification would in many cases make use of entirely different terms. Thus certain of the rocks classed loosely as trachytes are found, where fresh, to be composed almost wholly of fine-grained oligoclase, so that a correct name for them would be oligoclasite.

It is impossible in practice, however, to attempt a precise classification, as the number of varieties is immense, and each variety would require the protracted study of numerous thin sections to arrive with certainty at the original composition. The geologist who must extend his examination over a large area is forced to rely to a large extent on the general appearance of the rocks as shown by the weathered surfaces, supplemented by a microscopic examination of a number of selected specimens which, in many instances, prove to be of little value on account of alteration. The names in common use, accordingly, have about the following meanings:

"Basalt." Dark, basic-looking, much altered quartz-free lavas.

"Andesite." Not so dark, more feldspathic, quartz-free lavas.

"Dacite." Commonly lighter in colour and more feldspathic, but not necessarily so, with a small amount of quartz.

"Trachyte." Light-coloured, fine-grained lavas without quartz.

" Rhyolite." Light-coloured, fine-grained lavas with much free quartz, commonly porphyritic.

" Greenstone." This field term properly applies to the altered basic types, " basalt and andesite," but is in many cases applied in practice to any altered lava of basic appearance.

Basalt

The term " basalt " is here applied to all lavas of requisite basicity, regardless of their grain. Many writers regard grain as a controlling factor in nomenclature, and accordingly apply the word " basalt " only to the very fine-grained varieties, and refer to coarse-grained types as diabase or gabbro. The grain, however, is a more or less accidental feature, depending on the thickness of the flow and the position of the specimen in the flow; so that specimens varying from microcrystalline to coarse-grained may be obtained from a single thick flow. It seems preferable, therefore, to base the nomenclature on the origin of the rock. Accordingly, the word " basalt " is applied to all lavas of suitably basic composition, regardless of their grain, whereas " diabase " and " gabbro " are restricted in their application to basic intrusives. Here and there, nevertheless, rather contradictory terms such as " basalt dykes " or " rhyolite dykes " will be used to refer to dykes believed to have been the channels through which lava rose to the surface.

The " basalts " are dark greenish, rather thoroughly altered rocks, varying in grain from almost glassy to 1 or 2 mm. Commonly they are equigranular, but there are many variations ranging from types containing small phenocrysts of ferromagnesian mineral to types with many small phenocrysts of white feldspar. The original composition, as inferred from examination of clean weathered surfaces, varied from about 25 per cent feldspar and the remainder mainly pyroxene to about 50 per cent feldspar and 50 per cent pyroxene. The ferromagnesian phenocrysts are commonly found in the more basic varieties, the feldspar phenocrysts in the less basic. No sharp line may be drawn between the " basalts " and the next more acid type, the " andesites," so that in many instances the nomenclature is largely a matter of opinion.

In the ordinary type of " basalt " or greenstone, the original pyroxene has been almost entirely changed, in some instances, to secondary hornblende, or, more commonly, to mixtures of chlorite, carbonate, and iron oxides. The feldspars are altered to mixtures of carbonate, kaolin, sericite or paragonite, and epidote. Tremolite and actinolite are often present, formed, in many instances at least, by recrystallization of some of the altered materials by heat or pressure. The rock resulting from these alterations is dark greenish, soft, tough, and fairly resistant to erosion.

Under shear the greenstone is commonly converted into chlorite schist through recrystallization of its chlorite into leaflets with parallel orientation. The schist thus formed is in places very finely laminated, and contains so large a proportion of chlorite as to suggest that elimination of some of the other constituents must have taken place.

The " basalts " and their near relatives the " andesites " are of particular interest as they form the great bulk of the Keewatin volcanics. As a class they possess certain salient characteristics that distinguish them from lavas now being ejected from volcanoes at various points on the earth's surface. Present-day flows are rather thin, but these flows are individually of great thickness, commonly from 50 to 200 feet, and even greater thicknesses have been observed.[1] The lavas were, apparently, very fluid, spreading out to form flat sheets of great extent, and thus contrast sharply with the usual narrow, river-like extrusions from a volcano. As a rule there is no bed of ash or breccia between flows, though such beds characteristically occur between present-day lavas. The Keewatin lavas seem to have contained little gas, for although moderately amygdaloidal types occur here and there, the bulk of the lavas contain few bubble holes or none. In this way they are wholly unlike the highly vesicular lavas commonly extruded from present-day volcanoes. The great volumes of lava forming any one of the thick flows appear to have been poured out with extraordinary rapidity. This is indicated by the way in which they spread into wide sheets; had extrusion been slow and only a little lava poured out at one time, the small volumes would have cooled before travelling far and, hardening, piled up to form a cone instead of spreading into a flat sheet. Very rapid extrusion is also indicated by the very distinct stratification observable within individual flows. A mass of lava formed by a succession of thin belches, each of which cooled quickly, would be fine-grained and glassy throughout. These flows, on the other hand, exhibit a distinct and graduated change in grain, from a fine-grained glassy top to a holocrystalline, relatively coarse-grained base. The stratification is still further emphasized where, as in many instances, the fine-grained upper part is characterized by pillow structures, whereas the lower part is massive and coarser.

These characteristics, as H. S. Washington has shown,[2] are those of the plateau basalts, so-called because of their flatness and horizontality. The plateau basalts differ from ordinary lavas, not only in the above characteristics, but also in the fact that they were extruded from fissures instead of ordinary roughly circular volcanic throats. Such fissures have been observed in northern Quebec.[3]

Dr. Washington, in the paper cited above, has entered at some length into the possible causes of the high fluidity of the plateau basalts, concluding from the results of fifty-nine chemical analyses of such basalts from all parts of the world that it is due to the relatively high percentage of iron

[1] Areas containing a high percentage of thin flows are not at all uncommon.
[2] Washington, H. S.: Deccan traps and other plateau basalts; Bull. Geol. Soc. Am., vol. 33, pp. 765-804 (1922).
[3] Cooke, H. C.: "Progress of Structural Determination in the Archean Rocks of Ontario and Quebec"; Trans. Roy. Soc., Canada (3), vol. 19, sec. 4, p. 14 (1925).

oxides they contain, coupled with their relatively lower content of lime and magnesia. All the plateau basalts are remarkably uniform in this way, as the analyses below show. It is perhaps debatable whether the present composition of the metamorphosed Keewatin " basalts " is sufficiently like the original composition to be of much value for purposes of comparison; but analyses 6 to 10 of the accompanying table of analyses, of " basalts " from various parts of Ontario, do exhibit a marked resemblance to the averages obtained by Washington. To show how these lavas differ in composition from the ordinary basalts extruded from present-day volcanoes, analyses of recent Hawaiian basalts (Nos. 11 and 12) have been included. It will be observed that in the plateau basalts the total content of iron oxides averages between 13 and 14 per cent and the combined lime and magnesia 13 to 18 per cent, but commonly not more than 15 per cent. In the Kilauean lavas, on the other hand, the total iron oxide is only a little over 11 per cent, the lime and magnesia about 19 per cent.

Analyses of Basalts

No.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	TiO_2	P_2O_5	MnO	CO_2	Totals
1........	50·61	13·58	3·19	9·92	5·46	9·45	2·60	0·72	2·13	1·91	0·39	0·16	.....	100·12
2........	49·98	13·74	2·37	11·60	4·73	8·21	2·92	1·29	1·22	2·87	0·78	0·24	.....	99·95
3........	47·46	13·89	3·58	9·38	6·79	9·83	2·90	1·01	1·48	2·71	0·43	0·22	.....	99·78
4........	50·74	12·60	4·78	7·25	9·00	8·90	2·59	0·72	.....	2·73	0·37	0·31	.....	99·99
5........	50·66	14·28	3·41	8·58	6·92	8·60	2·92	0·72	2·28	1·30	0·17	0·12	.....	99·96
6........	46·66	15·47	3·16	8·48	3·99	9·69	2·06	0·35	4·27	......	......	.....	6·11	....
7........	45·67	19·64	1·44	10·04	0·41	8·30	2·68	0·24	4·66	......	......	.....	6·77	....
8........	48·70	15·21	4·28	8·35	3·76	11·11	3·23	0·59	0·65	......	......	.....	2·25	....
9........	53·90	19·67	0·71	10·21	0·72	8·30	2·78	0·58	1·80	......	......	0·32	1·80	....
10........	48·63	14·81	6·02	9·78	4·56	7·28	1·72	4·10	2·18	......	......	.....	0·88	....
11........	51·06	12·91	1·33	9·63	8·09	11·03	1·92	0·43	0·22	3·59	0·22	0·16	.....	100·59
12........	50·63	13·08	1·09	10·10	7·44	11·38	2·36	0·47	0·23	3·33	0·33	0·12	.....	100·56

1. Average of eleven analyses of the Deccan plateau basalts. H. S. Washington, Bull. Geol. Soc. Am., vol. 33, p. 797.
2. Average of six analyses of the Oregon plateau basalts. H. S. Washington, Bull. Geol. Soc. Am., vol. 33, p. 797.
3. Average of thirty-three analyses of plateau basalts from Thulean region, including Iceland, Faroe islands, western Scotland, Greenland, Spitzbergen, etc. H. S. Washington, Bull. Geol. Soc. Am., vol. 33, p. 797.
4. Patagonian basalt, one analysis. H. S. Washington, Bull. Geol. Soc. Am., vol. 33, p. 797.
5. New Jersey plateau basalts, average of eight analyses. H. S. Washington, Bull. Geol. Soc. Am., vol. 33, p. 797.
6. Badly altered "andesite" (?) from Porcupine, Ont. Rept. Ont. Dept. of Mines, vol. XXXIII, pt. 2, p. 20.
7. Badly altered "andesite" (?) from Porcupine, Ont. Rept. Ont. Dept. of Mines, vol. XXXIII, pt. 2, p. 20.
8. "Basalt" from Kirkland Lake, Ontario. Rept. Ont. Dept. of Mines, vol. XXIX, pt. 4, p. 7.
9. "Basalt" from Kirkland Lake, Ontario. Rept. Ont. Dept. of Mines, vol. XXIX, pt. 4, p. 7.
10. Bluish, slag-like material from Cook Township lava flows. Rept. Ont. Dept. of Mines, vol. XXX, pt. 6, p. 39.
11. Labradorite basalt, from Kilauea. H. S. Washington, Am. Jour. Sci., vol. 6, p. 342 (1923).
12. Labradorite basalt, flow of 1920, Kilauea. H. S. Washington, Am. Jour. Sci., vol. 6, p. 351.

Andesites

The more feldspathic types of the greenstones are here grouped under the term "andesites." In all characteristics they resemble the altered basalts, except for their larger content of feldspar, which appears as phenocrysts. The rocks thus consist of numerous phenocrysts of white feldspar up to 2 mm. in length embedded in a fine-grained greenish basaltic matrix. The matrix itself is commonly a little lighter in colour than the normal "basalt" as it contains more feldspar, possibly 50 to 60 per cent.

Like the "basalts," the "andesites" are always much altered to mixtures of secondary minerals. These alterations are the same as those already described for the "basalts."

A rather striking characteristic of the andesites is their tendency to form pillows or ellipsoids. All the Keewatin lavas exhibit the ellipsoidal structure in places, but whereas the other lavas, basic or acid, rarely form pillows exceeding 2 feet long, the andesites commonly form pillows 2 to 6 feet long, or more. In one place, on the south shore of lake De Montigny, pillows measure 30 feet in length.

Dacite and Trachyte

The rocks classed as dacite in this report vary from dark greenish grey to light grey. The darker varieties closely resemble the andesites, in the field, but thin sections show that small percentages of quartz are present. The lighter varieties are like the trachytes, with addition of small amounts of quartz. Most of the rocks classified in the field as dacite are of the light-coloured types, because the darker coloured would naturally be termed andesites unless, for some reason, they were studied in thin section.

Thus most of the so-called "trachytes" and "dacites" are light grey, fine-grained rocks to which the name "grey lavas" has appropriately been applied. The principal original constituent is a plagioclase feldspar near albite in composition; some orthoclase may be present, but the groundmass is commonly so fine (0·05 mm.) that it is difficult to determine its presence definitely. Albite phenocrysts up to 2 mm. in diameter are normally present. The ferromagnesian content is usually small, and consists of a few shreds of almost colourless chlorite. A little quartz is present in the dacites, but not in the trachytes.

In many places these rocks are comparatively fresh, by which it is meant that less than half of the original constituents have been transformed into secondary products, and the rock is still hard and brittle. More generally, however, they are altered to mixtures of carbonates, kaolin, sericite or paragonite, and epidotes, and are thus converted into soft rocks that crush rather than break under the hammer. Nevertheless, their metamorphism is usually far from complete, for parts of a flow may be altered, and other parts, particularly the finer grained, may have remained comparatively fresh. Under shear the partly altered dacites and trachytes are converted into sericite or paragonite schists.

Rhyolites

The rhyolites are commonly hard, brittle rocks of very fine grain and siliceous composition. They are all alike in being as a rule but little altered. They vary in colour from very dark, almost black in places, to colourless. Some are very beautiful rocks of a translucent sea-green tint, but most are light grey to white.

In composition, all are characterized by the presence of a considerable amount of quartz, partly in the form of phenocrysts, partly in the groundmass. The phenocrysts, as a rule, average from 1 to 2 mm. in diameter; more rarely they attain diameters of 5 or 6 mm. The very large phenocrysts usually characterize the highly siliceous rhyolites with translucent sea-green tints. The total quartz rarely exceeds 5 per cent of the rock. The feldspar is commonly albite or oligoclase-albite. Orthoclase has not been identified in any of the thin sections studied, although some may be present in the very fine-grained groundmass. Much of the feldspar forms small phenocrysts, less than 1 mm. in length. In some varieties feldspar phenocrysts compose nearly half the rock, in others 10 per cent less. The phenocrysts of quartz and feldspar are embedded in a groundmass of quartz and feldspar usually too fine-grained for accurate determination of the constituents or their proportions. The principal ferromagnesian minerals are mica and chlorite. In the lighter-coloured varieties only a few shreds of muscovite are present; the darker varieties contain varying proportions of chlorite.

The alteration of these rocks is less than that of any other type, possibly because of the comparative absence of ferromagnesian minerals and the presence of albite instead of the more easily altered labradorite and andesine; possibly also because these rocks on extrusion did not give off gases or solutions to the same extent as the more basic varieties. The feldspar is somewhat altered to sericite, though not usually enough to prevent identification. The little ferromagnesian mineral present is usually unaltered mica; where chlorite is present it may indicate that hornblende was an original constituent.

TUFFS AND OTHER SEDIMENTS

Tuffs are the fragmental materials thrown out during volcanic outbursts, and, therefore, exhibit a range of composition, from acid to basic, like the lavas themselves. They also vary widely in grain. Some are coarse boulder agglomerates, containing pebbles up to a foot or more in diameter. For some reason these are more common among the rhyolite tuffs than among the more basic varieties. From these coarse types down to the finest-grained varieties there is a complete series of gradations. The finest varieties are slaty in texture for the most part, but some form light-coloured cherty beds. The latter are probably a mixture of altered ash and chemically precipitated silica.[1]

[1] For the results of a detailed study on cherts of this type and origin *See* Clapp, C. H., and Cooke, H. C.; Sooke and Duncan Map-areas, Vancouver Island, B.C.; Geol. Surv., Canada, Mem. 96, pp. 136-143, 157-159, 162-167 (1917).

The tuffs have commonly suffered severe metamorphism of various kinds. The finer-grained beds yielded readily to pressure, and are now converted into slates and schists to a much larger proportional extent than the harder, more massive lavas. They have also been altered by solutions so thoroughly that in many cases the present composition is entirely unlike the original composition. This is particularly apt to be the case with the basic tuffs, which in places are altered by thermal solutions and recrystallization in an extraordinary manner.

Tuffs, particularly the coarse, fragmental varieties, are numerous in the region under discussion, especially in the western part where acid lavas are abundant, and make up a considerable proportion of the total thickness. The occurrences of the coarser types are prominent, because of the striking appearance of the light-coloured fragments in the darker groundmass. The fragments are of all sizes, from minute particles to pieces 2 or 3 feet across, although maximum diameters for the most part do not exceed 6 or 8 inches. A peculiarity of many breccias is the limitation in size of the largest fragments. Thus, one band will be found in which fragments of 4 to 5 inches in diameter are numerous, but no larger ones occur. A short distance stratigraphically above or below this bed will be found another in which the largest fragments do not exceed 1 to 2 inches in diameter. No cause for this limitation has been found.

Tuff breccias of this sort should not be confused with flow breccias, which are likewise exceedingly common, but which are really parts of true lava flows. The mode of formation of both types is discussed later, in the section on " Internal Structure of the Keewatin."

Both flow and tuff breccias occur in large numbers and with great thicknesses in western Montbray and Dasserat townships, and east as far as Dufault lake. Some important sulphide deposits are found in them. Farther east flow breccias are still numerous, tuff breccias much less so. Nevertheless, they occur in many places as thin bands between flows. In Dubuisson township a considerable thickness of coarse and fine tuffs interbedded with thin flows is found between the Keewatin lavas and Timiskaming sediments east of the narrows connecting lake De Montigny and lake Lemoine. Interbedded tuffs and flows are also found in a stratigraphically similar position southwest of lake La Motte, Malartic township.

Large bodies of sediments at present classed as Keewatin are found in Palmarolle, O'Brien, La Motte, and Fiedmont map-areas, and one in Opasatika area. The bodies in Palmarolle and O'Brien map-areas have been studied in more detail than the others, by B. S. Buffam, and as his descriptions have not been published, they are presented in the following pages.

Keewatin Sediments of Palmarolle and O'Brien Map-Areas

By

B. S. Buffam

GENERAL STATEMENT

The Keewatin sediments of Palmarolle and O'Brien map-areas are dominantly fine-grained, thinly bedded, and tuffaceous, and are interbedded with a few lava flows. They are exposed in six bands which have been named after the townships in which they principally occur. The bands are considered to be infolded with the older lavas and to mark the positions of synclinal structures in the folded Keewatin. The tuffs are conformable in strike with the lavas and no evidence of an unconformity was noted between them.

PRIVAT BAND

On the main street of Makamik, in front of the Parish House, there is a small outcrop of schistose, thinly bedded, tufaceous sediments which strike north 57 degrees west and dip vertically. These sediments can be traced for 25 miles southeast across the townships of Royal-Roussillon, Poularies, and Privat, into Manneville township where they wedge out in range VIII, west of the north-south centre line (*See* Plate II). The band varies in width from $\frac{1}{3}$ to $\frac{3}{4}$ mile and is exposed in fairly large outcrops. The strike of the individual beds is generally parallel to the length of the band and seldom varies more than 10 degrees from this direction (north 50 degrees west), though here and there it may depart as much as 45 degrees from the general strike.

The tuffs are very fine grained and thinly bedded. Few of the beds are more than a few millimetres thick, and by reason of slight differences in composition, weathering has produced a finely corrugated surface. In addition to the fine bedding, the tuffs are distinctly banded. The bands vary in width from 6 inches up to 2 or 3 feet and are composed of a number of beds of approximately the same composition and colour. The bands are predominantly greenish; light-coloured acid bands more than 6 inches thick are uncommon. Most outcrops are elongated parallel with the strike of the bedding and in many places individual bands exhibiting little or no variation in width can be traced along an outcrop for several hundred feet. Very little coarse volcanic material is observable; the bulk of the ash was, apparently, very fine-grained, but its original texture and structure have been obliterated in most places by dynamic metamorphism.

Study of thin sections revealed little of the primary character of the rocks. The sections are largely fine-grained aggregates of chlorite and epidote holding scattered fragments of albite-oligoclase feldspar much altered to kaolin and white mica. Considerable carbonate has been developed and also much disseminated dusty material.

The tuffs are cut by a quartz-feldspar porphyry dyke, by an irregular mass of granite, and by two small dykes, about 2 inches wide, of mica lamprophyre. Other intrusive rocks probably occur in the area mapped as tuff. Some of the basic, fine-grained rocks considered to be interbedded flows may be intrusives.

The sediments are schistose, but the intensity of the schistosity is not uniform. Generally a thin cleavage has developed parallel with the bedding. In places the beds have been intricately and minutely folded.

Attempts were made to determine the attitude of the flows on both sides of the Privat band of tuffs. On the north side of the band, 300 feet east of the north end of the portage from Lois lake to Genest lake, there is a high ridge of well-exposed andesitic flows. From north to south across this outcrop the succession of rock types is as follows. On the northern edge of the ridge massive, coarse-grained andesite 30 feet wide is followed southward by a zone 10 to 15 feet broad in which gradually appear small, indistinct pillows becoming progressively more distinct and better formed toward the south. The pillowed rock also becomes gradually amygdaloidal, the amygdules attaining a diameter of 3 to 5 mm. Then follows a band 18 inches thick of more or less scoriaceous lava which has a fairly definite contact with chilled andesite to the south. The andesite to the south is chilled over a width of 6 inches, beyond which it becomes ellipsoidal with pillows up to $2\frac{1}{2}$ feet in diameter. The contact between the scoriaceous lava and the chilled andesite strikes north 50 degrees west and dips 80 degrees north. From the relationships noted it is considered that the tops of the flows face south. Determinations corroborating this conception, but which were largely based on the shape of pillows, were made in Privat township on range-line III, lot 58; on range-line IV, lot 58; on range 5, lot 34; and on range-line VII, lot 18.

The lava flows south of the band of tuffs are more highly schistose and less well exposed than those north of the band, hence the determination of the attitude of the lavas on the south side are not as reliable as those made north of the band. In lots 37 and 38, 400 feet south of the Poularies-Royal Roussillon boundary, there are small outcrops of massive andesite. One of these exposures is composed of two beds of agglomerate separated by a massive andesitic flow. The more southerly band of agglomerate is 10 feet thick and the contact between it and the andesite strikes north 50 degrees west and dips slightly north. The contact is quite sharp, well defined, and slightly wavy. The andesite over a width of 8 inches adjacent to the contact is fine-grained and massive. This phase is succeeded by another that carries quartz-filled amygdules which show a slight tendency to increase in size towards the north and attain a maximum diameter of $1\frac{1}{4}$ inches. The amygdular part of the andesite is 20 inches wide; beyond this part, to the north, the andesite over a width of 12 inches is fine grained and more noticeably chilled than along the southern edge. The chilled andesite is in contact with the second band of agglomerate which is coarser and more uneven in character than the southern band. The northern contact of the andesite is also much more irregular than the southern contact. From the foregoing observations it is thought that the top of the andesite flow faces north.

The determinations noted above, though they are incomplete[1] indicate that the flows surrounding the tuffs have a synclinal attitude. The tuffs lying along the axis of this synclinal structure are, therefore, younger than the lavas about them. No unconformity was found at the base of the sediments and wherever the strike of the lavas could be determined, near the edges of the tufaceous band, it paralleled the bedding of the sediments. The base of the sediments as exposed on the boundary line between Poularies and Royal-Roussillon near lot 39, consists of a small amount of coarse agglomeratic material interbedded with lavas. Lavas are occasionally found at various horizons in the series of tufaceous sediments. On the other hand, very little coarse agglomeratic material was found in the band above what was arbitrarily chosen as the base, that is, where the fine-grained, thinly bedded tuff begins to appear.

LANGUEDOC BAND

A band of tuffaceous sediments similar to those of the Privat band can be traced in Languedoc township from lot 7, range II, southeast to lot 24, range I, a distance of 2½ miles. The band has in places an exposed width of ½ mile, but its total width is unknown, for neither the north nor south contacts are well exposed.

The tuffs are as thinly bedded, but not as highly schistose as those of the Privat band. The bedding strikes north 50 degrees west and dips 70 degrees east at the northern end of the band; at the southern end, the strike is north 75 degrees west and the dip 80 degrees east. The tuffs near the southeastern end of the band are cut by a dyke of diabase, striking north. A narrow dyke of granite, striking north 55 degrees west, cuts them in lot 11, ½ mile north of range I. The granite intrusion intersects the bedding of the tuffs at a small angle.

The available information is not sufficient to indicate definitely the structure of this band of tuffs. Immediately northeast of it the country is low and heavily clay covered and no outcrops of lava were encountered from which structural determinations might have been made. South of the band there are a few outcrops of lavas presenting evidence that seems to indicate that the tops of the flows face north. The most reliable evi-

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[1] Buffam makes no use here of his best piece of evidence of the structure south of the Privat band, evidence that places his conclusions on a much firmer basis. He details his facts very fully elsewhere, in demonstrating that the Palmaroile granodiorite mass occupies an anticline in the Keewatin. Most of the lavas in this neighbourhood are of basaltic types, and this fact encouraged him to trace the outcrop of an interbanded rhyolite flow; more particularly as the rhyolite had some well-marked peculiarities. Starting near the outlet of Lois lake, he succeeded in following it some 4 miles in an east-northeast direction, as far as lot 18, range II, Privat township; and at the same time he obtained structure determinations on flows close to it proving that they face southward. The flow then swings around in a smooth though rather abrupt curve, to strike northwest parallel to the Privat band of tuffs; and he was able to trace it some 4 miles farther, into range V, Poularies township, before losing it. The outcrop of the flow, as it appears on Buffam's manuscript map, is a perfect "canoe", like a textbook illustration; and the determination that the outer side is the upper proves that the fold of which it is a part is a broad anticline, with axis striking north 74 degrees west and plunging east. The Privat band of tuffs lies north of this anticline, between it and the south-facing flows described by Buffam and, therefore, must occupy a syncline (Figure 9).

dence was obtained in lot 13, ½ mile south of range I, Languedoc. At this place the following succession of rock types was observed in crossing the exposure from north to south.

Pillowed andesite, pillows flattened on south side	6 to 12 feet
Well-defined contact.	
Band showing small, irregular pillows and scoriaceous material	1 foot
Well-defined contact, strike north 80 degrees west, dip 50 degrees north.	
Very fine-grained amygdaloidal andesite	3 to 12 inches
Very fine-grained andesite	2 feet
Fine-grained andesite, becoming coarser to south	6 feet
Very coarse-grained andesite	10 feet

An outcrop of lava, on range-line II, lot 4, Languedoc township, exhibited gradation in grain and a flattening of a few indistinct pillows on their southern sides in a part of a flow, thus possibly indicating that the top of the flow faces north. The Languedoc band lies northeast of the Privat band, and it has been shown that there is very good reason to believe that, along the northeastern side of the Privat band, the flows face southwest. Farther northeast along the south side of the Languedoc band, they seem, as stated above, to face northeast. The evidence is, therefore, fairly complete that an anticlinal structure exists between the Privat band and the Languedoc band; and if the Privat band is synclinal, as is most probable, it is not unlikely that the Languedoc band is synclinal rather than monoclinal.

GUYENNE BAND

Another tuffaceous band similar to those described above is partly exposed in the southern part of the township of Guyenne. Small outcrops of thinly bedded tuff were found along range-line I from lots 15 to 21; the bedding strikes from north 65 degrees west to north 45 degrees west and dips 15 to 30 degrees east. Southeast of these scattered outcrops, along the strike of the strata, a large sand-plain extends as far as the north-south centre line of the township, but east of this centre line the band of tuff was picked up again and it is presumed to be continuous beneath the sand-plain. The second outcropping of the tuff occurs principally on the boundary between the townships of Launay and Guyenne and in range X of the former township. The strike of the bedding here is north 40 degrees west and the strata dip 50 degrees east.

The width of the band is not known because of the lack of a complete section, but it is at least ½ mile in northern Launay. The tuffs are cut off on the north by a mass of hornblende syenite of unknown extent and to the southeast the band passes beyond the area studied.

The structural relations of this tuffaceous band have not been definitely determined. The only information available is the strike and the exceptionally low dips of 15 to 50 degrees to the east. Lack of outcrops prevented any attempt being made to determine the attitude of the flows adjacent to the band. The low dip may indicate a monoclinal structure dipping east rather than an overturned syncline, in which case the Guyenne band of tuffs would be interbedded with the lavas. But as there is evidence that the other bands of similar tuff lie above the lavas, therefore, the Guyenne band is supposed to occupy a similar position and to be in the form of a highly overturned syncline.

LA SARRE BAND

A large outcrop of tuffs and of a basic border phase of hornblende syenite occurs in La Sarre township on range II, ¼ mile east of La Sarre river. The hornblende syenite holds numerous inclusions of thinly laminated tuff, some drawn out into long ribbons parallel with the strongly developed flow structure of the intrusive. The inclusions are highly schistose, but the igneous rock is massive and coarse-grained. The western part of the outcrop for a width of 300 feet and a traceable length of 3,300 feet, is composed of thinly bedded tuff. The strike of the bedding varies from north 35 degrees west to north 65 degrees west and the dip from 45 degrees east to 60 degrees east . Along the eastern edge of this belt of tuff, the intrusive cuts across the bedding and is injected, lit par lit, along the bedding.

The tuffs are very thinly bedded about 1 to 2 mm. and vary from light grey to dark green. The tuff is also banded parallel with the bedding. The bands vary in width from 6 inches to 5 feet and each is composed of thin beds of approximately uniform colour and composition. A mass of tuff 15 feet wide and 40 feet long lying in the intrusive syenitic rock contains a black bed 5 inches wide that extends the length of the inclusion. The tuffs on either side of the black bed are stained red with oxide of iron. The black bed holds very minute grains of magnetite and a few grains of chalcopyrite disseminated in a groundmass of recrystallized silica and arranged in bands paralleling the bedding. The black bed is so highly recrystallized that no original structures could be identified.

About ¾ mile southwest of the outcrop on range II and 700 feet east of La Sarre river, there is a small exposure of interbedded tuffs and andesitic flows, but the relation of these rocks to those on range II is uncertain, as the intervening country is low and heavily drift covered. The extent along the strike of the La Sarre band is equally ill defined, for in a southeasterly direction no rock outcrops were found in a distance of 3 miles and the first rock encountered was a basic phase of the hornblende syenite. It is likely that the exposure of tuffs on range II marks the contact between the Keewatin and the main body of hornblende syenite to the east, for no outcrops of syenite were found to the west. The small outcrop of andesitic flows and tuffs ¾ mile southwest possibly marks the western edge of the La Sarre band.

LA REINE BAND

T. L. Tanton, in his report on the Harricanaw-Turgeon basin, refers to an outcrop of banded mica schist on the east shore of lake Abitibi on the point which projects towards Kenosha island (isle La Reine), and considers that these schists are altered, waterlain tuffs. During the field season of 1926 a number of exposures of undoubted sedimentary rocks were found inland from this outcrop, on range II, La Reine. The most easterly exposures on lots 13 and 14 form a high ridge elongated north and south and are fine-grained, thinly bedded volcanic tuffs, folded, crenulated, and cut by narrow veins of milky white quartz, but not so highly schistose as the sediments on the lake shore.

The bedding in range II, lot 14, strikes north 45 degrees east and dips vertically. The strike is more or less parallel with the western contact of the La Reine granite-gneiss batholith. On the eastern side of the batholith the country rocks also strike parallel with the contact and it is, therefore, probable that the intrusion caused a doming of the surrounding Keewatin rocks, for nowhere else in the mapped area does the Keewatin strike east of north.

DUPARQUET BAND

Slate and phyllite outcrop on Duparquet lake near the entrance to Duparquet river and also occur about ½ mile inland along the township-line between Hébécourt and Duparquet. Because of the heavy overburden inland only small, isolated outcrops were found, but it is likely that these rocks extend at least 1½ miles east from the lake. The strata, from evidence obtained farther east, are believed to lie along the major synclinal axis, and, accordingly, occur relatively near the top of the Keewatin. As regards stratigraphical position, therefore, they are comparable to the other tuffaceous bands.

The band is approximately 2,000 feet wide from north to south; the strata are practically vertical, and strike north 65 degrees east. The beds vary from 1 mm. to 1½ cm. in thickness, and are black to light grey. The thinly bedded sediments have been intensely metamorphosed, and exhibit a thin, platy cleavage. In places they have been converted into highly crenulated talcose schists. The schistosity for the most part parallels the bedding and follows the most minute details of the small folds and crenulations of individual beds. Recrystallization has destroyed practically all primary textures. The extreme deformation of these weak plastic rocks contrasts strongly with the massive character of the more resistant andesite flows with which they are associated.

Tuff Band South of Pelletier Lake

South of Pelletier lake a body of fine-grained sediments outcrops over a width of half a mile, and a length of about 9 miles. The rocks are dark grey or greyish black, rather soft, for the most part very fine grained, and thinly and uniformly bedded. The beds vary from ⅛ inch to 4 inches in thickness, and individual beds may be traced across outcrops several hundred feet in length. Evidently, therefore, they were laid down in bodies of quiet water. A thin section from one of the beds showed it to be composed of about 60 per cent of actinolite laths largely converted into chlorite, a few grains of quartz, and the remainder oligoclase feldspar, $Ab_{70}An_{30}$. The feldspar is largely converted into kaolin. Average grain about 0·05 mm.

A sharp contact between the lavas and tuffs was seen on the large outcrop about 1½ miles southeast of the southeast corner of Pelletier lake. The lava is " basalt " with a well-developed pillow structure. The south side of the flow, in contact with the tuffs, is strongly pillowed, and the pillowed material grades northward into massive, coarser-grained " basalt " without pillows. This flow, therefore, faces toward the south. The contact strikes north 80 degrees west and dips about 60 degrees north, so that the flow has been overturned. In contact with the surface of the flow on the south there is a series of ash beds. There is no evidences of any gap or erosion interval having occurred between the consolidation of the lava and the deposition of the ash.

The individual beds directly south of the flow are 4 inches to 1 foot in thickness, and are composed of fragments of lava averaging about 1 mm. diameter. The stratigraphically higher beds become thinner and finer grained, until they pass into dark, fine-grained tuffs in beds about one-eighth of an inch thick. The total thickness of this set of beds was estimated at about 50 feet. Then follow some beds of coarse ash, containing fragments of lava up to an inch in diameter. The thickness of the coarser beds is 6 to 8 feet in all, and they are succeeded by beds in which the grain becomes rapidly finer, until the rock grades into the characteristic thin-bedded, blackish, slaty sediments that outcrop southward as far as the conglomerate contact.

Two or three flows of " basalt," up to 5 feet thick, were found interbanded with the ash beds described, within 75 feet of the main " basalt " contact.

The evidence, therefore, indicates that these sediments lie stratigraphically above the main body of lavas to the north, and are interbanded near the base with thin flows. There is no evidence of unconformity between them and the " basalts," but every indication on the contrary, that they were laid down directly on the uneroded surface of the flows. For this reason it was concluded that these sediments are a series of tuffs lying probably at or near the top of the Keewatin series.

Eastern Areas of Keewatin Sediments

The accompanying map shows the location, in La Motte and Fiedmont map-areas, of a number of masses of altered sediments provisionally classed as Keewatin. All the bodies consist of mica schist with minor quantities of hornblende schist, which are apparently the metamorphic equivalents of impure sandstones. The mica schists consist of quartz and biotite, with a little orthoclase and plagioclase, and in places considerable epidote and chlorite. They are banded in lighter and darker bands, the darker containing more mica, the lighter less; these bands, because they differ thus in composition, are taken to represent original beds of the sediment. The hornblende schists are darker than the mica schists, and differ from them in that hornblende takes the place of biotite; but the rocks are otherwise similar. The hornblende schists are probably the metamorphic equivalents of sediments that originally contained some corbonate of lime or magnesia.

The sedimentary areas are very difficult to study, as they lie within districts heavily blanketed with clay, and outcrops are few and small. A large number of them, also, are entirely or almost entirely surrounded by granite, so that relations to rocks other than the granite are impossible to obtain. On this account nothing is yet known as to their relations with the Keewatin, and they are grouped with it mainly because of their structural relations. Some of the masses lie on the very crest of the La Motte anticline (*See* Folds, page 92) and its projection into Fiedmont map-area, and others are scattered at varying distances between the crest and the synclinal axes to the north and south. These relations suggest that the sediments must be interbanded with the Keewatin lavas, and that some of them are low down in the Keewatin series.

The sediments exhibit considerable similarity, both in petrographic character and degree of metamorphism, to rocks on Grand lake Victoria and elsewhere that have been considered to belong to the Grenville series. A more detailed study of their relations to the Keewatin is desirable.

STRUCTURE OF THE KEEWATIN

Structures of the Individual Flows

The internal structural relations of the Keewatin may be considered under three heads, namely, the structures of individual flows, the folding, and the stratigraphy and thickness of the series.

The structures of the individual flows are of four general types; (*a*) pillow or ellipsoidal structures; (*b*) ropy or corded structures; (*c*) brecciated structures; (*d*) variations of grain, or crystal size, from top to bottom of a flow. These will be considered in turn, although the meaning and use of grain changes and pillow structure have been described elsewhere.[1]

PILLOW STRUCTURE

The pillow or ellipsoidal structure is found throughout northern Canada in all varieties of lava, from basalt to rhyolite. In most parts of the world, however, the structure appears to be confined to the more basic varieties. Lewis,[2] who has summarized exhaustively the literature on the pillow lavas of the world, states definitely that " every known example of this structure occurs in basalt or some closely related variety of basic igneous rock." Although it is admitted that most of the pillow structures in northern Canada are found in basic rocks, they have, however, been repeatedly observed in trachytes, dacites, and even in rhyolites, throughout Dasserat, Beauchastel, and Rouyn townships. Those in rhyolite are quite rare, but magnificent examples may be observed on claim No. M.L.1891, belonging to the Amulet Mining Company, Dufresnoy township.

Lewis' description of the pillow structure is difficult to improve. The pillowed lava is composed of

"separate or nearly separate masses of lava that yield rounded or oval cross-sections in all directions, though in many localities they are moulded in varying degree on one another or even flattened out like cushions or half-filled sacks, and in the latter case

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[1] Cooke, H. C.: "Some Stratigraphic and Structural Features of the Pre-Cambrian of Northern Quebec"; Jour. Geol., vol. 27, p. 75 (1919).
"Progress of Structural Determinations in the Archean Rocks of Ontario and Quebec"; Trans. Roy. Soc., Canada, 3rd ser., vol. 19, sect. IV, pp. 5-12 (1925).

[2] Lewis, J. V.: "Origin of Pillow Lavas"; Bull. Geol. Soc. Am., vol. 25, pp. 591-654 (1914). Above ref. on p. 595.

nearly or quite fill the space, without open interspaces . . . Where spaces exist between the masses they tend toward a rude tetrahedral form, with concave sides (hence are roughly triangular in cross-section), and are generally filled in part with flakes and angular fragments of the same character as the curved surfaces of the bounding masses. Filling the remaining spaces in many localities and cementing the fragments into a breccia are a great variety of minerals that are commonly considered secondary. Prominent among these are chlorite, calcite, quartz, chalcedony, agate, and other cherty and flinty forms of silica, together with epidote and the wonderful series of the zeolites. In some regions but few of these minerals occur, while elsewhere, even in other parts of the same flow, they are developed in marvellous variety and abundance. . . .

In many places the rounded masses are elongated and more or less flattened into bale-like or bolster-like forms, and indeed some degree of elongation is a very general characteristic. In such cases there is commonly also a pronounced parallelism of the longest axes of the masses and a like, though less prominent, parallelism of the intermediate and shortest axes as well. . . .

The individual pillows are commonly sheathed in a film of glass from 2 or 3 to 25 or more millimetres in thickness, and the microscope shows that this passes gradually into the crystalline lava of the interior. In many cases the rock is massive or only slightly vesicular, although some very light and spongy lavas are known in this form. A vesicular or variolitic zone (or both) very commonly lies just within the glassy crust, and in some localities a flow-structure is developed parallel to the outer surface of each mass. . . . The vesicular portions of pillow lava have been quite commonly converted into amygdaloid.

A pronounced radial columnar jointing is very commonly developed in the pillows and when these are broken down by the mechanical process of weathering or the corrosive action of waves and streams they fall into tapering, pointed, or wedge-shaped fragments. A concentric jointing or lamellar structure has been observed far less frequently.

In the metamorphic types of lava the characteristic structures are more or less masked by the results of subsequent processes. One of the most common, which is quite characteristic of the greenstones, is the development of chlorite from the glassy sheaths of the pillows and from the fragments in the interspaces, accompanied by the partial or complete chloritization of the ferromagnesian minerals throughout the mass of the rock. The chlorite in the interspaces commonly has a schist-like structure parallel to the surfaces of the adjacent ellipsoids."

All the characteristics mentioned by Lewis are found in the pillow lavas of northern Ontario and Quebec. Near Kenogami station, Ontario, the only place where fresh basalt has been found by any of the writers, the pillows are sheathed in a film of basalt glass, and the interspaces filled with fragments of glass slightly altered to epidote.

The only observer who has seen and described pillow lava during the process of formation appears to be Anderson.[1] His description is as follows:

"On a third occasion, when I got as near as possible in a boat, the lava was flowing in four large and distinct streams. . . . I was anxious to observe the formation of pillow lava and we got as near as possible without melting the pitch-caulking of the boat. . . . Where the lava was flowing in smaller quantity explosions were much less noticeable, and the lava extended itself into buds or lobes. The process was as follows: an ovoid mass of lava, still in communication with its source of supply and having its surface, though still red hot, reduced to a pasty condition by cooling, would be seen to swell, or crack, into a sort of bud with a narrow neck like a prickly pear or a cactus, and this would rapidly increase in heat, mobility, and size, until it either became a lobe as large as a sack or pillow, like the others, or perhaps stopped short at the size of an Indian club or Florence flask. Sometimes the neck supplying a new lobe would be several feet long and as thick as a man's arm before it expanded into a full-sized lobe; more commonly it would be shorter, so that the freshly-formed lobes were heaped together. They looked white-hot even in daylight,

"[1]Anderson, Tempest: "The Volcano of Matavanu in Savaii"; Quart. Jour. Geol. Soc. of London, vol. 66, p. 632 (1910).

and as the waves washed over them the water seemed to fall off unaltered without boiling, owing probably to its being in the spheroidal condition. I have watched the formation of ordinary corded lava on Vesuvius by a similar process of budding. When the hot lava of the interior has got vent and formed a pool, a soft scum forms on the surface, which is pushed forward by the fluid lava moving beneath, and is raised into a wrinkle or cord, then others are formed in the same way until the surface is entirely solidified into a succession of cords."

Green[1] has also observed the formation of somewhat similar structures in Hawaii. He says:

"The stream . . . while we were watching it, seemed first to form into a flattened spheroidal mass, the crust of which was constantly cooling and the fresh supply of molten lava was constantly increasing its size. At last a limit seemed to be arrived at between the retaining power of the cooling crust and the pressure of the column of liquid lava inside it, when the molten lava would break away from the lower edge of the dome and form another just like it and close to it, and so on, the molten lava . . . . continually keeping up the supply and running from one to another, forming a succession of domes."

The conditions necessary for the formation of pillow structure, as determined from these and other observations collated by Lewis (loc. cit.) are: (1) a free-flowing, highly liquid lava, particularly one which because of its thickness or any other cause maintains its liquidity for a long time; (2) the flow must be in its declining stages, so that the main body lies nearly motionless, and the accessions of liquid lava from beneath are sufficiently small to escape through small cracks in the cooling upper crust without causing forward motion of the entire flow; (3) the temperature of the lava must have dropped to the point where lava escaping through a crack on the surface is immediately surrounded by a tough, viscous surface film, strong enough to retain the still liquid lava within. Under these conditions the lava that continues to enter the pillow will produce a rounded, bolster-like form; if the lava is too hot for such a film to form quickly, the liquid spreads out into a thin, plate-like mass. The stretching of the tough surface crust as the pillow increases in size produces in the crust a pseudo-flow texture parallel to the outer surface, by the stretching and flattening of the vesicles.

Many writers have considered that pillow structures could be formed only under water, and, therefore, that the structure could be accepted as a criterion of submarine extrusion. This opinion appears to be erroneous, however, for although there is no doubt that pillow structures are common in lavas extruded under water, nevertheless the presence of water is not essential to their formation, as Anderson and Green, already quoted, and A. L. Day of the Geophysical Laboratory, Washington, have repeatedly observed their formation in air. Dr. Day, in fact, states[2] emphatically that there is little or no difference between the cooling of a stream of lava in water and in air; as when water comes in contact with molten lava a non-conducting cushion of steam is immediately formed between the two, through which the heat of the lava escapes very slowly, and, consequently, the water above a hot flow is not in a state of violent ebullition, as might be expected, but is as quiet and cool as the water elsewhere.

[1] Green, W. L.: "Vestiges of the Molten Globe, pt. II: The Earth's Surface Features and Volcanic Phenomena"; Honolulu, 1887, pp. 172-3.
[2] Day, A. L.: Personal communication.

In northern Canada great numbers, if not the majority, of the pillowed flows are made up of two distinct parts, a pillowed part that varies in grain from glassy on the outsides of the pillows to finely crystalline in the interiors, and a non-pillowed part of considerably coarser grain. It is obvious, both from the grain and from the mode of origin of the pillow structure, that the pillowed part of the flow must originally have been its upper facies, the massive its lower, more slowly cooling part. From what has been said, it seems probable that the lower, massive part was that which was rapidly extruded from the fissures beneath, and spread out into flat sheets while still very fluid and hot; whereas the upper, pillowed part was formed as the lava cooled sufficiently to form a viscous upper crust, and at the same time the flow from the vents slackened so much that the pressures from below could be relieved by the gradual escape of lava through small cracks in the upper crust rather than by movement of the whole mass. As might be expected in such circumstances, all types of flows are found from those in which the lower, massive part is very thin or lacking to those in which it is very thick; the pillowed parts likewise exhibit all variations from very thin to very thick; and no uniform relation between the thicknesses of the massive and of the pillowed parts is to be found or expected.

Flows of this type naturally afford an excellent criterion for structural determination, as when the necessary observations are accurately made there can be absolutely no doubt of the attitude.

ROPY STRUCTURE

The ropy or corded structure is another surface structure formed during the process of cooling. Many observers have described its formation, among whom is Tempest Anderson (loc. cit.). The essential requirements for its formation appear to be as follows; the lava must be one that is fairly fluid, and that contains and emits little steam or other gas; it must form a pool, or slowly moving stream. Under such conditions, as the rapidly cooling surface becomes viscous with approaching consolidation, the gentle forward motion of the more liquid part beneath pushes up the viscous surface into a series of wrinkles or cords, until by repetition of the process the whole surface becomes corded. The resultant surface is vividly described by Bonney[1] thus: " The surface . . . is wrinkled with the curved lines of viscous flowing, it has a "ropy" aspect resembling a lot of entangled cables, or a heap of gigantic slugs crawling over one another."

The Keewatin lavas are commonly seen in cross-section, as the flows in most places have been forced into steeply inclined or vertical attitudes and afterwards planed off by erosional processes to form the present surface. A flow, characterized by the ropy texture and seen in cross-section, exhibits a lower section of massive lava, which passes at the top into a zone of ribbon-like forms. The individual ribbons are roughly parallel to the strike of the flow, that is, to the old surface; they exhibit flow textures; they are not of uniform size throughout their length, but

[1] Bonney, T. G.: "Volcanoes," Ed. 3, p. 110.

pinch out usually within a few feet; they need not be perfectly parallel with one another but may show rather large variations in direction; in other words, the ropy zone has all the irregularity that one would see if a pile of interwoven cables were cut across with a sharp knife. The ropy zone is not commonly of great thickness; an average minimum thickness might be about 2 feet, and a maximum perhaps 10 feet. True ropy structures are rather rare within the Keewatin, perhaps because general conditions were more favourable to the production of pillow structure, which, as the previous descriptions show, is rather closely allied to the ropy structure in mode of origin.

BRECCIATED STRUCTURE

Breccias are exceedingly common in the Keewatin series. Two general types of breccia exist, the flow breccia, and the tuff breccia or agglomerate. The tuff breccia or agglomerate is an accumulation of lava materials broken to fragments within volcanic vents, by the explosive expansion of steam and other gaseous materials, and hurled from the vents by the force of the explosions. The materials so ejected vary in size from large blocks down to impalpable dust. Some of this dust is so fine that it has been known to float in the upper atmosphere for days, and to be blown completely round the world. Professor Bonney examined some of the fine dust from an eruption of Cotopaxi, and calculated that it would take from 4,000 to 25,000 particles to make up a grain in weight. The tuff breccia is, therefore, a rock made of fragments of all sizes, piled together pell-mell. The characteristic that distinguishes it from the flow breccia is that the larger and easily visible fragments are embedded in a matrix of finer fragments down to the size of dust. Careful examination of clean weathered surfaces with the naked eye or with a hand glass is generally all that is necessary to establish the nature of the matrix, although occasionally the microscope is required.

A flow breccia is made up of fragments of lava which have been engulfed in a matrix of liquid lava. The lava matrix, of course, possesses a uniform grain and composition throughout, instead of a variable grain and a finely fragmental character as in the case of the agglomerate. The character of the matrix, therefore, distinguishes the two types.

A flow breccia may form in a number of different ways. A flood of lava advancing over any surface will pick up and engulf any loose materials it encounters; and these fragments may easily be of rock entirely different from the lava itself. Again, fragments of ash hurled out from an active volcano may fall into liquid lava, forming a breccia. In this case the fragments will be of material like the lava, unless two neighbouring volcanoes are simultaneously erupting. A third possibility is for the lava, when forcing its way to the surface, to break off fragments of the rocks through which it passes and carry them up with it. Bonney (loc. cit.) says:

"In some of the debris from the Eifel volcanoes bits of shattered slate frequently form a considerable fraction of the whole mass. . . . Blocks of white crystalline marble are common among the heaps of ashes, or even lie loose, on the slopes of

Vesuvius. . . . Fragments of various sedimentary rocks, more or less altered, are sometimes included in lava streams or in big lumps of scoria. . . . Fragments of crystalline rocks also occur, sometimes from such as are of doubtful origin, like mica schist or gneiss; sometimes from indubitable igneous rocks, such as granite, diorite, dolerite, or peridotite."

One of the most outstanding Canadian examples is found on St. Helen island, Montreal, where great blocks of fossiliferous limestone are surrounded by a matrix of lava, in the neck of an ancient volcano.

All of the three methods outlined, however, together produce but a very small percentage of the flow breccias of the world or of any section of it; in fact, instances of flow breccias in which the fragments are unlike the matrix are so few as to be almost negligible. Nearly all flow breccias are formed by the consolidation of the surfaces of lava flows while movement is still going on, and the subsequent engulfing of these crusts. The descriptions of the type of lava forming such breccias, and of the process of formation have been given by many writers; but that by Scrope[1] can scarcely be improved:

"The surface of flowing lava, on its exposure to the air, cools and hardens with remarkable rapidity—indeed almost instantaneously, owing, no doubt, chiefly to the immediate expansion and escape of the abundant aqueous vapour discharged from it, by which a large portion of its heat must be suddenly absorbed. . . . . . Its liquidity, when greatest, does not appear to exceed that of honey, but is generally so imperfect that considerable pressure is needed to cause the point of a stick or an iron rod to penetrate its surface. Indeed, its consistency more usually resembles that of coarse, half-dry mortar, or of meal as it issues hot from the stones of a mill, than of a substance in complete fusion. . . . . It is by the innumerable shrinkage cracks that much of the vapour of the lava escapes; and by the force of this escape, but still more, perhaps, by the friction and irregular motion of the matter flowing on underneath, the surface of most lava currents is broken and tilted up, as it moves on, into coarse, scoriform crusts or slabs, ragged or angular, which give it a resemblance to the frozen rivers or seas of northern latitudes, where thick ice, shattered by the movements of currents or waves, has been jammed together in a multitude of shapeless projecting masses. Some of these tilted slag-masses of lava may be seen to rise 10, 20, or even 50 feet above the level of the current. Hence arises the generally rough and savage surface of the great lava streams of Iceland, Teneriffe, Etna, and other volcanic districts. . . . . Professor Dana describes some of the lava-currents of Hawaii as composed of loose, angular blocks of all shapes and sizes, from that of a bushel to that of a house—"a surface of horrible roughness"............Owing to this rapid consolidation of its external surfaces, a current of lava advances generally with a rotatory motion, the slags and crusts that cake on its front rolling down before it and forming a sort of broken pavement, over which the central part protrudes and falls, and on which it finally reposes. It is thus seen why a bed of scoriæ usually underlies every lava current, even where ejected matters had not previously covered the ground."

It is evident from the above descriptions that a cross-section of the clinkery or brecciated type of flow, such as is seen in many places in the Keewatin series, might exhibit brecciation throughout the full thickness, or on one side only, or on both sides with massive lava between. With such a wide range of possibilities, brecciated flows can afford no means of determining attitudes.

It is now fairly generally agreed by the authorities on volcanology that a lava flow assumes the ropy or the clinkery form according to the amount

[1] Scrope, G. D.: "Volcanoes"; 2nd ed., pp. 69-71 (1872).

of water and gases dissolved in the liquid rock at the time of extrusion. It has frequently been noted that the lavas solidifying in corded and pillowed forms give off very little gas as they cool; and further, that such lavas, although commonly quite fluid when they leave the crater, quickly become viscous and move very slowly. The clinkery type of lava, however, gives off enormous volumes of gas and steam as it cools, is apt to be highly fluid to begin with, and retains its fluidity much longer than the corded type.

A modification of the flow breccia is occasionally found, particularly in the more acid lavas, very rarely in basic lavas. A fluid lava, either before or after extrusion, may encounter a mass which has already become solid, break it up, and carry along fragments of it. If the mass broken up were quite cold, an ordinary flow breccia would usually result; but if it were hot or only partly consolidated, the heat of the new lava might soften and partly remelt the older material, the fragments of which would then tend to be drawn out into lens-like masses, or even long, narrow streaks. This structure is termed fluidal or fluxion structure, and has been observed in a few places in the Keewatin areas.

CHANGES OF GRAIN

As the descriptions indicate, heat is lost from the surface of a lava flow with extreme rapidity, so that the upper parts are apt to consolidate into a glass, that is, a rock in which the constituents have not separated into crystals of individual minerals. This rocky crust, however, is a very poor conductor of heat, so that the part of the flow beneath cools much more slowly and has time to crystallize. The actual time required for the cooling of a flow does not appear to have been measured; but different observers state that lavas have been observed still hot and glowing a few feet below the surface, months or even years after eruption. It is probable, therefore, that flows 100 feet or more in thickness would require many years to cool. In such circumstances crystals of moderate size could readily form in the lower parts.

Observations made in many places in northern Quebec have shown that, in the cross-section of a flow, the size of the crystal grains exhibits a very definite variation. On one side of the flow, the original top, the lava is glassy or exceedingly fine grained, and from this downward there is a very slight increase in the size of grain until a point perhaps half-way through the flow is reached. Below this the grain increases in size somewhat more rapidly, attaining a maximum size a few inches from the bottom of the flow, where the liquid lava was again chilled by contact with the cold earth (*See* Figure 1, a).

This peculiar variation in texture is undoubtedly caused by the difference with which heat is lost from the top and bottom of the flow. The bottom is in contact with cold rocks which are very poor conductors of heat; the top is in contact with the atmosphere, which, being constantly in motion, will carry away heat as fast as it is brought to the surface. In addition, the gases and vapours dissolved in the liquid lava escape first from the surface parts; and as they absorb large quantities of heat in assuming the gaseous form, they must thereby greatly promote the cooling of the upper parts of the flow. The base, therefore, from which little heat can escape, remains hot the longest and accordingly crystallizes the most

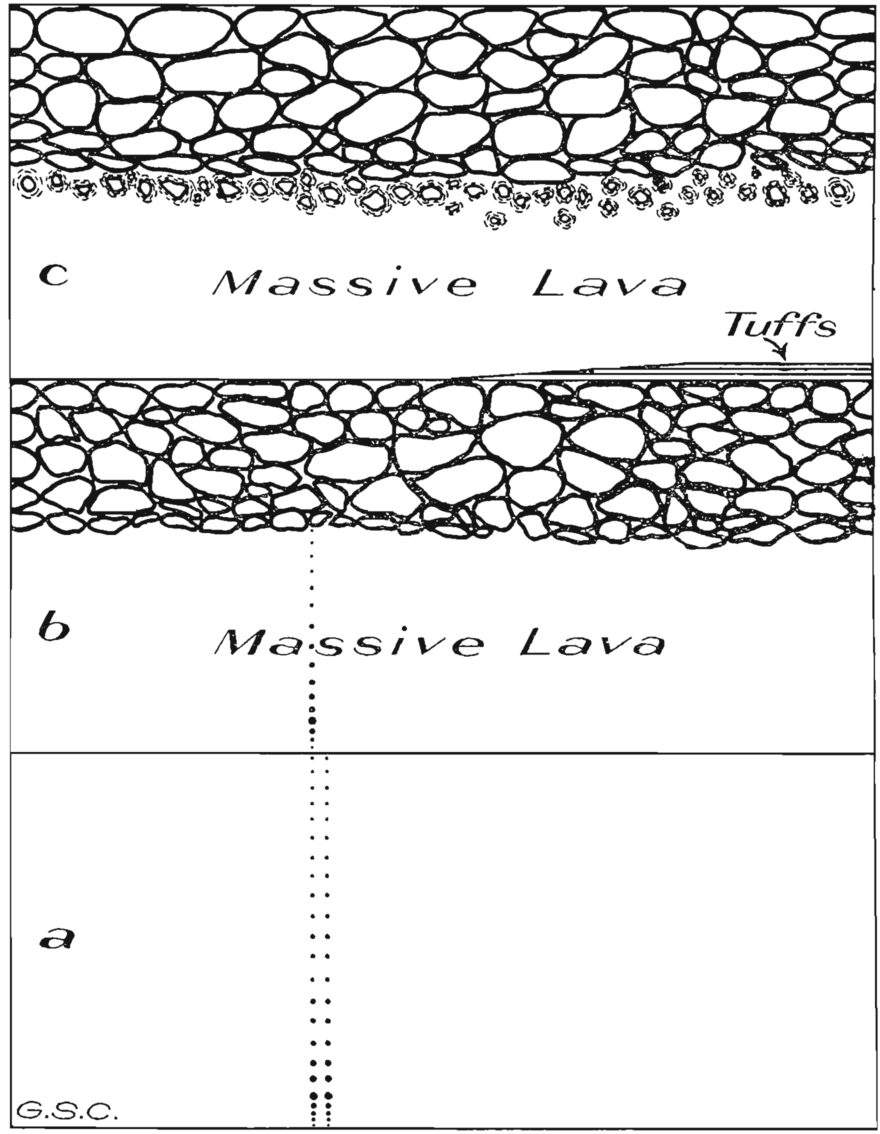

Figure 1. Diagram illustrating principles of the use of pillow structure and grain to determine the attitude of lava flows. In a, the size of the dots illustrates roughly the change in size of the crystal grains, from top to bottom of the flow.

coarsely; and a progressive diminution in size of the crystals is to be expected upward, because cooling was progressively more rapid as the surface was approached.

Use of Internal Structures in Determining Folding

It is evident that some of the internal structures described, namely the pillow structure, the ropy or corded structure, and the changes in grain, might be used under suitable conditions, in an area of folded lavas such as the Keewatin, to determine the strike, dip, and original upper side of the flows; so that by obtaining a large number of such observations the nature of the folding might be worked out. The importance of obtaining information about the folding is great, both to the geologist and the miner; for without it nothing can be known as to the thickness of the series of lavas or the succession in which they were poured out; as to whether the ancient sediments lie above the lavas or below them; as to whether the sediments are conformable with the lavas or unconformable; as to the positions or directions of the axes of the folds; or as to the relations existing between the folds, vein systems, ore-bodies, or faults. The determination of all these facts depends on obtaining a knowledge of the existing structures, and these cannot be known until many structural determinations have been made.

The principles of the use of pillow structure for determining the attitudes of lava flows have been indicated in the preceding pages, but may now be described in more detail (*See* Figure 1, b and c). In certain flows a zone of pillows, each composed of fine-grained glassy lava, occurs at the top of the flow, and an unpillowed zone of massive, coarser-grained lava at the bottom. Between the two zones there may or may not occur a belt, rarely more than 5 or 6 feet thick, that may be termed the transition zone. It is made up of what appear to be small blocks or fragments of lava in a lava matrix; and each block is surrounded, usually, by a band of lava half an inch to an inch in width marked by flow textures that circle round the block as if the block had been revolving a little in a viscous matrix. Little change of grain can be detected in the zone of pillowed material from one side to the other, but a careful comparison of specimens from different parts of the massive zone shows that the grain is finer close to the pillowed zone and becomes coarser farther away, to within an inch or two of the lower contact. The contact with the cold surface on which the lava was extruded has commonly caused a narrow, chilled edge to form.

The explanation of this peculiar internal structure is probably to be found in the manner of formation of the pillow structure. If the theory of formation on page 43 is correct, then the "transition zone" above described undoubtedly represents the surface of the preliminary flood of hot, very fluid lava; the first crusts formed by cooling were broken up by the final movements of the liquid lava, yielding the fragments of the "transition zone"; and the revolution of these fragments during the final movements formed the whorl of flow-textured lava now surrounding the individual fragments. Then when the body of the flow became too viscous for further forward movement, the pressure from behind was relieved by cracking of the surface, allowing liquid lava to escape upward and form the pillowed zone.

Regardless, however, of the correctness of this theory, it is obvious that the pillowed zone, where the grain is fine and glassy, must represent the original surface of the flow, and the coarser, massive zone must represent the bottom, where cooling was slowest and crystals, therefore, had a longer time to grow.

The shapes of individual pillows, and the manner in which pillows fit together, may also be used in places to determine the attitudes of flows. As pillows are only formed at the surface of a flow, so far as known, a thick, pillowed zone must have been gradually built up, by formation first of a layer of pillows, then of other successive layers above the first. An individual pillow, therefore, should exhibit a fairly smoothly rounded upper surface, where it was in contact with air only; but the plastic lava of the pillow would naturally sink into and fill any irregularity in the floor on which it lay, such as a triangular space between two older pillows. A cross-section of a pillowed zone, such as most Keewatin outcrops afford, should, therefore, show a pattern like that seen in Plate III, enabling the direction in which the flow faces to be determined. The method should be used with care, however, and checked wherever possible by other methods of structure determination.

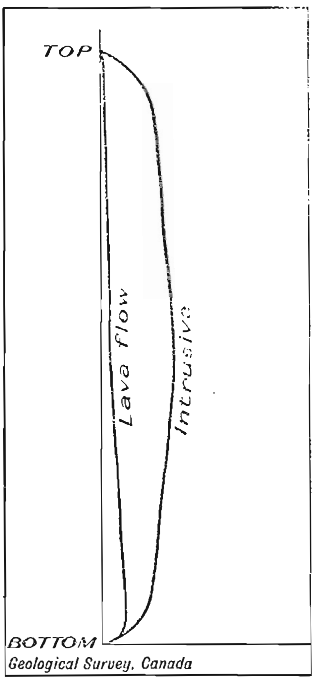

Figure 2. Comparison of lava flow and intrusive dyke or sill with regard to change of grain from top to bottom.

A third method of establishing the attitude of a flow, which cannot be used often but sometimes proves valuable, is to determine the change in grain from one edge of a cross-section to the other (Figure 1, a). This method may be used on flows that do not exhibit pillow structure, provided they have the necessary composition and thickness. Usually it is difficult or impossible to use the method on rhyolites or trachytes, or on very thin flows of any kind. Under favourable conditions of composition and thickness, the upper parts of the flow are usually found to be fine-grained or glassy. A careful comparison of specimens reveals an extremely slight increase in the size of the grain downward, until a point about half-way across the flow is reached; then the rate of increase rises somewhat, and the grain coarsens, until the bottom of the flow is almost reached. At the very bottom the same narrow, chilled edge is found as in the pillowed flows. Figure 2 shows the curve for the change in grain from top to bottom, and introduces, for comparison, a curve showing the change in grain of an intrusive sill or dyke of the same composition and thickness. The intrusive becomes much coarser in grain, owing to the longer time it had for crystallization; and its decrease in size of grain proceeds at the same rate toward the two sides, indicating equal losses of heat from both edges.

The ropy or corded structure is useful in occasional instances for making determinations of attitude. The ropy zone of the flow is, of course, the original upper side. It is rarely more than 10 feet thick, so far as noted, and passes downward into very fine-grained, massive lava. The lower parts of the flow exhibit the changes of grain described in the previous paragraph.

DIFFICULTIES ENCOUNTERED IN APPLYING THE METHODS

Although the methods of determining attitudes of lavas are apparently simple, the application of them in the field is a most difficult operation, and must be done with the greatest care and skill if correct results are to be obtained. It is evident that once the strike of the flows is known—and this is usually rather easy to obtain—a determination of attitude must show the top of the flow facing either to the one side or to the other. One of these directions is the correct attitude, the other wrong. There can thus be no compromise or half-way correctness about these determinations; in the nature of things they must be either entirely right or absolutely wrong.

The difficulties in the way of making correct observations are numerous. (1) Many flows, for a variety of reasons, are unsuitable for purposes of structural determination. Rhyolites are poor for this purpose, as few of them exhibit pillow structure, and the normally viscous character of rhyolite lava prevents it commonly from solidifying so as to exhibit any notable difference in grain from top to bottom. Very thin flows, and all flows pillowed from top to bottom, are likewise obviously unsuitable as they do not show the necessary internal variations in texture or structure. In the case of extremely thick flows it is usually impossible to obtain a sufficient width of good outcrop to cover the whole flow from its upper to its lower contact. Thus there is a moderately large proportion of any assemblage of lavas on which structure determinations cannot possibly be made. (2) It is evident that before any determination of the internal texture or structure of a flow can be made, it is first necessary to determine *with absolute certainty* the positions of the upper and lower boundaries, so that it may be definitely known that one unit only, and all of it, is being dealt with and not a part of one flow, or one flow and a part of another. Unless this determination of boundaries is both definite and certain, all sorts of errors can be introduced into the conclusions. The determination of the upper and lower boundaries is extremely hard to make; it is, in fact, the most critical and laborious part of the work; for once the boundaries of the flow are certain, it is commonly easy enough to make sure of the attitude. The difficulties in the way of accurate determination of the boundaries are several. In the best of circumstances, the contacts of flows of similar composition are lines that are difficult to detect, as there is no great difference in composition, grain, or weathering on the two sides. Again, contacts, being lines of weakness, are in many places somewhat sheared, or else rotted by circulation of water so as to be concealed by weathered materials. Again, as photographs of present-day lavas show, lava surfaces are commonly not planes, but rough, irregular, and covered with debris. If another lava were to flow out upon such a surface, the contact line might be almost impossible to detect. Still another difficulty, and one of the commonest in actual practice, is the common occurrence of dykes or sills intruded into the lavas parallel to the bedding or nearly so, and composed of rock similar both in composition and grain to the massive parts of the flows. Consequently the discovery of a line of contact is not alone proof that this line is a flow boundary; it may be, and in many cases is, a contact between an intrusive dyke and a flow; and the dyke may have broken through the flow at any horizon in it. It is never enough, therefore, merely to find a contact and assume that it is the upper or lower boundary of the flow. It is necessary, also, to determine whether the rock on the other side of the line of contact is itself a flow or a dyke. If a dyke, then the line of contact is of no value for purposes of structure determination.

Determination of the lines of contact is rendered easier and more certain when: (1) a band of bedded tuff or chert has been deposited between two flows (Figure 1, c); and (2) when the two flows in contact differ notably in composition. In the latter case it is not necessary to find the exact line of contact, but merely to establish the fact that the rocks on both sides of the contact are flows. Luckily for the geologist, one or other of these two conditions occurs with reasonable frequency.

The descriptions make it clear that several conditions must be fulfilled if satisfactory structure determinations are to be made. (1) The lavas must be of suitable composition—rhyolites can rarely be employed; (2) the flows must be neither too thin nor too thick; (3) the flows must not be pillowed from top to bottom—determination is possible when they are massive from top to bottom, but is easiest when they are partly pillowed and partly massive; (4) the outcrops must be very clean, so that the observer can view the rock across *every inch* of the width, and thus make absolutely certain that no line of contact has been overlooked; (5) the outcrops must be very wide, since not only the full width of the flow, in many cases 200 to 300 feet, must be exposed, but also a sufficient width of the rock with which it is in contact must be exposed to prove that it is likewise a flow and not a dyke or sill. It is because all these factors must be satisfied that structure determinations are so difficult to obtain. The final factor, that of great widths of clean outcrop, is perhaps the hardest to satisfy, as in general such outcrops are rarely obtained except: (1) on the wave or current-washed shores of lakes or streams of clear water; and (2) in areas burnt long enough for rain to have washed away the ash and smoke from the rocks, but not so long that moss and lichen have recommenced their growth.

Stratigraphy

No detailed section of the Keewatin rocks can be made in this region on account of the heavy drift cover and the vertical attitudes of the rocks. As the rocks are lavas, presumably extruded from many vents, it is probable that any one section would have little resemblance to other sections, even those only a few miles away.

The rocks forming the crest of the broad Dufault anticline (*See* section on Folds and Faults) are largely rhyolites and dacites. Therefore, in this district at least, the rocks fairly low in the Keewatin series are acidic. On the other hand, throughout the region there is a tendency for sedimentary rocks to appear in considerable thickness in the synclines. Several bands of such sediments occur in Privat, Languedoc, Guyenne, and Palmarolle townships, and some of these, at least, lie along synclinal axes. Similar sediments are found near the Keewatin-Timiskaming boundary south of Pelletier, Malartic, and Demontigny lakes; and these positions are structurally near the tops of Keewatin synclines. Although the evidence is far from complete, it rather strongly suggests that the Keewatin period closed with an epoch of fairly widespread deposition of sediments which are in part tufaceous and in part the fine-grained products of erosion of the lava flows.

The thickness of the Keewatin series has not been determined, since neither the top nor the bottom has yet been found. The uppermost known beds do not represent the original top of the series, as they undoubtedly suffered erosion before the Timiskaming series was deposited on them. The floor on which the Keewatin was laid down is still unknown.

From the centre of the Dufault anticline to the Keewatin-Timiskaming boundary on Pelletier creek is approximately 10 miles. Throughout about 7½ miles of this distance the flows face southward with steeply inclined or vertical dips. In this space of 7½ miles there are at least two fairly large strike faults, but the movement along them, as determined by the striæ, appears to have been mainly horizontal, the north side moving west, so that their probable effect would be to decrease the apparent thickness rather than increase it. If the average dip of the flows is considered as 60 degrees, a figure which all observations indicate as probably less than the true value, the thickness of the flows in this section must amount to more than 6 miles; if the average dip is vertical, the thickness must be at least 7½ miles. Although the value of such figures is weakened because of the possible repetition of strata by faulting, yet they give some conception of the enormous thicknesses of lavas that piled up during this great age of extrusion.

AGE AND CORRELATION

The term Keewatin was originally applied by A. C. Lawson in 1885 to a series of hornblende schists, diabases, diorites, chloritic schists, and volcanic agglomerates in the Lake of the Woods region. This assemblage Lawson found highly folded, metamorphosed, and cut by bodies of granite; and he, therefore, coined the term Keewatin to differentiate these rocks from the Huronian, which was less metamorphosed and younger than the granite. The term was quickly adopted in Lake Superior region, and was eventually quite precisely applied there to altered volcanics of pre-Huronian age. When detailed study of northern Ontario began, particularly after the discovery of Cobalt in 1903, it was natural to use the same term in referring to the pre-Huronian volcanic asemblage, in spite of the fact that gaps which cannot be bridged by correlation exist between northern Ontario, Lake Superior, and Lake of the Woods districts. Twenty-five years of geologic study have proved the areal continuity of these volcanic rocks throughout thousands of square miles in northern Ontario and Quebec, and have thoroughly established the name "Keewatin" for them both in geologic literature and in the minds of the general public.

It is now a fact that when the term "Keewatin" is used the great majority of both readers and writers of geological literature think first of the great volcanic assemblage of northern Ontario and Quebec, rather than of the few small areas of these rocks on the south shore of lake Superior, or the original small area in Lake of the Woods district. It is also true that not only is the area of these rocks hundreds of times greater and more continuous in northern Ontario and Quebec, but the rocks themselves are much less metamorphosed, so that their structure and relationships can be better studied than in either of the older districts. For all these reasons the writers believe that the northern Ontario-Quebec region has now become the type locality of these rocks, from which their petrography and relationships should be determined; and that minor areas of similar rocks should be correlated with it rather than it with minor areas.

The Keewatin is accordingly defined as the assemblage of ancient lavas and their associated sediments in northern Ontario and Quebec, as these have been proved areally continuous. The series is the oldest known in the region. It is overlain with unconformity by the Timiskaming series of sediments, and both Keewatin and Timiskaming series have been intensely folded, intruded by great bodies of granite, and deeply eroded prior to the deposition of the Huronian formations.

CHAPTER IV

TIMISKAMING SERIES

DISTRIBUTION

The rocks here grouped provisionally in the Timiskaming series underlie much of the southern half of the region. They are mainly sediments, but also include some volcanics. Their principal occurrence is throughout a belt 10 to 18 miles wide extending from the east to the west boundary of the area, but two smaller bands, the Clericy and Duparquet bands, are also considered for reasons advanced later to be Timiskaming.

About 2 miles east of the interprovincial boundary the main band of Timiskaming series emerges from beneath the strata of the Cobalt series. There it forms a band a little more than 2 miles wide straddling the Dasserat-Dufay line, and cut off on the south by granite. To the east the band widens quickly to 9 miles, along the west side of Opasatika lake, and thence eastward continues to widen gradually to more than 19 miles in Kinojevis map-area. East of this the band narrows, turning southward at the same time, and on lake Lemoine, Dubuisson township, it is only 7 miles wide. East of lake Lemoine it passes southward, so that much of it is outside the area mapped. In the southeastern corner of the mapped area there is a width of only $2\frac{1}{2}$ miles of sediments. The changes in width are due in part to the general structure, but in the main to differences in the distance to which the invading granite on the south has penetrated.

The Duparquet band of sediments has a length of about 10 miles, and a width of $\frac{1}{2}$ to 1 mile. It strikes east through the middle of Duparquet and Destor townships. The Clericy band of sediments is supposedly about 24 miles long, with a maximum width of $2\frac{1}{2}$ miles. It runs southeast through Destor, Clericy, La Pause, and Bousquet townships.

SOUTHERN BAND

SUMMARY DESCRIPTION

The southern or main body of Timiskaming sediments is composed of conglomerate and greywacke, with a little interbedded lava. The conglomerates lie either at or near the base of the series. In the eastern two-thirds of the area they form rather small to medium-sized lenses, in the western third, masses of great thickness. West of Kekeko lake the Timiskaming conglomerate is overlain by the Cobalt series, but though concealed it undoubtedly is present, as it is exposed between Renaud and Olier lakes, where an oblong hole has been worn through the Cobalt series; near the interprovincial boundary, on the north side of the Cobalt series; and near the headwaters of the creek flowing into Renault bay, Dasserat lake. East of Kekeko lake the largest mass of conglomerate in the region occurs. It extends to Kinojevis river, a distance of 12 miles, and throughout this distance maintains an average width of one mile.

Greywacke is the term applied to the remaining sedimentary part of the series, and is here used to refer to a variety of impure sands and sandy silts rather completely metamorphosed to micaceous or hornblendic rocks. In places these rocks have become schists, in other places they are still massive. Only in a few places has metamorphism been so intense as to obliterate the original bedding.

A large, comparatively flat-lying mass of a greatly altered rock that appears to have been a basic lava occurs on Opasatika lake. It is definitely interbedded with the Timiskaming greywackes. In the eastern part of the region lavas like the Keewatin lavas lie within the area of supposed Timiskaming sediments, and are apparently interbedded with them.

CONGLOMERATES

The composition of the conglomerates is difficult to determine in many places, because shearing has obliterated the character of the pebbles; in other places, however, shearing is less intense and the conglomerate may be analysed. One such place is southwest of Pelletier lake, near the north edge of the conglomerate band. There a careful examination was made of a surface of some 30 square feet, from which the moss was freshly stripped. The pebbles include at least six large boulders of coarse hornblende syenite, and one of coarse reddish syenite or pegmatite composed wholly of reddish feldspars about 6 mm. square. Except for a few pebbles of quartz, the remaining pebbles are of basic lavas difficult to distinguish from the matrix except on well-cleaned surfaces. All the pebbles are well rounded, and of all sizes up to a foot in diameter. They lie in a matrix of dark grey, fine-grained greywacke which composes about half the rock.

This band of conglomerate, which is very wide, has been traced eastward as far as Kinojevis river. As might be expected, it exhibits considerable variation of composition from place to place. In general, however, it is like the above description. A minor number of the pebbles consist of granite, syenite, and syenite porphyry, but the bulk of them are of various lavas such as are found to the north. They are rounded to subangular, vary in size up to 1 foot in diameter, and compose from 40 to 70 per cent of the rock. They are smaller in the northern part of the band than in the southern part. The matrix is invariably a more or less sheared greywacke.

The south side of this conglomerate band, throughout the whole exposed length, is characterized by a most unusual conglomerate in which the pebbles consist of a light-grey, fine-grained, recrystallized greywacke, embedded in a dark greenish groundmass. The pebbles are of all sizes up to 4 inches in length, and compose about 75 per cent of the rock. Beds of this sort, up to 20 or 30 feet in thickness, are interbedded with conglomerates of quite normal composition; and it is extraordinary that the beds with the pebbles of greywacke as a rule contain no pebbles of any other kind, except for an occasional lump of some dark greenish, chloritic rock. These beds are best exposed and least altered in the conglomerate area between Renaud and Olier lakes.

In Joanne township, near Kinojevis river, the conglomerates near the Keewatin contact differ from the normal conglomerate of the series in containing large numbers of granite pebbles. In places pebbles of red granite and syenite form half or more of the total number of pebbles. A few are of large size, up to a foot in diameter, but most are less than 2 inches. The granite pebbles, and the granite debris in the matrix, are sufficient in amount, in places, to give the whole rock a reddish cast. The pebbles other than granite are of Keewatin materials, but are commonly so stretched and squeezed as to make identification difficult.

The eastern areas of conglomerate, and in general any areas not specifically described, are like the main band in composition, and consist mainly of Keewatin debris with a sprinkling of granite, syenite, diorite, and quartz pebbles.

The parts of the Timiskaming series represented as conglomerate on the large-scale published maps do not consist wholly of conglomerate. They are composed of conglomerate beds of all widths, from one foot to several hundred feet, interbanded with beds of sandy greywacke like the matrix of the conglomerate in composition. The beds of conglomerate are lens-shaped; they thicken and thin again, and finally wedge out altogether. The interbedded greywackes exhibit crossbedding in places, although throughout most of the region such features, if they originally existed, have been obliterated by shearing.

GREYWACKE

The greywackes of the Timiskaming series appear to have originally been arkoses, impure sands, and sandy silts. They are light grey to dark grey and vary in grain according to the texture of the original material. They are now practically completely recrystallized. Composed originally, it may be presumed, of quartz, feldspar, and ferromagnesian minerals, together with weathered products derived from them, such as clay, chlorite, and carbonate, they now consist practically altogether of quartz and fairly fresh albite, biotite, and muscovite, with accessory magnetite, pyrite, and apatite. Some varieties have hornblende with or without mica. The proportions of the different minerals vary a great deal. Thus, in some beds quartz forms half the rock, in others 20 per cent or even less. The other constituents exhibit similar variations. Recrystallization has been so complete that it is rare to find in a thin section a grain of quartz or feldspar that may have been original.

The heat and pressure to which the greywackes have been subjected have not commonly destroyed the original bedding, which is beautifully developed in most places. The beds are usually from 1 to 3 inches thick, although both thicker and thinner beds are numerous. Exception must be made, however, of the greywackes close to the granite, where coarse recrystallization has caused the disappearance of a part of the original bedding.

LAVAS

A large mass of a peculiar rock that has been diagnosed as an altered lava underlies an area of 10 or 12 square miles on Opasatika lake, Dufay township. Other masses of more normal lava are found south and south-east of Kewagama lake.

The mass in Dufay township was originally described by Wilson[1] under the name of "chloritic rock," as follows:

> "The chloritic rocks are greyish green, massive rocks which, when examined under the microscope, are found to consist entirely of chlorite, pyrite, and a small quantity of carbonate. The exposures of the chlorite rocks which occur on the north and south sides of the entrance to Moose bay are peculiar in that in both localities the rock is traversed by a network of seams containing a carbonate and chlorite. The rock throughout a zone about an inch wide on either side of the seams has undergone a change, for it stands up conspicuously with a white appearance on the weathered surface."

Wilson's description cannot be improved; the rock is simply a mass of felted fibres of dark green chlorite, and displays no feature whatever that gives a clue to its origin. Fortunately in one place in the area west of Opasatika lake, the rock is only slightly altered, and exhibits good variolitic textures, such as are highly characteristic of basaltic lavas in many parts of northern Ontario and Quebec.[2] It was concluded, therefore, that the rock was a lava of about the composition of a basalt.

A careful examination was made of the exposures of the rock on the shores of Moose bay, to determine if possible the origin of its peculiar veined structure, and to obtain additional evidence as to its original nature. On the north shore of the entrance to the bay the alteration has been extreme, and the rock, as Wilson describes, is thoroughly chloritized, and cut by numerous cracks into blocks of all sizes up to 3 or 4 feet in length, giving it a deceptive appearance of pillow structure. The larger of these cracks contain much iron carbonate, in addition to schistose chlorite. On each side of a crack there is a band an inch or less in width of a massive material that weathers whiter than the bulk of the rock, although the two cannot be distinguished on the freshly broken surface. There is no sharp boundary between the whitish material and the darker rock composing the inside of a block; but the two merge into one another, with an irregular ragged contact. The width of the whitish band is roughly proportional to the size of the crack between them.

Evidently carbonate-bearing solutions entered the rock along the cracks, which were formed by movement, as the schistose chlorite in the larger of them indicates. The carbonate-bearing solutions replaced part of the chlorite with carbonate, the amount of replacement being roughly

[1] Wilson, M. E.: Geol. Surv., Canada, Mem. 39, p. 61; also Mem. 103, p. 84.

[2] The term "variolitic" is used to describe the texture of a lava which is always fine grained and occasionally amygdaloidal, and contains numerous round or oval lumps, like small marbles; these lumps likewise consisting of lava of the same composition as the matrix, but finer grained and often a little lighter in colour. The cause of the formation of this peculiar texture is not known, but the texture is highly characteristic of lavas and is probably due to some special condition of cooling. *See* Cole and Gregory, "Variolitic Rocks of Mont Genèvre," Quart. Jour. of the Geol. Soc. of London, vol. 46, p. 295 (1890).

proportional to the size of the crack. The larger the crack, the longer the solutions could presumably flow through it before it was choked by a deposit of carbonate.

On the west shore of Moose bay, about three-quarters of a mile from its northern end, chloritized rock, cracked and carbonated as described, is in contact with the same rock not cracked nor carbonated. As this place appeared very favourable for the determination of the points under investigation, it was examined with great care. The outcrop is 40 or 50 feet long by 30 to 40 feet wide, and the contact mentioned, between the cracked and the uncracked varieties, lies from 5 to 10 feet from the western edge. The contact is a sharp line, strike north 20 degrees east, dip steeply east. The massive, uncracked material lies on the east side of this line, the

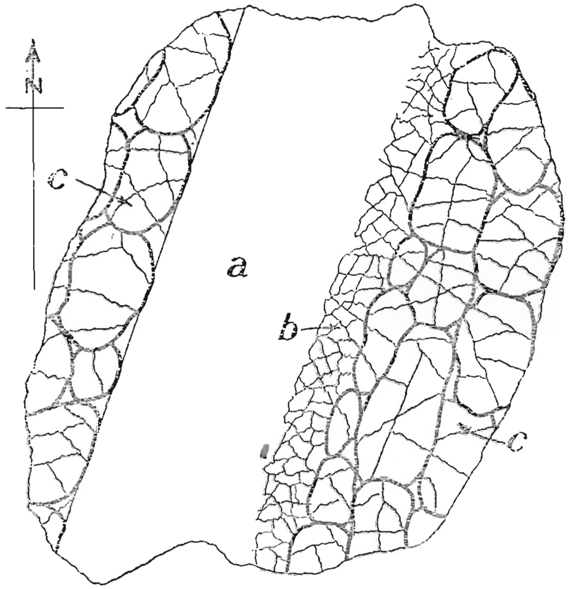

Figure 3. Diagram to illustrate structures in Timiskaming lava: (*a*) massive lava, (*b*) massive lava broken by narrow whitish bands, (*c*) lava with both wide and narrow white bands.

cracked variety on the west side. The massive rock outcrops over a width of 10 to 15 feet from the contact, and then begins to show a large number of small cracks bordered by very narrow bands of whitish carbonated material, cutting the rock into polygonal blocks 1 to 2 inches in diameter. A few feet farther eastward these small blocks give way to larger blocks generally similar to those previously described.

The part that is cut into larger blocks contains two distinct sets of the whitish bands. In one set the bands have a total width of $\frac{3}{4}$ inch to 1 inch; they are mostly somewhat curved, and they divide the rock into large, rounded blocks or masses 1 to 3 feet long by perhaps half as wide.

These large blocks are subdivided into smaller masses by whitish bands of the other set, which are one-eighth to one-half inch in width, and mostly straight or sinuous, though sometimes curved. If this latter set of whitish bands were not present, or were painted out so as not to be visible, the blocks outlined by the larger whitish bands would unhesitatingly be called pillows, and the structure, pillow structure, by anyone acquainted with the lavas of the Precambrian.

If the structure described be regarded as primarily a pillow structure, this outcrop affords a perfectly normal sequence of lava phases. On the west side of the outcrop the pillowed top of a flow is seen. It is in sharp contact with the massive bottom of the next flow to the east, the strike of the contact being north 20 degrees east, the dip steeply east. The massive phase grades stratigraphically upward, quite normally, into a pillowed top. Thus all the observed facts are accounted for.

It was concluded that the chloritic rocks are badly altered lavas of about the composition of basalts. The cause of the primary chloritization is not known. At some period after their extrusion, however, movement took place, and fracturing occurred along the natural lines of separation between pillows, and the pillows were themselves broken by small cracks which also extended for a short distance into the massive lava below the pillowed zone. Solutions bearing iron carbonate and probably also other carbonates circulated through the cracks and replaced the chloritic rocks in part by carbonate for distances that varied with the size of the crack. As to the cause of the latter relationship, it may be that the size of the crack controlled the length of time throughout which circulation of the solution continued.

The lavas are conformably interbedded with the Timiskaming greywackes. In several places around the shores of Moose bay outcrops of the two may be seen within a few feet of each other, although not actually in contact; and the dip and strike of the sediments are such as to carry them either under or over the lava. On the west shore of Opasatika lake a small flow about 15 feet thick outcrops between well-bedded, sandy greywackes. The contact between the upper edge of the lava and the greywacke is exposed, and there is no conglomerate, irregular erosion surface, or other evidence of stratigraphic break between them. The greywacke lies directly on the pillowed top of the lava, and the dip and strike of its bedding parallel the contact perfectly. The sediments beneath the lava also parallel the contact, but the contact itself is not visible, for it has been worn by the waves into a crack a foot or two wide, which is now filled with boulders and soil.

South and southeast of Kewagama lake a number of lava flows are interbanded with the sedimentary rocks mapped as Timiskaming. For the most part these are ordinary andesites locally pillowed, such as are found also in the Keewatin, and merit no special description.

In Bousquet, Cadillac, and Fournière townships, lava flows were found immediately to the south of bands of conglomerate and in direct contact with them.

CLERICY BAND

The Clericy band of sediments appears as a number of low outcrops projecting through a plain of lacustrine clays. The outcrops are scattered throughout an area 24 miles or more in length and 2½ miles in greatest width. The northernmost outcrop is in the southeastern quarter of Destor township, and from this point the band appears to run south 60 degrees east through Clericy and La Pause townships, into the northeastern quarter of Bousquet township. The poor exposure of these sediments renders the data obtained very meagre.

The westernmost occurrence, in the southeast quarter of Destor, is about half a mile long and 1,500 feet wide. The northern edge of it consists of fine-grained greywacke containing lenses of coarser arkose. About 200 feet south, lenses of conglomerate 10 to 50 feet wide occur in the fine-grained greywacke. The conglomerate contains pebbles of porphyritic rhyolite, granite, dark-coloured jasper, quartz, and other rocks. The pebbles are well rounded and seldom exceed 3 inches in diameter. South of the conglomerate lenses there is a width of about 1,000 feet of fine-grained, distinctly banded sediments that weather to a light grey colour. Then follows a narrow band of conglomerate, made up mainly of pebbles and boulders of volcanic rocks in a greenish matrix, which probably represents the same basic volcanic material ground to powder. The boulders are of all sizes up to 15 inches diameter, are slightly rounded, and have been a good deal squeezed. One pebble of glassy quartz was seen. These sediments commonly strike north 60 degrees west, and dip vertically.

Outcrops of coarse arkose with some argillaceous layers occur along the strike of the main band northwest of Kinojevis river, in scattered exposures. The arkose is composed of grains up to 7 mm. in diameter of quartz, orthoclase, and plagioclase, with a little biotite and epidote. The feldspar is much altered. Some of the quartz fragments are a mosaic of smaller grains and may possibly be chert.

The strata are better exposed just southeast of Kinojevis river. Near the northern contact there is a small band of conglomerate containing pebbles and boulders of the Keewatin volcanics. The rest of the sediments are arkoses like those just described, interbedded with slaty rocks. The strike is commonly nearly parallel to that of the band, the dip nearly vertical.

A gap of 5 miles separates the outcrops just described from the next set of outcrops near lake Chassignole. The latter consist of an altered greenish greywacke with some interbedded slaty bands. Much of the rock is schist, and consists largely of quartz grains with some orthoclase and acid plagioclase, a good deal of pale brown mica, and some white mica. Rocks similar to these are also found south of Chassignole and Kewagama lakes, and may possibly form a southeastward extension of the Clericy band.

The strike of the Clericy band, and its general parallelism with the Keewatin structure, made it at first seem probable that it was of Keewatin rather than Timiskaming age. Its composition has proved, however, to be unlike that of any of the bodies of Keewatin sediment later studied, and this fact, together with the evidence of the conglomerates that the Clericy band is formed of material eroded from the Keewatin, makes a Timiskaming age seem more likely. While awaiting more precise evidence, therefore, the writers have tentatively grouped these sediments with the Timiskaming.

DESTOR-DUPARQUET BAND

The Destor-Duparquet band of sediments is about 9 miles long and $\frac{1}{2}$ to 1 mile wide. Its western end is about $\frac{3}{4}$ mile east of Duparquet lake, and it runs nearly due east along the centre line of Duparquet and Destor townships. Two smaller bodies of sediments lie to the east of the main band and a little north of the centre line, one, more than a mile long, separated from the main band by a gap of 1,700 feet, the other, a little smaller, about $4\frac{1}{2}$ miles east of the end of the main band. The main band forks at the east end in a suggestive manner, and the two isolated occurrences would appear to be continuations of the northern branch.

The great bulk of these sediments consists of conglomerates and arkoses so interbedded that they could not be separated in mapping. The beds strike mostly from north 75 degrees west to due west, and dip almost vertically. The sediments are much less metamorphosed than in the main body of Timiskaming series to the south. There is very little schistosity, on the whole, although locally the matrix of the conglomerate and a few of the softer pebbles have been sheared. In the most easterly outcrop, however, shearing has been intense, and the greater number of the pebbles have been mashed beyond recognition.

The arkose has an unusually even grain of $\frac{1}{40}$-inch diameter, or less. It is composed of numerous angular fragments of quartz and a few relatively fresh feldspar grains embedded in a matrix of kaolin, sericite, chlorite, and calcite. The quartz fragments did not show strain shadows in the thin section examined.

The conglomerate is very uniform both in composition and the size and shape of its pebbles. The latter are invariably well rounded, and very commonly form flattened ellipsoids. The largest found was 18 inches long, but most of them do not exceed 4 inches. Pebble counts made in a number of places showed that the different types of pebbles maintain about the same proportion from place to place. The following average, therefore, represents approximately the proportions that occur: andesite, 51 pebbles; other volcanics, 46; syenite, 9; granite, 7; diorite, 9; feldspar porphyry, 6; quartz, 3; red jaspilite, 2.

In addition to these normal rock types, two conglomerates of unusual character are found on the edges of the band. The first, a red feldspar porphyry conglomerate, occurs on the northern edge of the band near its western extremity. The second, a quartz porphyry conglomerate, lies on the southern edge of the band near its eastern extremity. Both of these conglomerates appear to consist of the disintegration products of an igneous rock directly beneath them, and to contain little material from other sources.

A mass of coarse purplish red feldspar porphyry 3 miles long borders the northern edge of the Duparquet-Destor band near its western end. It is rather poorly exposed, but was observed at one locality along its southern edge to grade imperceptibly into a conglomerate composed largely of porphyry boulders. The boulders vary from angular to rounded, and attain a maximum diameter of 9 feet, though the average is about 6 inches. Careful counts made of the pebbles in several places showed that a number of pebbles of rhyolite and other volcanic rocks are present in addition to the porphyry pebbles, but the relatively small sizes of the volcanic pebbles, usually less than 2 inches diameter, make their relative volume very small. An area of 16 square feet, in which the number of volcanic pebbles was unusually large, showed 61 porphyry pebbles and 22 pebbles of andesite and rhyolite, all over 1 inch in diameter. The volume of the volcanics, however, was estimated at only about one per cent of the volume of all the pebbles. The pebbles and boulders are enclosed in a matrix of smaller pebbles and fragments of porphyry, andesite, and rhyolite, which is rather badly sheared.

On the south side of the sedimentary band, at the Destor-Duparquet boundary, there is a mass of quartz porphyry three-quarters of a mile in length. The porphyry is composed of large phenocrysts of quartz up to the size of a bean, in light-coloured aphanitic groundmass. The porphyry grades on the north, without any sharply defined boundary, into a conglomerate composed of angular and rounded boulders of all sizes up to 3 feet in diameter. The boulders and pebbles are mainly of quartz porphyry, but also include those of the ordinary Keewatin volcanics. Actual pebble counts showed that the other volcanics form about 43 per cent of the total number of pebbles, but those of quartz porphyry are so much the larger that they compose about 90 per cent, by volume, of the pebbles. The matrix forms only about 1 per cent of the volume of the rock, and is a mixture of quartz and feldspar grains with particles of andesite, rhyolite, and possibly other volcanic rocks.

Between the normal Timiskaming sediments and each of these bodies of unusual conglomerate there is a band of slate up to 100 feet wide. It is a dark brown, grey, or black rock, fine grained, and usually very fissile. In one place, on the Makamik road, the original bedding is preserved, and the rock is made up of alternating beds of fine-grained, dark green argillite and coarser, dark grey argillite. The beds vary in thickness from $\frac{1}{2}$ to $1\frac{3}{4}$ inches, and strike north 25 degrees west, with a vertical dip. The slate band may follow the margin of the sedimentary band fairly continuously, as it was traced for $1\frac{1}{4}$ miles along the northern contact in the centre of Duparquet township, and also found at several other places, on the Destor-Duparquet boundary, on the Makamik road, and on the south side between the quartz porphyry conglomerate and the main body of sediments.

The position of the peculiar porphyry conglomerates on the extreme margin of the Timiskaming syncline indicates that they underlie and are older than the more normal sediments composing the rest of the band.

Their composition shows that they were formed by disintegration, in place, of the porphyries. The quartz porphyry may be a flow rock, but there can be little doubt that the red feldspar porphyry was intrusive into the Keewatin. Between the end of the Keewatin period and the formation of the red porphyry conglomerate, therefore, sufficient time must have elapsed to permit of the intrusion of the porphyry mass and its exposure by erosion of any overlying Keewatin rocks. It seems necessary to conclude, therefore, that there is erosional unconformity between the Keewatin series and the red porphyry conglomerate.

As these conglomerates lie between the Keewatin rocks and the Timiskaming sediments of more normal composition, it is further evident that a still greater time interval existed between the end of Keewatin deposition and the beginning of normal Timiskaming sedimentation at this locality. In this interval, these conglomerates suggest, the Keewatin rocks were undergoing rapid subaerial disintegration. The great volume of loose material thus produced may well have been the source of the enormously thick Timiskaming conglomerates.

The age relationship of the porphyry conglomerates to the normal Timiskaming series is still unsolved. It is possible that there was no great time interval between them, and that deposition went on without any break of importance from the time the conglomerates were first formed until the end of Timiskaming deposition. It is also possible that deposition was not continuous, and that a longer or shorter period of time intervened between the end of the conglomerate deposition and the beginning of Timiskaming deposition.

TOPOGRAPHIC EXPRESSION OF THE TIMISKAMING SERIES

The conglomerates vary a good deal in their topographic expression, depending probably in part on the proportion of interbanded greywacke and in part on the extent to which they have been sheared. Where the conglomerate beds are fairly thick and not too intensely sheared they tend to stand up as ridges of low to medium height. Northeast of Kekeko lake and across to Kinojevis river there are several ridges of conglomerate standing 200 to 250 feet above the level of Opasatika lake, whereas in other parts of the same area the conglomerates are worn down to the general level or form a series of low knobs.

The greywackes are very soft, easily eroded rocks, and, therefore, stand low. The wide area underlain by greywackes has in large part been worn down below a level ranging from 900 feet above sea-level around Opasatika lake to 1,000 feet above sea-level around the headwaters of Harricanaw river. This low area has since been filled with a thick deposit of post-Glacial lake clays, so that it now forms a monotonous, gently rolling clay plain from which rise low and usually widely separated outcrops of the greywackes. Only in a few places do the greywackes form hills up to 250 feet high. One of these is on the east shore of Opasatika lake south of Moose bay, Montbeillard township; another is east of the north end of lake

Lemoine, Dubuisson township. These must be considered merely as erosion remnants, that is, areas between drainage basins which the forces of erosion have not yet had time to level.

The chloritic lava on the west shore of Opasatika lake is a very soft rock, but its highly chloritic composition and the felted texture have apparently rendered it quite resistant to erosion. Much of the area underlain by it is from 200 to 250 feet above lake Opasatika.

METAMORPHISM

The Timiskaming series in Quebec is in general somewhat more highly altered than in Ontario. This is due in part to greater intensity of folding, and in part, no doubt, to higher temperatures induced by intrusion of the immense granite masses.

The conglomerates are in general strongly compressed and sheared, although parts of them have escaped shearing. Commonly, however, the pebbles are compressed into elliptical forms, and even drawn into long, narrow strings where compression has been particularly severe. The pebbles of granite and syenite, being hardest, have suffered least in this way, and are normally only cracked by the pressures which have been relieved by the flowage of the softer matrix. The pebbles of the volcanics, on the other hand, are strongly flattened. As the crushing strength of fresh basalt, andesite, and rhyolite is approximately as great as that of granite or syenite, this flattening evidences that the volcanics must have been softened by alteration before deformation.

The greywackes have been very completely altered by heat and pressure to mica schists, or in places to hornblende schists. The schistosity is almost everywhere perfectly parallel to the bedding. The rocks now consist of white and black mica, or hornblende, quartz, and feldspar usually close to albite in composition. That these minerals have all been formed by recrystallization is shown by their entire lack of alteration, and by their freedom from the cracks and strain shadows invariably present if a rock has been squeezed without recrystallizing. The parallelism of schistosity to bedding indicates that recrystallization has been effected during the folding of the series, and that the schistosity was caused mainly by the slipping of the beds on one another at that time. If it were due to any other pressure, the schistosity would cut across the bedding in many places. Metamorphism is more extreme in the southern part of the series than in the northern. The differences consist: (1) in a more perfect development of the schistosity; the rocks are commonly very cleavable, whereas the more northern greywackes are massive, in many instances entirely without cleavage; (2) in a coarser crystallization; the plates of mica may attain a diameter of 1 mm., whereas in the massive types to the north they are much smaller, and even invisible to the naked eye in many varieties; (3) in the obliteration of many of the bedding planes; and (4) in the occasional development of such minerals as sillimanite, garnet, and staurolite, characteristic of very high temperatures and pressures. Thus a bed of sillimanite-garnet schist was found on the east shore of Joanne lake, about ¾-mile from the southern end; and a bed or band of staurolite schist was traced for many miles parallel to the general strike through southern Dubuisson township and to the east and west. These differences in the degree of metamorphism are undoubtedly to be ascribed to the heat supplied by the great mass of intrusive granite to the south.

STRATIGRAPHY AND THICKNESS

As already stated, the Timiskaming series in most places consists of a conglomerate member and a greywacke member. The conglomerate occurs at or near the base of the series, and the greywacke forms the upper horizons. The conglomerate occurs in discontinuous lenses, some of great thickness, others quite small. West of Kinojevis river the amount of conglomerate is large; east of that river it is small.

On Opasatika lake a lava is interbedded with the greywackes. As this locality is on the summit of an anticline, the lava must be rather low in the series, probably not far above the top of the conglomerate horizon. Southeast of Kewagama lake, again, lavas are found within the sedimentary area, some of them considerable distances south of the northern boundary. The stratigraphical position of these is unknown, owing to ignorance of the general structure of this section.

Estimates of the thickness of the series are impossible to make with accuracy, as the series is severely folded, and contains no characteristic beds that might serve as horizon markers from fold to fold. About all that can be done, therefore, is to estimate the thickness of the strata exposed in any individual fold, and to hazard a guess as to the total thickness. On Kinojevis river some careful work was done in 1929 on the folds exposed between Davidson creek and lake Vallet (*See* Chapter V). The folds there have a width of approximately seven-eighths of a mile from the crest of an anticline to the axis of the following syncline; and by platting all the numerous dips obtained on one of these, it was roughly determined that the strata involved are approximately 2,900 feet thick. However, neither the top nor the bottom of the pile of strata is visible in one of these folds, so that undoubtedly the series is much thicker than the figure mentioned, possibly twice as thick or even more.

This conclusion is suggested by two considerations. In the first place, the northernmost folds contain a large proportion of conglomerate—perhaps 50 per cent—whereas in the folds farther south no conglomerate is exposed. The natural deduction is that the conglomerate beds dip southward beneath the greywackes, so deeply that they are not brought to the surface in the southern anticlines; and if this is true the thickness of the whole series must be at least double the thickness of a single fold. Of course, the conglomerates, when depositing, might have thinned so rapidly southward as practically to disappear, in which case the total thickness might or might not be much greater than 2,900 feet. The second consideration is, that the sediments as a whole form a great synclinorium, with a present maximum width of 19 miles, and a still greater width before the south part was cut off by granite. It may, therefore, be assumed as a probability that there is a general southward dip within the northern half, at least, of the existing band. An average dip of 20 degrees, for this distance, would give the series a thickness of nearly 4 miles; so that the dip must be low indeed if the total thickness does not considerably exceed the 2,900 feet calculated for one fold.

RELATIONS TO OTHER FORMATIONS

RELATIONS TO THE KEEWATIN SERIES

The Timiskaming conglomerates are made up of debris entirely similar in composition to the Keewatin flows on the north, and as there is no other evident source of such debris, it is generally presumed that it was derived by erosion of the Keewatin. If this is true, the Timiskaming series must be younger than the Keewatin. To prove more definitely this presumption, efforts have been made to identify definitely the sources of the conglomerate pebbles, and in certain instances these efforts have been successful. Thus it has been noted that the conglomerate south of Rouyn lake contains many pebbles of a carbonated acid schist, a porphyritic trachyte, and a porphyritic andesite, identical with rocks found near the lake.

Better evidence as to the age relations of the two series is obtained from the attitudes of the lava flows near the Timiskaming boundary. A large number of determinations of attitude were made on the flows just north of the boundary in Malartic and Dubuisson townships, and a smaller number in Rouyn and Joanne townships; and in all cases the upper sides of the flows face south, commonly with an overturned dip to the north. The sediments, therefore, before folding, must have been deposited on the tops of the flows; in other words, the Timiskaming series is the younger.

The contact between the Keewatin series and the main body of Timiskaming sediments is striking and unusual. To the south the Timiskaming is thrown into normal upright folds that are broad and open on Opasatika lake, and rather closer elsewhere. To the north the Keewatin is folded in a similar manner. The folding is far more intense at the contact, as if it had been a line of overthrusting; and the strata for a mile or more north and south of the contact are strongly overturned, and display dips that average 70 degrees north and locally may be as low as 40 degrees north.

The dip and strike of the lavas, wherever directly observed south of Pelletier lake and eastward, are approximately parallel to the Timiskaming contact. It will be shown, however (page 89), that west of Pelletier lake an axis of a Keewatin syncline strikes somewhat south of east and apparently passes beneath the Timiskaming boundary. If this is true, the sediments west of the axis must rest on the *bottoms* of the lava flows lying north of them. Such a conclusion implies that before the Timiskaming series was deposited the lavas must have been intensely folded, so intensely that the strata were turned bottoms-up in this locality.

There is no evidence elsewhere that so strong a folding took place at this time. On the contrary, the discordance between the Keewatin and Timiskaming series in most localities is very small. Had Keewatin folding been so intense in one locality, the area affected must have been large, and important discordances would surely be visible in many places. The conclusion seems inevitable, therefore, that some other explanation must be sought to explain the phenomena west of Pelletier lake. The only other way by which the strata might have been brought into their present relationships is by faulting. Where strata are so strongly compressed that overturned folds are formed, as in this locality, it is common to find the folds passing into overthrust faults. Overthrust faulting taking place after Timiskaming deposition could readily bring the strata into the positions observed.

Unfortunately it is not possible to test the truth of this hypothesis in the field, as the Timiskaming-Keewatin contact north of Opasatika lake is hidden by the overlying Cobalt series. The following data, however, suggest that the above conclusion is not far-fetched.

A strong fault, the Lake Fortune fault, cuts east and west through the lavas a short distance north of the Timiskaming-Keewatin boundary. A second fault cuts across Pelletier lake on nearly the same line of strike. These faults might be subsidiaries of the main inferred fault.

Near the north end of Opasatika lake, and also just south and southeast of Renaud lake, ridges of Timiskaming conglomerate and greywacke rise 100 feet or more above water-level. Within a few hundred feet north, in both places, the Cobalt series outcrops at water-level and for an unknown distance below. Evidently the Cobalt series fills a deep and steep-sided, east-west valley along the north edge of the Timiskaming series. The existence of such a valley does not prove that a fault existed; but if a strike fault defined the Keewatin-Timiskaming boundary, a pre-Cobalt valley would certainly have been developed upon it.

Farther east no locality has been found where the Keewatin is actually in contact with the Timiskaming series. In areas of good outcrop they are commonly separated by a narrow linear valley about 200 feet wide, the sides of which are quite steep in places.

A very strong fault, a branch of the Davidson Creek fault, runs east and west just north of the Timiskaming boundary west of Kinojevis river. It was traced west about 2½ miles, and may be a continuation of the Pelletier Lake fault. A second fault, parallel to the one mentioned, or nearly so, probably cuts the Timiskaming conglomerate close to the Keewatin contact (*See* pages 79, 80).

Farther east, along almost the same line of strike, a strong strike fault cuts the sediments on the O'Brien and other claims in Cadillac and Bousquet townships (page 103).

The interbanding of lava flows and sediments in Bousquet, Cadillac, and Malartic townships is possibly due to strike faulting.

Thus several strong strike faults are known to occur along or close to the Timiskaming-Keewatin boundary, and there is presumptive evidence of the presence of others. It is not improbable, therefore, that the boundary in Quebec is in the main a fault boundary; while, as has been shown, faulting appears the only likely means of accounting for the relationships west of Pelletier lake.

It has been shown that the Timiskaming series in Quebec is younger than the Keewatin and overlies it, but definite further evidence as to the relationships, whether conformable or unconformable, is difficult to obtain. It is generally conceded, however, that the Timiskaming series lies unconformably upon the Keewatin, for the following reasons:

The Timiskaming conglomerates are composed of pebbles and boulders of Keewatin rocks, some of which are identifiable as originating in lava flows not far away. This fact suggests that uplift and erosion of the Keewatin took place prior to the deposition of the Timiskaming.

Pebbles of coarse-grained granite, syenite, and diorite are moderately numerous in the conglomerates even at the very base. The intrusive bodies from which these were derived must, therefore, have been older than the Timiskaming series. They could have come from only three sources: (a) from bodies intrusive into the Keewatin; (b) from a possible granite floor on which the Keewatin lavas flowed out; (c) from lumps of granite torn away by the lavas in their passage to the surface, and included in the flows. If the granite pebbles in the conglomerate were few and far between, the third suggested source would be the most probable; but, as stated, they are moderately numerous, whereas no lump of granite has ever been observed as an inclusion in a flow. The third suggestion may, therefore, be eliminated as a probability, and the possible sources of the pebbles limited either to intrusives in the Keewatin, or to the original floor of the Keewatin. If they were derived from batholithic intrusives, as the coarse, equigranular texture indicates, then the Keewatin must have undergone long-continued erosion before the Timiskaming was deposited, erosion sufficient to remove the roofs of the intrusive masses. If, on the other hand, they were parts of the basement beneath the Keewatin, then the Keewatin must have undergone folding and very long-continued erosion before Timiskaming deposition began, in order that any part of the base should be exposed. The presence of these coarse-grained granite and syenite pebbles, therefore, appears to be indubitable evidence of unconformity.

It is shown in a later section of this report (page 71) that the character of the conglomerate beds indicates that they are subaerial deposits formed by streams descending from a hilly or mountainous area. Such an area was presumably elevated by mountain-building forces between the close of Keewatin and the commencement of Timiskaming deposition. If this inference is correct, the two series are undoubtedly unconformable.

Excellent evidence of unconformity between the Keewatin and the Destor-Duparquet band of sediments was found. Either at the very base, or below the base, of the normal Timiskaming series, there is a conglomerate formed largely of debris of a porphyry intrusive into the Keewatin series (page 62).

Unconformity between two series is not necessarily visible in all places. In studying the Palæozoic and later strata it is frequently found that formations unconformable in some localities appear perfectly conformable in others, and that in the latter places the gap in the sedimentary record can be recognized only by abrupt change in the fossil contents of the beds. If beds such as these lacked fossils, as in the Precambrian, it would be difficult or impossible to draw a boundary line between the older and younger formations, or even to prove that a boundary line exists.

It is believed that the eastern end of the district under consideration is a locality of this sort. The great sedimentary band extends without break from the western end of the district to the eastern, as does the belt of lavas to the north of it. It must be concluded, therefore, tentatively at least, that the great body of the eastern sediments forms part of the Timiskaming series, and that a gap, or time interval, occurred between their deposition and that of the Keewatin. East of Kinojevis river, however, and particularly east of Kewagama lake, it has as yet been found impossible to draw a boundary with certainty between the two series. The boundary indicated on the large-scale published maps marks only the position where lavas in the main give place to sediments. It is not believed that this boundary marks the true contact of the Keewatin and Timiskaming series. The difficulties in the way of determining the true boundary are as follows:

The strong band of conglomerate that lies at or close to the base of the series in the west disappears east of Kinojevis river, and bodies of conglomerate are thenceforth small and widely scattered.

Considerable bodies of fine-grained, bedded tuff are associated with the lavas near the boundary. These tuff beds are petrographically almost indistinguishable from many of the Timiskaming greywackes, since both are lava powders, recrystallized and converted into schists.

The strike of the lavas and tuffs is closely the same as that of the greywackes. In addition, outcrops are small and scattered, so that it has been impossible, as yet at least, to work out the structure of either so as to bring out the existence of possible structural discordance.

The existence in the sediments south and southeast of Kewagama lake, of considerable masses of lava petrographically identical with the Keewatin lavas, strongly suggests that much remains to be learned of the geology of this district. These masses of lava may be: (a) lavas of Timiskaming age; (b) Keewatin lavas brought into contact with Timiskaming strata by strike faulting or anticlinal folding; (c) Keewatin lavas, interbanded with Keewatin sediments, the true Keewatin-Timiskaming boundary lying somewhere to the south. At present there is no means of knowing which alternative is correct.

The unconformity inferred between the two series in Ontario and in the western part of this region, therefore, seems to disappear in the eastern part, leaving them in apparent conformity.

RELATIONS TO YOUNGER FORMATIONS

The Timiskaming series is in contact on the south with an immense body of granite. The granite invades the sediments in a complex manner, sending off great apophyses northward across the strike of the beds, and cutting off and surrounding great masses of them. The sediments are much more highly altered close to the granite than farther away, and are converted into schistose mica gneisses. In the granite thousands of inclusions of the sediments can be observed, of all sizes up to masses large enough to map; and these inclusions are in all stages of digestion, from lumps with sharp edges, through pieces more or less melted and recrystallized, to the final stage of absorption, where a former fragment is now no more than a patch of granite somewhat darker in colour and more micaceous than the surrounding rock. In addition to these phenomena, numerous small dykes of granite run through the sediments, usually paralleling the bedding, but in places cutting across it. All these phenomena unite in proving the granite later than and intrusive into the Timiskaming series.

The syenite porphyry, and the later gabbro also cut the Timiskaming series in Quebec. To avoid repetition, the discussion of the mutual relations will be postponed until the intrusives are individually discussed.

The Cobalt series is in contact with the Timiskaming and Keewatin series in the western end of the region. The Cobalt series stands well above the general level of the country, and the Keewatin or Timiskaming is exposed wherever a moderately deep valley is incised in the Cobalt series. Such places are: between Renaud and Olier lakes, southwest of Renault bay, Dasserat lake, and around Ogima lake. Practically all the re-entrants in the boundary of the Cobalt series are valleys. Again, on the west shore of Kekeko lake, there is a little oval outcrop of Cobalt series isolated from the main body of that series by a quarter-mile gap. The outcrop, a steep-sided knob, was evidently a part of the main body at one time, but has been cut off from it by erosion. The original floor of the Cobalt series at this place must have been, therefore, approximately the level of the ground between the knob and the main body.

Such exposures of the basement of the Cobalt series can indicate only that its base is a comparatively flat plane, lying nearly at the level of the surrounding greywackes and lavas. A more extended description of this plane is given in connexion with the description of that series.

The Timiskaming beds on which this plane has been developed by erosion are steeply inclined, and the plane cuts across them at a large angle. It is, therefore, evident that an enormous interval of time lapsed between the depositions of the two series, an interval in which the lower series was strongly folded, and the folds eroded down to a comparatively flat surface.

ORIGIN AND HISTORY

The conglomerate of the Timiskaming series is possessed of a number of peculiarities from which its origin may be deduced. The most striking is the lens-like nature of the beds and the enormous thicknesses the lenses attain in many places. In Opasatika-Kinojevis map-areas the thickness of the conglomerate and interbedded greywacke is at least 2,900 feet, and individual beds of conglomerate south of Pelletier lake are many hundred feet thick. Within a distance of 10 miles to the east, these enormous thicknesses disappear and the conglomerates are represented only by isolated, comparatively thin lenses. Individual beds of conglomerate behave in a similar manner, maintaining a maximum thickness for a longer or shorter distance, then thinning rapidly to a fraction of their former widths, and finally pinching out entirely.

Conglomerate deposits of such shapes and thicknesses are uncommon, and only one way is as yet known by which they may have formed. Where torrential streams descend from mountain ranges, sweeping along coarse detritus which is dropped wherever the current is checked, as where the stream passes from the mountains to a plain, or into a sea or lake, thick conglomerates of this sort are built up. The pebbles and boulders rapidly fill the bed of the stream, forcing the stream into new channels which, in turn, are quickly filled. By the repetition of this process a wide, fan-shaped mass of gravel and boulders, interbedded with sands and silts, is built up; and where streams are fairly closely spaced, in an area of dry climate, the combined fans may form a deposit hundreds of miles in length and width.

Many of the beds of greywacke interbanded with the Timiskaming conglomerates exhibit pronounced crossbedding in places where shearing has not destroyed the original structures. Crossbedding is characteristic of sands deposited in strong currents of water.

The shapes of the pebbles, again, are such as might be expected in stream-deposited sediments. Although most of them are well rounded, as if rolled for long distances, many are subangular and even sharply angular, as if they had come from sources near at hand. If the pebbles had been worn by wave action on a beach, the pebbles would tend to a similar degree of rounding, and differences in the rounding would be proportioned to the varying hardness of the pebbles.

The structures of the great mass of greywacke to the south of the conglomerate suggest a change of conditions. Individual beds maintain a very even thickness over considerable lengths. Many are only a fraction of an inch thick, but even these display no markedly lenticular shape. Crossbedding, so far as observed, is entirely absent. Where the original texture is not entirely destroyed by alteration, it shows that the rocks, for the most part, were originally quite fine-grained, although coarse types, from arkose to conglomerate, do occur in places. These facts indicate that the greywacke was deposited in some body of quiet water rather than in the bed of a stream. The water, however, was probably rather shallow, as even moderately fine sands would not be carried to great depths by the comparatively gentle currents occurring in standing water.

Thus it appears that after the deposition of the conglomerate the area of sedimentation became covered with a shallow body of standing water. Such a body might have been a great lake formed by blocking of the drainage; or the land surface, owing to the weight of conglomerate piled on it, may have sunk, permitting the sea to flow in. The great thickness of the greywacke suggests that the second possibility is the more likely, and that sinking of the bottom went on gradually as more and more sediments were piled up.

It is fitting at this point to draw attention to the changes in the character of the Timiskaming conglomerate throughout the 90 miles or more of country in which it appears. These changes are undoubtedly due to differences in the conditions of sedimentation, such as proximity to the sources of supply of sediment, slope of the land, and size and velocity of streams; but still fuller regional information is desirable before any attempt to interpret them is made. The points to be considered are, the changing thicknesses of the conglomerate, the size of the contained pebbles, and the proportion of sharp-angled pebbles.

At the west end of the Timiskaming band in Teck township, Ontario, the amount of conglomerate is large; in fact the greater part of the rock, estimated at some 3,600 feet thick, might be classed as the conglomerate member of the series, composed of beds of conglomerate with more or less interbanded greywacke. The proportion of conglomerate decreases eastward to a maximum of about 600 feet in McGarry and McVittie townships; and the conglomerate lenses also become discontinuous, so that along short lengths of contact the greywackes lie directly on the Keewatin lavas. This condition persists to where the Timiskaming disappears beneath the Cobalt series. Where it reappears south of Renaud lake and again east of Pelletier creek the conglomerate member is again very thick, attaining a maximum of 2,900 feet or more. Great thickness is maintained as far east as Kinojevis river, beyond which a sudden thinning occurs. One fairly large lens, with an exposed length of 5 miles and a maximum thickness of about 2,000 feet, is known in the area between Kinojevis river and Kiekkiek (Bousquet) lake, but east of Kiekkiek lake the lenses become much smaller and are separated by wide intervals. The maximum thickness of those that are known is about 700 feet.

The sizes of the pebbles appear to be more or less proportional to the thickness of the conglomerate masses. Boulders up to a foot or more in diameter are common in the thick conglomerates of Teck township, and also in the thick conglomerates west of Kinojevis lake; and many beds, in these areas, are made up of pebbles averaging 4 to 6 inches in diameter. In the thinner conglomerates of McGarry township the pebbles average somewhat smaller, a length of 3 or 4 inches being about the maximum. In most of the small lenses east of Kiekkiek (Bousquet) lake the conglomerates are composed entirely of small pebbles, those with a diameter of more than an inch being rare.

The proportion of sharp-angled pebbles steadily decreases from west to east. West of Swastika, Ontario, there are many beds of conglomerate made up entirely of pebbles so sharp-angled that the beds are more like breccias than conglomerates. In Larder Lake area sharp-angled pebbles are not rare, but are far from numerous. In Quebec, sharp-angled pebbles are so rare as to be practically absent.

AGE

The close folding of post-Timiskaming time deformed immense thicknesses of Keewatin and Timiskaming strata. The tremendous thrusts necessary to produce such great deformation must have elevated the areas affected and produced great mountain ranges. These mountains were worn down to a peneplain by removal of great thicknesses of rock before the Cobalt series was deposited. A very long interval of time elapsed, therefore, between the formation of the Timiskaming and Cobalt series. The Cobalt series outcrops in an almost continuous sheet southwestward to the north shore of lake Huron. Northwest of Sudbury the Bruce series (Lower Huronian) appears, underlying the Cobalt series; and the peneplain on which the latter lies passes beneath the Bruce series. It is evident, therefore, that all the rocks truncated by this peneplain must be pre-Bruce as well as pre-Cobalt. The Timiskaming, therefore, must be pre-Lower Huronian in age.

The Timiskaming series overlies the Keewatin series with erosional and structural unconformity. The period of erosion between the two is inferred to have been of moderate length. The structural unconformity is small, and was apparently caused by a gentle folding movement during the interval prior to Timiskaming deposition. Good evidence of this pre-Timiskaming folding has not been obtained in the Quebec region, but is known from the study of areas of Timiskaming series in Ontario.

CHAPTER V

FOLDS AND FAULTS

INTRODUCTION

When Opasatika map-area was first studied in 1922, the data obtained appeared to indicate the existence of pronounced structural discordance between the Keewatin and Timiskaming series. Later study showed that throughout the remainder of the Rouyn-Harricanaw region no structural discordance could be detected, and also that the apparent discordance in Opasatika map-area was probably due to faulting (pages 66, 67). For the present, therefore, it is preferable to consider both Timiskaming and Keewatin series as folded at the same time, and, therefore, to describe all the folds of the region together.

The stresses causing folding were undoubtedly relieved in part by faulting, so that many of the known faults were formed during the folding period. Some of the others were of later age, as they cut unfolded intrusives, such as the granites and later gabbros. All the rocks in the area are pre-Huronian, however, except for the small area of Cobalt series in the west; and it is consequently impossible to know whether any of the faults are younger than pre-Huronian. For this reason, and for convenience of reference, the descriptions of all the known faults are grouped in the following pages.

FOLDS IN THE TIMISKAMING SERIES

The folding of the Timiskaming series has been complex, and many difficulties are encountered in the effort to decipher it. Owing to the similarity of the beds of greywacke, it is impossible to trace a given bed beyond the limits of a single outcrop. Thus structure cannot be worked out by following a single bed or series of beds, but must be determined from dip and strike observations and from observations on small drag-folds. The dips are commonly steep and in many cases overturned, so that they yield scanty information in many sections of the region; and the small and rather poor exposures do not commonly show enough drag-folds for satisfactory conclusions to be drawn.

As shown in the previous section of the report, the Timiskaming series overlies the Keewatin, so that bodies of it must either have a synclinal structure or must be downfaulted on one or both sides. The data at hand appear to indicate that the bodies in Quebec are synclinal, but that faulting may also have been present along parts, at least, of the margin of the southern or main band.

STRUCTURE OF MAIN BAND

The main band of Timiskaming series was formerly much wider than at present, as the southern part has been destroyed by the invasion of great bodies of granite. Inclusions of Timiskaming sediments in the granite, some of them miles in length, show that the former width of the sedimentary band was more than 25 miles. Consequently the whole structure of the original band cannot now be known.

The known folds, for the most part, are of the normal upright type and rather closely compressed; one, however, the Opasatika anticline, is broad and open. The northern boundary of the series, for some reason, has been a place of unusually severe deformation, and the Timiskaming strata, together with the lavas on the north, have been overturned for distances of about a mile on each side of the contact. In all probability, also, the overturning has been accompanied by overthrust faulting (pages 66, 67). As a result, all the beds and flows in this 2-mile belt dip north at angles varying from 70 to 40 degrees.

The western end of the Timiskaming band is as yet the only part whose structure is known. The excellently exposed cross-section in the gorge of Opasatika lake, the section in the Kekeko-Evain-Albee chain of lakes, and the section on Kinojevis lake have yielded information enough for recognition of the folds. Farther east, observations are more scattered or impossible to obtain in critical localities, and the folding has not yet been worked out.

On Opasatika lake the strata are thrown into a closely compressed overturned syncline on the north, followed on the south by a very broad, open anticline, the south limb of which is cut off by granite. These folds plunge eastward at a small angle, as shown by the plunge of small drag-folds, and by the gentle eastward dips of the strata on the crest of the anticline.

The existence of the overturned syncline was at first inferred from the known fact that the first fold to appear in a synclinorium must be a syncline. As, however, all the strata dip north, the necessary information could not be obtained merely from dip and strike observations. On the bare, burnt cliffs of the west shore north of Klock bay, however, the Timiskaming greywackes, in beds up to a foot thick, have been bent by the strains of deformation into numerous drag-folds, the study of which reveals the structure. The principle governing the use of drag-folds is as follows:

When a series of fairly competent beds is folded into a syncline (*See* Figure 4), the upper beds must accommodate themselves to the decreased length of the surface on which they rest by slipping upwards, using the bedding planes as gliding planes.[1] Friction between beds opposes the slipping process, and puts a strain on the beds on each side of the plane of slipping. If one of these beds be thin, or be composed of soft material such as shale, so that it is too weak to resist the strain, it may yield in one of several ways. A very soft material will recrystallize to form large amounts of mica or chlorite, the flat plates of which will slip easily on one

[1] The effect may be observed on a small scale by bending a pile of sheets of paper.

another, so that a schist is produced. A thin bed of harder rock may yield by fracturing in many places; or may be bent bodily, producing small drag-folds (Figure 5 a and b). The intensity of the drag will depend, of course, on the amount of differential movement between the beds on the two sides and on the strength of the bed to resist drag.

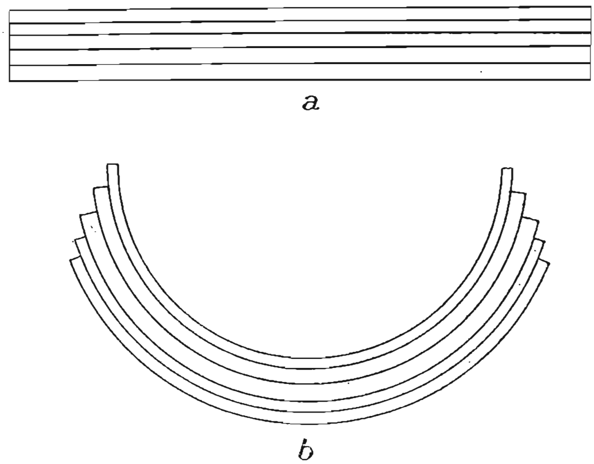

Figure 4. Diagram to show movement between adjacent strata when folded: (*a*) unfolded strata, (*b*) folded.

Figure 5 c shows the sort of drag-folds that might be expected to form when moderately thick beds of a rock fairly resistant to shearing stresses are bent into an overturned syncline. On the north side of the syncline the general dip is 70 degrees north, but drag has produced *steeper* dips, up to vertical and even southward in places. On the south side of the syncline the general dip is 50 degrees north, but drag produces locally *shallower* dips, almost flat in places.

The facts observed around Opasatika lake correspond exactly with the principle as above developed. Steep dips prevail on the north limb of the syncline; to the east of the lake there are several steep southward dips, as theory demands. On the mile of west shore directly north of Klock bay the dips are beautifully shown on the bare burnt cliffs; the average dip is about 50 degrees north, but the strata pass from one drag-fold into another and the dips of the dragged beds are all flatter than 50 degrees, in places quite flat or slightly south.

The axis of the overturned syncline must lie between the places where the dips of the drag-folded beds are steeper and where they are shallower than the general dip. This point cannot be exactly determined, within a quarter mile; but it lies about a mile from the extreme north end of the lake.

On the south side of this synclinal axis the beds maintain their northward dip of about 50 degrees, with numerous drag-folds exhibiting shallower dips, as far as the south side of Klock bay, a distance of about 1½ miles. Here the strata begin to flatten out, giving progressively lower dips as far as a point about half a mile north of the mouth of Atikameg bay, where the axis of a low, flat anticline crosses, and the strata are either quite flat or dip gently to the east. For 5 miles farther south, on Opasatika lake, the beds are gently undulating, and the dips, which rarely exceed 25 degrees and are usually much less, are controlled in their direction as much by the crossfolding as by the major folding. The sediments are then replaced by granite; but nearly opposite the mouth of Lonely bay, there

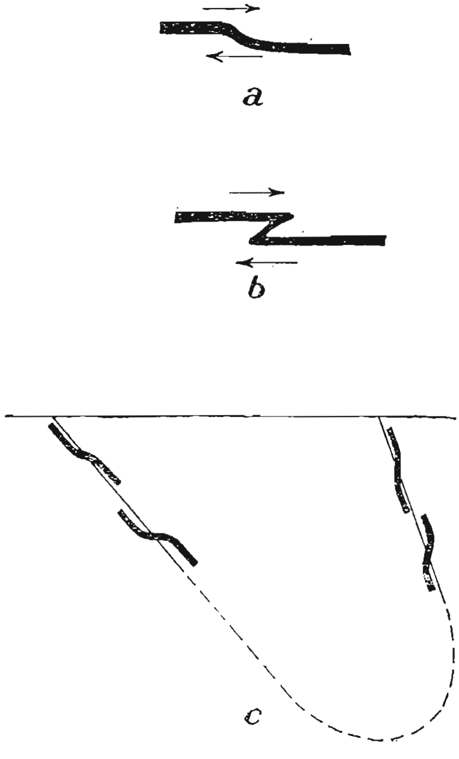

Figure 5. Diagram to show shapes of drag-folds developed in weak strata: (*a*) gently deformed, (*b*) more severely deformed, (*c*) drag-folds on limbs of an overturned syncline. Arrows indicate directions of movement.

is a large inclusion or roof pendant, nearly half a mile in width across the strike, in which the beds dip about 60 degrees south, and strike nearly east and west.

On the Kekeko-Evain-Albee chain of lakes the structure varies somewhat from that on Opasatika lake. The northern syncline is overturned in the same way, but the position of the axis is not so well known, for drag-folds are harder to obtain. It appears to lie, however, about on the eastern arm of Kekeko lake. South of the supposed position of the axis very few dips are obtainable, but those obtained are all about 50 degrees north, as on the south limb of this syncline on Opasatika lake. At the north end of lake Evain over a width of about 1¼ miles the sediments lie almost flat, with a gentle dip to the east. This area is probably the crest of the anticline, corresponding to the much larger area of flat-lying sediments on Opasatika lake near Moose bay. On the southern part of lake Evain and on Albee lake the beds all dip southward, increasing from about 35 degrees at the north to about 70 degrees at the south. Granite has destroyed the sediments south of Albee lake.

In two or three places small anticlines or synclines were observed on the flanks of one of the larger folds, from which direct data as to the strike and plunge of the axes could be obtained. The strike of the axes, in every case, is north 70 to 80 degrees east, and the plunge eastwards at low angles. The eastward plunge is also indicated by the eastward dip of the strata on the axis of the folds. West of Opasatika lake the eastward plunge of the folds appears to be between 15 and 20 degrees. To the east of Opasa-

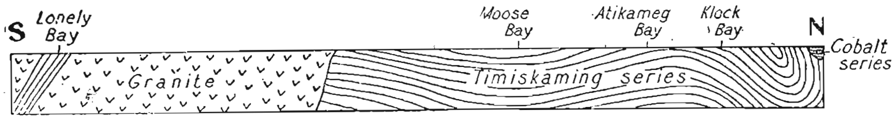

Figure 6. Vertical cross-section showing structure of the Timiskaming from north end of Opasatika lake to Lonely bay.

tika lake, as far as Kekeko lake and the lakes to the south of it, the eastward plunge flattens to 5 degrees or even less in places. To the east of Kekeko, Evain, and Albee lakes the plunge becomes suddenly much steeper, probably about 25 degrees, but good observations could not be obtained and the above figure is merely an estimate based on the dips near the axes of the folds.

In the Kinojevis section the structure has not yet been worked out, except in the northern 1½ miles, where it is very complicated (*See* Figure 7). The Keewatin lavas and tuffs, together with the Timiskaming conglomerates and greywackes, all dip northwards in this locality, as elsewhere along the contact. In several places good observations were obtained on the lavas, all of which indicate that the flows face southwards, so that the sediments, in spite of their northward dip, are stratigraphically above the lavas. The lavas and sediments are cut by the great Davidson Creek fault, striking north 50 degrees east, approximately. Like most of the larger faults of this region, the southeast side of this fault was shifted to the northeast, so that the Keewatin-Timiskaming contact east of Davidson creek is nearly 3 miles, measured along the fault, from the contact on the west side of Kinojevis river. The fault movement probably had a large vertical component, so that the southeast side was thrust upward as well as to the northeast. This is inferred from the fact that the drag-folds in the sediments just west of the fault pitch sharply westward, with an average plunge of 40 degrees; whereas throughout most of the area to the west the plunge of

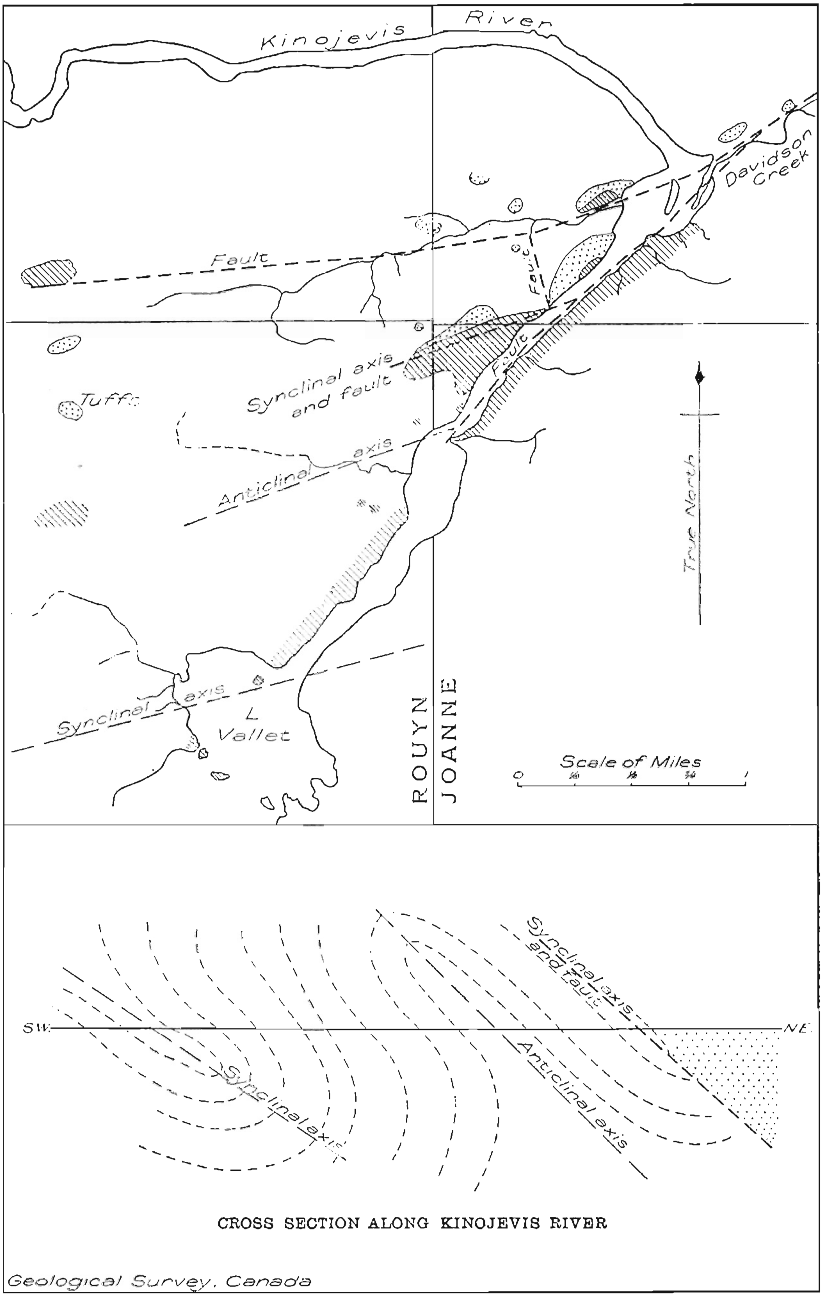

Figure 7. Plan and cross-section of Kinojevis River area. Outcrops of Keewatin lavas and tuff shown by stipple; outcrops of Timiskaming sediments by diagonal ruling.

the drag-folds is eastward. The westerly pitch at this point, therefore, suggests that the folded strata have been dragged upward by the upmoving southeast side of the fault.

At the junction of Davidson creek and Kinojevis river the fault branches, one branch continuing southwest down the course of the river, the other swinging more toward the west, up the valley of a small creek. The northern side of the latter fault was observed in two places, one near the mouth of the creek, the other about 2½ miles inland. The strike of this branch of the fault, in the part observed, is about north 82 degrees east, and the dip about 60 degrees north. This fault lies almost directly on the strike of the large fault crossing Pelletier lake, 6 miles to the east; and it is quite possible, therefore, that the two are sections of a single throughgoing fault.

The effect of this fault has been to bring to the surface two small bodies of Timiskaming conglomerate, one near Kinojevis river, the other about 2½ miles to the west. Others may also exist, beneath the heavy drift that hides most of the rock surface in this locality. On the westernmost exposure of conglomerate, a band 150 feet wide along the southern edge has been converted by the faulting into papery schist; and it is probable that a belt of swamp 1,200 feet wide, on the south side of the outcrop, may be also underlain in part by schist, as the soft schist would yield readily to erosion. The available evidence, therefore, suggests that this fault is very large; it may even represent the greater part of the whole Davidson Creek fault.

The contact between the Keewatin and the main area of the Timiskaming series occurs on the west side of Kinojevis river, about 450 feet north of the centre line of Joanne township. The sediments, for some hundreds of feet from the contact, are strongly sheared conglomerates, which display little trace of original bedding. However, drag-folds occurring in the schistose lava just north of the contact, approximately 800 feet from the Rouyn-Joanne boundary, and a few feet north of the Joanne centre line, indicate that the rocks at this point lie on the north side of a syncline. The heavy conglomerates close to the contact are followed, on the south, by conglomerate with a good deal of interbanded greywacke, in which drag-folds are numerous, and can be seen in both horizontal and vertical section on the shore cliffs. The first of these was observed about 1,300 feet from the contact, measured along the shore, or 400 feet south of the Joanne centre line. It indicated that the rocks at this point lie on the south side of a syncline. The axis of this syncline, therefore, cuts the shore of the river somewhere near the centre line.

The drag-folds are the same shape as far as the point where the Rouyn-Joanne boundary cuts the north shore of the river. Then follows the valley of a small tributary, about 2,000 feet wide, and clay-filled, with no outcrops. On the other side of this depression the drag-folds are opposite in shape to those on the north side. The axis of an anticline in the sedimentary series, therefore, underlies the valley.

From the valley south to Vallet lake the drag-folds all preserve the same shape. The dips become gradually flatter, until at the north end of the lake the strata have an average dip of about 10 degrees only. The northwest end of the lake is a large bay, from which another low, clay-filled valley extends westward; and south of this, on the point forming the southern extremity of the bay, the drag-folds are once more found reversed. Evidently, therefore, a synclinal axis runs westward beneath the soil-filled valley.

It will be noted (*See* Figure 7) that the distance from the southern synclinal axis to the anticlinal axis on the north, is about $\frac{3}{4}$ mile; and that the distance from the anticlinal axis to the next synclinal axis is about $\frac{3}{8}$ mile. The distance from the northernmost synclinal axis to the contact with the Keewatin is very short, only a few hundred feet, and the dips of the strata to the north and south of this synclinal axis are approximately the same. Under normal circumstances, therefore, the Keewatin rocks should appear at the surface a few hundred feet south of the synclinal axis. As they do not so appear, or appear anywhere in the anticline, it is necessary to conclude that something more than normal folding has taken place in the formation of the northernmost syncline. The intense shearing of the conglomerates and lavas close to the contact, which is particularly well shown along the Rouyn-Joanne boundary, suggests that the folding here has passed into faulting, as so often happens in closely compressed, overturned folds; the result being to shorten the fold by uplift of the north side.

The complexity of the relationships in this neighbourhood is still further increased by the occurrence on the west shore of the river about a quarter-mile north of the Joanne centre line, of a crescent-shaped mass of Timiskaming conglomerate. The body is about 650 feet in length, along the shore, and extends back from the shore a maximum distance of 150 to 200 feet. It is bounded on the north, west, and south by lavas, and on the east by the fault that runs down the bed of the river. The relationships here are well exposed on the steep cliffs of the shore, and will be described in detail.

The lavas at this place form a series of flows, each 25 to 40 feet in thickness. Five of the flows were individually distinguished, and their contacts studied. In each case, one side of the vertically-dipping flow consisted of very fine-grained lava, marked in some instances by very well-developed flow textures, in other instances by less conspicuous flow texture. The flow-textured band varies from 4 to 6 feet in width, and passes gradationally into rock of increasingly coarse grain. Near the other edge of the flow the average grain attains about 0·5 mm., and, at the margin, rock of this grain ends sharply, with a chilled edge perhaps half an inch wide, against the fine-grained, flow-textured material of the next sheet. It was, therefore, concluded that these sheet-like masses are flows, the fine-grained, flow-textured parts forming the tops, the coarser parts the bottoms. The strike, to be discussed more in detail later, is about north, the dip vertical, and the flows face toward the east.

The contact between the flows and the conglomerate was sought for, and cleared of moss and soil. The conglomerate lies directly on the flow-textured top of the uppermost lava, and the contact appears closely parallel to the strike of the lava. There were irregularities about an inch deep in the surface of the lava, which were filled with sediment, and in some instances the holes seemed to cut across the lines of flow. The evidence is not sufficient to conclude, however, that the conglomerate was deposited on an erosion surface.

The strike of the lavas at the northernmost end of the outcrop is about north 40 degrees west. It swings rapidly, on the south, to north 20 degrees west, then to north, then to north 30 degrees east, then to north 50 degrees east. At the latter point the conglomerate outcrops on the shore, and the lava strikes inland behind it. The strike of the lava then changes further to north 30 degrees east, then to north, then to north 30 degrees west. The conglomerate contact, which parallels the strike of the lava throughout, is thus brought out to the shore some 650 feet below the point where it first appears. The lavas maintain their strike of north 30 degrees west for 750 feet farther downstream. The strikes in the southernmost outcrop of lavas were not obtained.

It is evident, from the facts obtained, that the conglomerate overlies the lavas, and occupies a small synclinal dip in the top of what must be an anticlinal structure. The extreme eastward dip, vertical or even overturned to the west in places, indicates that this anticlinal mass must have undergone an extraordinary local tilting, since the folds in this region in general plunge east or west at low angles. The position of this block, in the angle between the main Davidson Creek fault and its westward branch, suggests that the unusual tilting is due to the fault movements. It is believed that in all probability a third fault cuts across between the two main faults behind the tilted block (*See* Figure 7), so that the block thus cut off has suffered rotation during the fault movements, sufficient to bring it into its present position. The supposed fault between the two main faults can not be directly observed, however, on account of the heavy drift cover.

The detailed study of the structure was not carried south of Vallet lake, beyond which point, accordingly, information is limited to the dips and strikes obtained during the preliminary study of 1923. These are not numerous between Vallet lake and Kinojevis lake, as outcrops are comparatively few. At the north end of Kinojevis lake, in the neighbourhood of the Rouyn-Bellecombe line, the strikes and dips suggest the presence of an axis of a fold. The strata on an island one-quarter mile north of this line strike west-northwest, and dip 75 degrees north. Beds one-half mile south of this line strike northeast to north-northeast, and dip about 75 degrees southeast. It appears, therefore, as if an anticlinal axis crosses the lake near the Rouyn-Bellecombe line.

Southward along Kinojevis lake for about 2 miles the dips are all south, at angles averaging 75 to 80 degrees. Then follows about a mile of drift-covered shore, beyond which the dips are all north, at angles of 60 to 65 degrees. Evidently, therefore, a synclinal axis crosses the lake, probably beneath the drift-covered area.

The correlation of these axes between the three lines of cross-section is naturally uncertain, in view of the imperfection of the present data, and the faulting which is known to be present in the Kekeko and Kinojevis sections. The following attempt at correlation is, therefore, to be considered purely tentative.

A broad, flat anticline, more than 5 miles wide, occurs on Opasatika lake; and a similar area of almost flat strata, about 2 miles wide, at the north end of Evain lake. A line drawn through the middle of these two areas may be considered as the axis of the anticline, and this line, projected east, crosses Kinojevis lake near the Rouyn-Bellecombe boundary, where an anticlinal axis has already been inferred to exist. It seems probable, therefore, that this line, striking north 78 degrees east, is one of the principal axes of folding in the sediments.

A synclinal axis crosses Opasatika lake about a mile from its northern end, about 1½ miles, or thereabouts, from the inferred position of the northern boundary of the Timiskaming beneath the Cobalt series. No corresponding determination was made on Kekeko lake, but the synclinal axis crossing the north end of Vallet lake is likewise about 1½ miles from the Keewatin-Timiskaming contact. It is, therefore, possible, or even probable, that the two axes determined form parts of a single major synclinal axis continuous throughout the intervening territory.

A second synclinal axis has been inferred to cross Kinojevis lake just north of its junction with Caron lake. On Evain and Albee lakes, the dips are uniformly southward up to the granite contact at the head of Albee lake, and average about 60 degrees. The last-mentioned synclinal axis, on Kinojevis lake, must, therefore, have passed somewhere close to the head or south of Albee lake. If it be assumed that it passed through the south end of the lake, its strike lies between north 63 degrees east and north 68 degrees east; if it passed farther south, its strike is still more northerly.

To sum up: the axis of the northern syncline strikes slightly north of east; that of the succeeding anticline, north 78 degrees east; and the axis of the following syncline, north 68 degrees east or more northerly. The axes, therefore, converge toward the east.

The approximate dip of the axial plane of the northern syncline on Kinojevis lake may be inferred from the dips on the limbs. The maximum dips of the strata of the north limb are 60 to 65 degrees north. South of the axis the strata dip northward at angles varying between 45 and 70 degrees, with 65 degrees as an approximate average. The fold, therefore, is overturned, almost isoclinal, and the axial plane dips about 65 degrees north. This figure is practically identical with that determined, for the same fold, on Opasatika lake.

In the succeeding anticline to the south no great difference prevails between the dips on the north limb and those on the south. More information than is available is required to determine with certainty the dip of the axial plane. The data at hand seem to indicate that the general dip on the south limb is 5 to 10 degrees higher than on the north limb; if this be true, the axial plane dips about 85 degrees north. This fold is not overturned, but is very open in the Opasatika section and becomes more closely compressed toward the east.

On the following syncline the recorded dips on Kinojevis lake average 75 to 80 degrees south on the north limb, and 60 to 65 degrees north on the south limb. The axial plane, therefore, dips north at an angle of about 83 degrees. This fold is likewise not overturned.

The rolling eastward pitch of the folds, already described, appears to continue eastward nearly as far as Kinojevis river; but close to the river the plunge is steeply west, due, it is thought, to the strata having been dragged upward on the east by the Davidson Creek fault.

The eastward convergence of the axes of folding may be due in part to the strata having undergone greater compression in the east. This is suggested by the prevalence of steeper dips in the east. There is also the possibility, which the convergence itself suggests, that the large anticline forming so important an element of the structure on Opasatika and Evain lakes may die out a short distance east of Kinojevis lake, leaving the northern and southern synclines united into a single syncline.

CLERICY BAND

The structure of the Clericy band is not known from study of the sediments themselves. The strata are in vertical attitudes, from which little can be learned. It will be shown, however, that the band apparently occupies a syncline in the Keewatin series; and this, coupled with the fact that the sediments are younger than the Keewatin, indicates the structure of the band to be also synclinal.

DUPARQUET-DESTOR BAND

The Duparquet-Destor band is definitely synclinal in structure. The red porphyry conglomerate on the north side of the band grades northward into red porphyry, indicating that the upper side faces south. The quartz porphyry conglomerate on the south side of the band, from similar evidence, faces north. The band must, therefore, be a syncline.

The band forks at the east end. The axis of the north fork, projected, passes eastward through two isolated bodies of sediments, the farthest outcrop of which is 6 miles away. The southern fork is in line with the axis of the Clericy band of sediments. The relations suggest that the fork is the nose of an anticline which breaks the syncline of sediments into two, one of which continues eastward, the other is turned toward the southeast. The projection of the latter meets the end of the axis of the Clericy syncline.

FOLDS IN THE KEEWATIN SERIES

Information regarding the folding of the Keewatin is still very incomplete. There are large areas in which no observations for structure have been made. The determinations that have been made have been collected during several years by different observers, and it is quite possible that some will eventually be proved incorrect. This is suggested by the fact that in a few places the observations of two or more men appear to be contradictory; if all these observations are accurate, the structure of these particular areas must be very complex, as, of course, is possible. On the whole, however, the correspondence between the structure observations of the different workers is remarkably good.

At the present time, a considerable number of observations for structure have been made in the Dasserat Lake section, from the north end of the lake southeastward to Opasatika and Fortune lakes. Fourteen miles to the east, a large number of observations have been made along a section extending from a point somewhat north of the Waite-Ackerman-Montgomery mine, near the eastern border of Duprat township, to the boundary of the Timiskaming series south of Pelletier lake. Still farther east, the attitude of the lavas north of the Timiskaming series, in Malartic and Dubuisson townships, has been established by a large number of observations made at various points throughout a band 5 or 6 miles wide. A good many determinations have been made in Abijevis hills in Aiguebelle and Manneville townships, and likewise in the south and southeastern parts of Palmarolle and O'Brien map-areas. Outside of these districts structure determinations are rather sparsely scattered.

These observations have proved that the axis of a synclinal fold passes through the south end of Dasserat lake; that an anticlinal axis passes through Dufault lake; that a synclinal axis underlies the Duparquet-Destor band of sediments, and that this fold splits into two at the east end; that the Privat band of tuffs lies along a synclinical axis, which is separated from the Destor-Duparquet band by an anticline; and that there appears to be a synclinal axis located beneath the Clericy band of sediments. Other axes can be inferred with reasonable certainty from the existence of those known, aided by the use of scattered structural determinations. Thus, an anticline must exist between the Clericy band and the main body of Timiskaming sediments, and from its position this can be only the eastward extension of the Dufault anticline. Again, an anticline must occur between the two synclines into which the Duparquet-Destor band splits at its eastern end. This axis, projected east, passes through the centre of the great granite mass in Preissac and La Motte townships. A synclinal axis must occur north of the last-mentioned anticline, and this must be the axis formed by the junction of the Privat syncline and the northern branch of the Duparquet-Destor syncline. With the aid of three structure determinations between Amos and Okikeska lake, the probable position of this axis is determined, fairly closely, to pass through the northeastern corner of La Motte township.

The various axes, thus determined and inferred, are shown on the accompanying map, No. 2275. A more detailed description of each, with the data from which they were determined, follows.

DUFAULT ANTICLINAL AXIS

The Dufault anticline is a very broad, open fold involving all the lavas between the north end of Dufault lake and the Timiskaming boundary on the south. The southernmost flows, about a mile south of Pelletier lake, are separated from the Timiskaming conglomerates by a band of slaty, thin-bedded tuffs. The lava, at its contact with the tuffs, is a well-pillowed "basalt" that grades on the north into non-pillowed "basalt." This flow, therefore, faces south. It strikes north 80 degrees west, and dips 60 degrees north, so that the flows and tuffs are overturned.

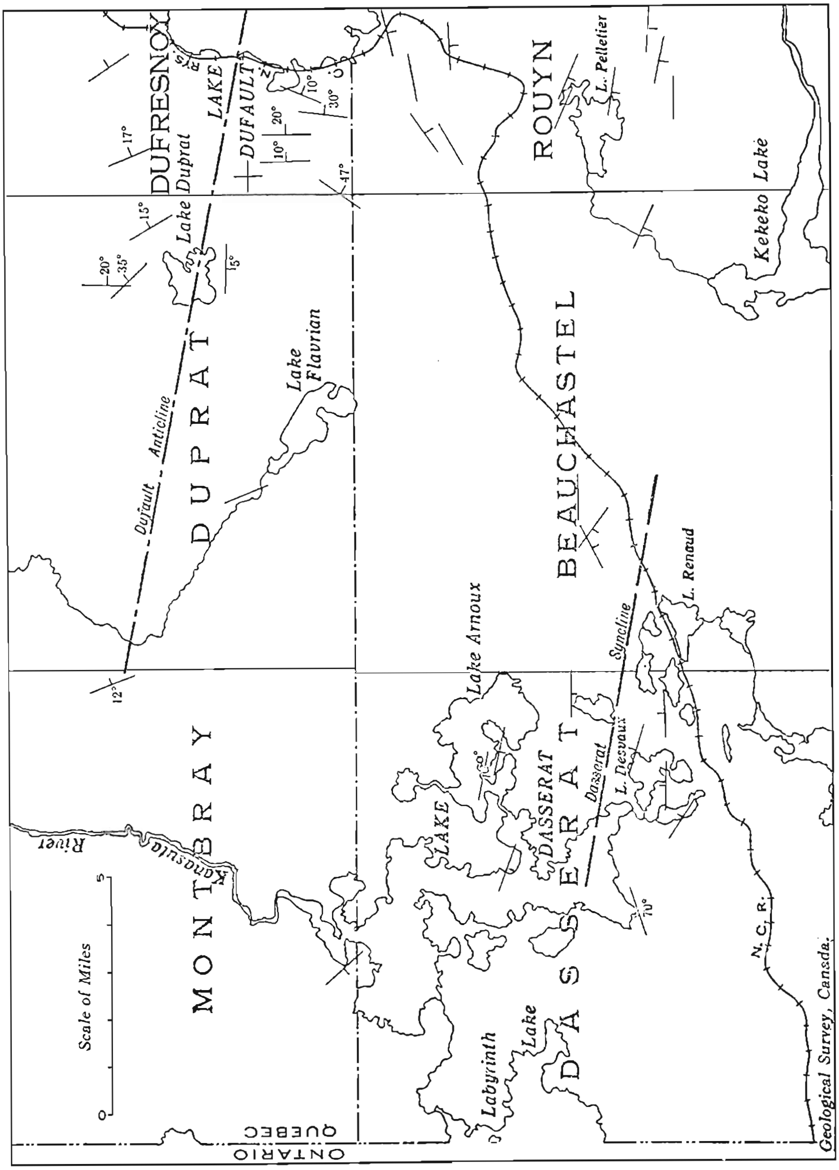

Figure 8. Structure observations near the Dufault anticline and Dasserat syncline; symbols indicate strike of flows and, where determined, direction towards which tops of flows face.

For 5 miles northward, to the southern end of lake Dufault, a considerable number of well-spaced observations for structure have been obtained, and at each place the strike is nearly east and the flows face toward the south. The overturned attitude existing at the locality south of Pelletier lake does not persist northward, but within a mile or so changes to the usual vertical dip. It is concluded, therefore, that all the Keewatin rocks between Dufault lake and the Keewatin-Timiskaming contact form part of one limb of one fold.

A belt of swampy and soil-covered country from 1 to 2 miles wide lies between the relatively rocky area just mentioned and another area of good exposures west of Dufault lake. Outcrops are few and small in this soil-covered belt, and no determinations of structure have been made there. On the rocky ridges west of lake Dufault, however, numerous excellent determinations have been obtained, many of them on bands of thin-bedded tuff, the strike and dip of which can be read without possibility of error. In this area the lava flows and interbedded tuffs lie almost flat, with gentle eastward dips of 5 to 30 degrees. In places the dip is southeast, in others northeast, but everywhere the angle is low and the direction eastward. The area over which such dips prevail is wide. The southernmost determination was made near the Duprat-Dufresnoy boundary about ¼ mile north of the Sullivan line, where the flows strike north 35 degrees east, dip 47 degrees southeast, and face southeast. The northernmost observation was on the centre line of Dufresnoy township about 3 miles from the west side of the township, and the flows there strike northwesterly, dip about 45 degrees northeast, and face northeast. Throughout the 5 miles of country between these positions the dips are in various directions, east, northeast, or southeast, but all are easterly and the angles vary between 5 and 30 degrees. The flat structure has been proved to extend west at least as far as the centre of Duprat township. Some rather unsatisfactory data obtained along the centre line of Montbray township about half a mile from the Duprat boundary indicate that the structure there is also flat, with a gentle dip to the northeast.

As lavas north of the flat area face north or northeast, and those south of it face south, it is evident that the area of low dips is the broad top of a great anticline. The variation in direction of the low dips from northeast to southeast indicates that the wide top of the anticline has been crinkled into short secondary folds. (*See* description of Amulet mines, page 211.) The uniform eastward dip indicates that in this area the main fold plunges east, probably at some small angle between 5 and 30 degrees.

The axis of this eastward-plunging anticline probably lies approximately in the centre of the area of flat-bedded lavas, crossing the Duprat-Dufresnoy boundary about 3 miles from the south boundary of the townships. Its strike may be inferred, roughly, from the strikes of the flows on the north and south flanks of the fold. Those on the south strike nearly east, those on the north, about north 55 degrees west. The axis of the fold must, therefore, strike in a direction intermediate between these, or in the neighbourhood of north 73 degrees west.

The strike of the axis may also be estimated, roughly, from other data. An excellent determination of structure was obtained on a large knob of "basalt" rising from the sand-plain just north of the Duprat centre line, 2 miles from the east boundary of the township. This knob, perhaps 75 feet high, is composed at the base of massive lava, which becomes progressively more amygdaloidal upwards. About 20 feet from the top the amygdaloidal lava grades into ropy lava, the ropy zone being about 2 feet thick. The ropy zone, which lies almost horizontal, is broken up on the southeast side of the hill into a breccia of small fragments averaging about an inch in diameter. Overlying the ropy and brecciated zone is a zone of pillows. This beautiful exposure is, therefore, definite evidence that the lavas are almost flat at this point.

This hill lies due west of the northern edge of the anticlinal crest in Dufresnoy township, so that if it likewise happens to lie on the northern edge of the anticlinal crest, the anticline must strike due west. Should the hill in Duprat lie near the southern edge of the anticlinal crest, the anticline must strike about northwest. As there are no facts to indicate on just what part of the crest this hill lies, it can only be concluded that the strike of the anticlinal axis lies somewhere between these two directions.

Near the eastern boundary of Montbray township, along the centre line, no good determinations of structure were made, but the lavas are intruded by several small, sill-like masses of quartz diorite, which dip about 20 degrees east. If these are conceded to be sills injected along bedding planes, they narrow down the strike of the anticlinal axis to a figure between due west and north 70 degrees west.

To the east, in Bousquet township, the synclinal band of Clericy sediments approaches or runs into the main body of Timiskaming sediments, and the Keewatin between them must, therefore, have an anticlinal structure. No anticlinal axis is known to exist between the Dufault anticlinal axis and the Clericy synclinal axis, and it is, therefore, concluded that the Dufault axis, projected eastward, coincides with the anticlinal axis just mentioned. A straight line drawn from the axial position west of lake Dufault to the axial position in Bousquet strikes north 82 degrees west, but this is not the true axial direction, as the axis must be displaced by the Davidson Creek fault, and perhaps by other faults or by flexure. A line drawn so as to bisect the angle between the Clericy band and the main Timiskaming band strikes about north 78 degrees west; and this figure probably approximates fairly closely the general strike of the anticlinal axis, although, like many of the axes in the region, it is undoubtedly bent in places.

DASSERAT SYNCLINAL AXIS

At the south end of Dasserat lake and around Washusk and Ogima lakes the Keewatin flows are well exposed and afforded a considerable number of structure determinations. All the flows face north, with strikes that vary from 10 to 30 degrees south of east. At the most northerly locality, on the south side of Renault bay, Dasserat lake, the dip is 70 degrees north; at the next most northerly locality, the north end of Washusk lake, the dip is vertical; at the south end of Washusk lake, and about half-way down the lake, the dip is 85 degrees south; and at the most southerly locality, near the south end of Ogima lake, the dip is 50 degrees south. The strata are thus overturned toward the south, the amount of overturn apparently increasing southward. The large overturn near the south end of Ogima lake might be doubted, were it not that the observation was particularly good, a layer of thin-bedded chert, about 4 inches thick, separating the flows at this point.

A considerable number of observations were made on Dasserat lake between the north end and the mouth of the inlet to Arnoux (Mishikwish) lake, on Arnoux lake itself, and at the north end of Uwass lake. In all cases the flows face south; the strikes vary between east and 30 degrees south of east, and all the dips are steeply south or vertical, except at the southernmost locality, the north end of Uwass lake, where the flows are overturned and dip 70 degrees north.

These observations indicate that a synclinal axis passes through the south end of Dasserat lake and approximately across the south end of Uwass lake. The strikes of the strata on the limbs of the fold vary from east to 30 degrees south of east, and most of them are 10 to 15 degrees south of east; the fold is very close, so that these strikes will be approximately parallel to that of the axis, which may accordingly be taken as 10 to 15 degrees south of east. The axial plane of this fold, at the surface, dips about 70 degrees north, and the folding is so close that the flows immediately north of the axis are overturned, and likewise dip north at 70 degrees.

If this synclinal axis be projected eastward, it must strike the Keewatin-Timiskaming contact, beneath the Cobalt series, somewhere west of Pelletier creek. It cannot swing northward so as not to meet this contact, because, if it did, the flows nearest the contact south of Pelletier lake would face north, which they do not. It is probable, therefore, that this axis runs as far as the contact, and is there cut off by the faulting inferred, from other data, to exist there (page 67). Since the inferred fault, if it exists, must be an overthrust from the north, the Dasserat syncline must now be farther south than if faulting had not occurred, and it is interesting to speculate as to where the continuation of the axis enters the Timiskaming area. It must enter to the east of its present position; but cannot do so for at least as far east as a line drawn between Routhier and La Bruère lakes, because throughout this distance the flows near the Timiskaming contact all face south. At Kinojevis river, however, there is a very narrow syncline in the Timiskaming series (page 81), and it was inferred that the narrowness was due to strike faulting. It may easily be, therefore, that the northernmost synclinal axis at Kinojevis river is the continuation of the Dasserat synclinal axis, broken by faulting. This axis, shifted northward by the Davidson Creek fault, may then continue eastward, parallel to the northern margin of the sediments; and its existence would explain the occurrence, in Bousquet, Cadillac, and Fournière townships, of the series of lava flows that lie from 1½ to 2 miles within the sedimentary border. These flows, under this conception of structure, would mark the southern edge of the syncline, and be merely Keewatin flows appearing along the summit of the succeeding anticline.

PRIVAT SYNCLINE

The evidence from which the Privat tuff band was determined to be synclinal has already been given (pages 34, 35), and will not be repeated. The strike of the Privat axis is north 53 degrees west. At the extreme south end the strike swings east to north 70 degrees west, a fact that will later be shown to be significant.

CLERICY SYNCLINE

The Clericy band of sediments appears to occupy a syncline in the Keewatin series, and the data suggesting this may, therefore, properly be mentioned here. On the northeast side of the band, and 6 miles away, in Manneville township, lot 24, range I, and lot 22, range II, two good determinations were obtained, the first striking north 55 degrees west, dip 70 degrees north, top facing southwest; the second striking north 80 degrees west, dip vertical, top facing south. Supplementary strike determinations in this neighbourhood indicate that the average strike varies from north 60 to 80 degrees west. On the west side of Abijevis lake, 5 miles from the Clericy band, the flows strike east, dip vertical, and have their top facing south. On the east shore of the expansion of Kinojevis river, about $\frac{3}{4}$ mile northeast of the Clericy band, a curving flow contact swings in strike from north 45 degrees west at the northwest end of the outcrop to north 70 degrees west at the southeast end; the dip is 75 degrees southwest, and the top faces southwest, toward the sedimentary band. On the other side of the band no determinations were obtained until Windfall rapid, at Clericy station, 3 miles away, was reached. There strikes vary from north 35 to 60 degrees west, dips are vertical, and tops face northeast.

These determinations point to the conclusion that the Clericy band fills a synclinal basin in the Keewatin lavas. More observations are needed, however, particularly on the south side of the band, and closer to it, before a final conclusion may be drawn. The strike of the band, north 60 degrees west, is closely parallel to that of the Privat band.

POULARIES ANTICLINE

Southwest of the Privat tuff band nearly all the lavas are dark-coloured "basalts" and "andesites," with which a very distinctive, light-coloured rhyolite is interbanded. This distinctive flow was carefully traced by B. S. Buffam. From a point in the southeast corner of Poularies township near the outlet of Lois lake, it was followed east-northeast for about 4 miles, into lot 18, range II, Privat township. It was there found to swing, in a smooth though rather abrupt curve, to the northwest; and was followed in this direction for about 4 miles farther, into range V, Poularies township. The outcrop is thus shaped like the prow of a canoe. Buffam obtained a large number of structure determinations in this vicinity, showing that the flows along the south limb of the canoe face south, those along the north limb, northeast. This flow has, therefore, been bent so as to pass completely round the nose of an anticline plunging to the southeast. The axis of the anticline must pass through the nose and approximately half-way between the limbs, and its strike is thus closely determined as north 74 degrees west (Figure 9).

DUPARQUET-DESTOR SYNCLINE-OKIKESKA SYNCLINE

A large number of structure determinations have been made on the north side of the Duparquet-Destor band of sediments, in all of which the flows strike approximately east-west and face south. On the south side of the band, however, no determinations have yet been obtained. Knowledge of the Keewatin structure is as yet, therefore, imperfect; but as the sediments themselves are known to be a closely compressed syncline, it seems reasonable to conclude that the Keewatin, in which they are infolded, is likewise synclinal.

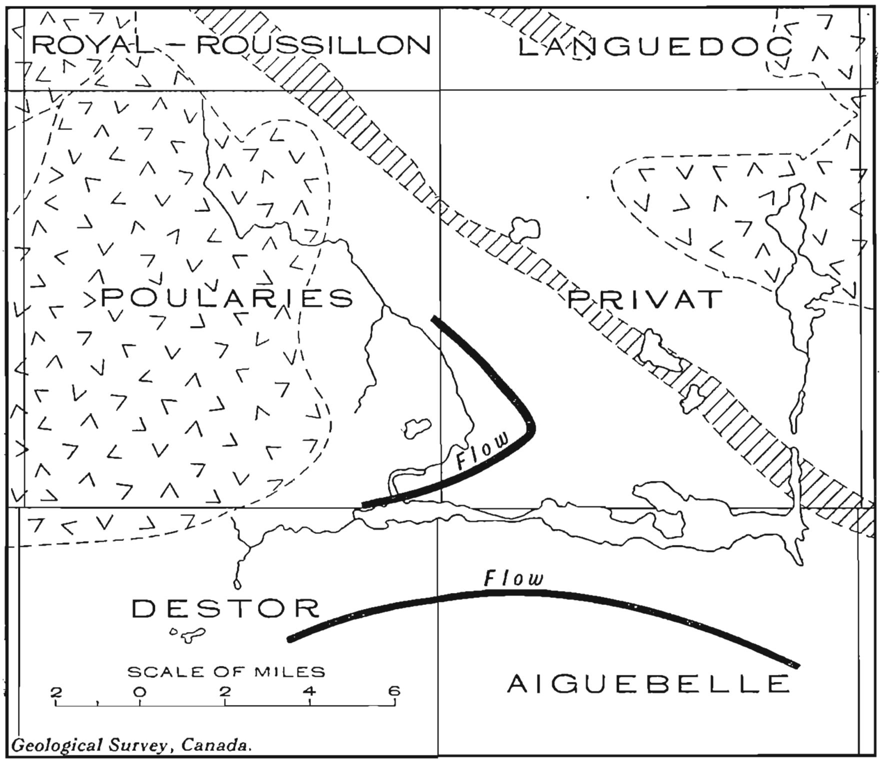

Figure 9. Poularies, Privat, and parts of Destor and Aiguebelle townships, showing traced positions of rhyolite flows (solid black); granite areas are shown by a pattern of angles; the Privat tuff band by oblique lines; areas of lavas (other than the rhyolite flows) are left blank.

The fork at the east end of the Duparquet-Destor band has already been noted. It apparently breaks the sediments into two synclines, the projected axis of the southern fork forming the axis of the Clericy syncline. The axis of the northern fork strikes north 79 degrees east, and, projected, meets the axis of the Privat syncline just about where the latter swings to a more easterly strike. The projection of the axis of the Poularies anticline also comes to about the same point. It is concluded, therefore, that at this point there is a junction of the Privat syncline and the northern branch of the Duparquet-Destor syncline, and that the combined syncline continues east on a strike somewhat south of east. It is here termed the Okikeska syncline.

There is no great amount of data from which the eastward course of the Okikeska syncline can be determined. In Manneville township, 3¾ miles from the east boundary and 3¼ miles from the south boundary, the lavas strike east and face north. In Villemontel township, 4½ miles from the west boundary and 3½ miles from the south boundary, the lavas strike nearly east and face north. In lot 27, range VIII, Figuery township, the lavas strike north 85 degrees west and face south. In range IV, Figuery township, close to the centre line, the strike is north 70 degrees west, and the flows face south. In range II of the same township, 3½ miles from the west boundary and 1¾ miles from the south boundary, the flows strike north 60 degrees west, and face south. These observations, though few in number, confine the possible course of the Okikeska syncline within very narrow limits, and seem to indicate that it must pass through the centre of the band of sediments along the north shore of Okikeska lake. These sediments, accordingly, would be comparable in age and stratigraphic position with the Privat tuffs, and lie at or near the top of the Keewatin.

LA MOTTE ANTICLINE

An anticline must be developed between the Clericy syncline on the south and the Okikeska-Destor syncline on the north. The west end of this anticline must lie between the fork of the Duparquet-Destor band of sediments. As in the case of the Okikeska syncline, its eastward course is roughly defined by scattered observations. The easternmost of these was found in range VI, La Motte township, 4½ miles from the northern and 3½ miles from the eastern boundary. At this point a flow strikes north 12 degrees west, and faces east, suggesting that it lies directly upon the axis of the anticline. This anticline may be termed the La Motte anticline.

AMOS ANTICLINE

In the northwest corner of Landrienne township, about 1 mile from the north boundary and 1½ miles from the west boundary, a single determination was obtained, yielding a strike of north 80 degrees east, top facing north. This, coupled with the determinations south of Amos, indicates that an anticlinal axis passes through or near the town of Amos, presumably in a direction more or less parallel to the known axes. It may be termed the Amos anticline.

The various determinations of structure on which the foregoing conclusions are based are listed in the following pages. The various abbreviations used are as follows:

ch.—chains. One chain equals 66 feet.
mi.—miles.
H. C. C.—H. C. Cooke.
J. B. M.—J. B. Mawdsley.
W. F. J.—W. F. James.
B. S. B.—B. S. Buffam.
S. H. R.—S. H. Ross.
E. K. F.—E. K. Fockler.
Vert.—Vertical.
Undet.—Undetermined.

The "Value" column indicates the observer's estimate of the reliability of the observation. E, is excellent; G, good; F, fair; and P, poor. The evaluation is made at the same time as the determination, and depends on a number of factors, such as the excellence of exposure, number of flows seen in contact, and perfection of development of the characteristic textures and structures used in making the determinations. It is not influenced by the fact that the observation corroborates, or is corroborated by, others. If corroboration were taken into account, many observations marked "F" or "P" in the list could be given a higher value, but this is not done; on the contrary, it is endeavoured to indicate the merits of each observation, individually.

The following list does not include the fairly numerous determinations of structure made upon the Horne drag-fold. These are given in detail in the section dealing with the structure around the Horne (Noranda) mine, pages 190, 191.

Locality	Observer	Value	Strike	Dip	Face to
2¼ mi. north of range X, lot 25, Desmeloizes tp.	J.B.M.	G	N. 65° E.	Vert.	SE.
800 ft. north of range X, lot 43, Desmeloizes tp.	J.B.M.	G	N. 53° W.	85° S.	S.
Desmeloizes tp., north boundary, lot 26	J.B.M.	P	N. 70° W.	83° N.	S.
Desmeloizes tp., range IX, lot 41, north half	J.B.M.	F	N. 67° W.	85° N.	S.
Desmeloizes tp., range VII, lot 47, west side of road	J.B.M.	F	N. 52° W.	50° N.	S.
La Reine tp., range II, lot 55-56	B.S.B.	P	N. 20° E.	85° W.	W.
Roquemaure tp., south side Nepawa island	B.S.B.	F	N. 55° E.	Vert.	SE.
Roquemaure tp., range VI, lots 23-24, lake shore	B.S.B.	F	N. 53° W.	Undet.	Undet.
Roquemaure tp., range III, lot 5, creek mouth	B.S.B.	F	N. 35° W.	75° E.	W.
Hébécourt township, island, N.W. bay, Duparquet lake	B.S.B.	F	N. 50° E.	80° S.	SE.
Montbray tp., 20 ch. from east boundary, near centre line	H.C.C.	P	N. to NW.	10-15° E.	E.

Locality	Observer	Value	Strike	Dip	Face to
Montbray tp., 300 ch. from west boundary, 25 ch. from south boundary	H.C.C.	G	N. 45° W.	Vert.	SW.
Dasserat tp., Ogima lake, middle of west shore	H.C.C.	E	N. 60° W.	45° S.	N.
Dasserat tp., Dasserat lake, south shore Renault bay	H.C.C.	P	N. 70° E.	70° N.	N.
Dasserat tp., Desvaux lake, east side, just south of creek from Uwass lake	H.C.C.	G	N. 75° W.	Vert.	N.
Dasserat tp., Desvaux lake, middle of southwest shore	H.C.C.	E	East	Vert.	N.
Dasserat tp., 25 ch. north of MacDonald lake	H.C.C.	G	N. 85° E.	Vert.	N.
Dasserat tp., Dasserat lake, east shore, just north of mouth of bay running east toward Arnoux lake	H.C.C.	G	N. 70° W.	Undet.	S.
Dasserat tp., Arnoux lake, northwest end of Y-shaped point	H.C.C.	E	N. 80° W.	60° S.	S.
Dasserat tp., Arnoux lake, middle of Y-shaped point	H.C.C.	G	N. 80° W.	Undet.	S.
Dasserat tp., 10 ch. east of north end of Uwass lake	H.C.C.	G	East	70° N.	S.
Clermont tp., range IV, lot 28-29	S.H.R.	P	N. 65° W.	75° S.	S.
Duparquet tp., 4¾ mi. from south boundary, 2¼ mi. from west boundary, on pt	B.S.B.	G	N. 70° E.	Undet.	N.
Duparquet tp., 1·12 mi. from north boundary, island in river	B.S.B.	G	N. 75° W.	Vert.	S.
Duparquet tp., 135 ch. from west boundary, 30 ch. south of centre line, island	B.S.B.	E	N. 62° E.	55° N.	N.
Duprat tp., 45 ch. from east boundary, 260 ch. from south boundary, A 2958	H.C.C.	E	N. 30° W.	15° E.	E.
Duprat tp., 120 ch. from east boundary, 210 ch. from south boundary, A 3698	H.C.C.	F	East	5° S.	S.
Duprat tp., 145 ch. from east boundary, 30 ch. south of centre line	H.C.C.	F	NW.	35° NE.	NE.
Duprat tp., 150 ch. from east boundary, just north of centre line	H.C.C.	E	North	Flat to 20° E.	E.
Duprat tp., 180 ch. from south boundary, 25 ch. west of centre line	H.C.C.	P	NNW.	35° E.	....
	H.C.C.	E	N. 60° W.	33° N.	N.
Beauchastel tp., 3½ mi. from west boundary, 20 ch. north of centre line	H.C.C.	E	East	Steeply S.	....
Beauchastel tp., 56 ch. from east boundary, 312 ch. from south boundary	H.C.C.	G	N. 65° W.	70° N.	S.
Beauchastel tp., about 3 mi. from west boundary, near centre line	H.C.C.	P	N. 55° W.	Undet.	S.
Beauchastel tp., about 3 mi. from west boundary, near centre line	H.C.C.	P	N. 80° W.	Vert.	S.
Beauchastel tp., 212 ch. from west boundary, just north of centre line	H.C.C.	E	N. 62° E.	Steeply N.	S.
Royal-Roussillon tp., range-line I-II, lot 57	E.K.F.	P	N. 30° W.	Undet.	SW.
Poularies tp., range X, lot 37-38	E.K.F.	F	N. 50° W.	85° NE.	NE.
Poularies tp., range I, lots 52-62	B.S.B.	E	N. 70° E.	Steeply S.	S.
Destor tp., 2·9 mi. from north boundary, 0·2 mi. west of Makamik rd	B.S.B.	F	N. 70° E.	Undet.	S.

Locality	Observer	Value	Strike	Dip	Face to
Destor tp., 2·0 mi. from north boundary, 0·2 mi. east of Makamik rd	B.S.B.	E	N. 75° E.	Undet.	S.
Destor tp., 20 ch. south of centre line, just east of Makamik rd	B.S.B.	F	N. 63° W.	Undet.	N.
Destor tp., 2 mi. from north boundary, ½ mile west of centre line	B.S.B.	F	N. 80° E.	Undet.	S.
Destor tp., 3 mi. from north boundary, on centre line	B.S.B.	F	N. 65° E.	Undet.	S.
Destor tp., 3·35 mi. from north boundary, ¾ mile west of centre line	B.S.B.	F	N. 70° E.	85° N.	S.
Destor tp., 2¾ mi. from north boundary, 2·2 mi. east of centre line	B.S.B.	F	N. 83° E.	70° N.	S.
Destor tp., 4½ mi. from south boundary, 25 ch. from east boundary	B.S.B.	F	East	Undet.	N.
Dufresnoy tp., 2¾ mi. from west boundary, on centre line	H.C.C.	G	N. 35° W.	NE.	NE.
Dufresnoy tp., 160 ch. from west boundary, 75 ch. from south boundary	H.C.C.	E	N to NE.	10° E.	E.
Dufresnoy tp., 30 ch. from west boundary, 175 ch. from south boundary	H.C.C.	E	None	Flat	....
Dufresnoy tp., 58 ch. from west boundary, 112 ch. from south boundary	H.C.C.	E	North	10° E.	E.
Dufresnoy tp., 65 ch. from west boundary, 35 ch. south of centre line, A 3456	H.C.C.	E	N. to NW.	17° E.	E.
Dufresnoy tp., 100 ch. from west boundary, 90 ch. from south boundary	H.C.C.	F	N.	20° E.	E
Dufresnoy tp., 132 ch. from west boundary, 47 ch. from south boundary	H.C.C.	F	N. 10° W.	30° E.	E
Dufresnoy tp., on west boundary, 21 ch. from south boundary	H.C.C.	G	N. 35° E.	47° SE.	SE.
Dufresnoy tp., west shore of lake Savard	H.C.C.	P	N. 50° W.	Undet.	NE.
Dufresnoy tp., isle 49, south end Dufault lake	H.C.C.	F	N. 30° E.	Undet.	E.
Dufresnoy tp., isle 48, south end Dufault lake	H.C.C.	G	N. 30° E.	Vert.	E.
Dufresnoy tp., 60 ch. north-northwest of centre point	H.C.C.	P	N. 55° W.	60-90° N.	N.
Dufresnoy tp., 235 ch. from west boundary, 335 ch. from south boundary	H.C.C.	E	N. 20° W.	35° E.	E.
Rouyn tp., northeast corner Routhier lake	H.C.C.	G	N. 85° E.	62° N.	Undet.
Rouyn tp., 120 ch. from north boundary, 105 ch. from west boundary, Bl. 60	H.C.C.	G	N. 55° E.	Vert.	SE.
Rouyn tp., 155 ch. from north boundary, 90 ch. from west boundary, Bl. 140	H.C.C.	G	N. 60° E.	Vert.	Undet.
Rouyn tp., 105 ch. from north boundary, 190 ch. from west boundary, Bl. 58	H.C.C.	G	N. 80° E.	Vert.	Undet.
Rouyn tp., 160 ch. from north boundary, 250 ch. from west boundary, Bl. 98	H.C.C.	G	N. 85° E.	Vert.	S.
Rouyn tp., 308 ch. from south boundary, 275 ch. from west boundary	H.C.C.	G	N. 85° W.	45° N.	S.

Locality	Observer	Value	Strike	Dip	Face to
Rouyn tp., islet in east bay of Pelletier lake	H.C.C.	G	N. 65° W.	Vert.	Undet.
Rouyn tp., east shore of east bay, Pelletier lake	H.C.C.	E	N. 65° W.	Vert.	S.
Rouyn tp., southeast corner of Pelletier lake, main expansion	H.C.C.	E	N. 80° W.	65° N.	S.
Rouyn tp., 264 ch. from south boundary, 164 ch. from west boundary	H.C.C.	G	East	Steeply N.	Undet.
Rouyn tp., 288 ch. from south boundary, 224 ch. from west boundary	H.C.C.	E	N. 80° W.	60° N.	S.
Rouyn tp., 55 ch. from north boundary, 270 ch. from west boundary	H.C.C.	G	N. 80° E.	Vert.	S.
Rouyn tp., east-west centre line, 212 ch. from east boundary	H.C.C.	G	N. 80° E.	Vert.	S.
Rouyn tp., east-west centre line, 187 ch. from east boundary	H.C.C.	G	N. 85° W.	Undet.	S.
Rouyn tp., Kinojevis river, 120 ch. from east boundary	H.C.C.	F	N. 80° W.	60° N.	S.
Languedoc tp., range I, lot 13	E.K.F.	F	N. 80° W.	50° N.	N.
Languedoc tp., range I, lot 30	B.S.B.	P	N. 15° E.	50° E.	E.
Privat tp., range II, lot 52	B.S.B.	G	N. 50° W.	80° N.	S.
Privat tp., range III, lot 58	J.B.M.	P	N. 80° E.	Undet.	S.
Privat tp., range IV, lot 58	J.B.M.	P	N. 80° W.	Undet.	S.
Privat tp., range V, lot 34	E.K.F.	P	N. 60° W.	Undet.	S.
Privat tp., range V, lot 40-41	E.K.F.	P	N. 10° W.	Undet.	W.
Privat tp., west boundary, range I, to range II, lot 18, north end	B.S.B.	E	N. 65° E.	Undet.	S.
Privat tp., west boundary, range V, to range III, lot 18, south end	B.S.B.	E	N. 45° W.	Undet.	NE.
Aiguebelle tp., west side of south end of Abijevis lake	H.C.C.	P	East	Vert.	S.
Aiguebelle tp., ½ mi. from west boundary, 1·5 mi. from south boundary	W.F.J.	P	N. 85° W.	Vert.	N.
Aiguebelle tp., 30 ch. from west boundary, 70 ch. from north boundary	B.S.B.	G	East	75° N.	S.
Aiguebelle tp., 35 ch. from west boundary, 220 ch. from north boundary	B.S.B.	F	N. 70° W.	Vert.	S.
Aiguebelle tp., 3·9 mi. from west boundary, 4·6 mi. from north boundary	B.S.B.	F	N. 77° W.	Undet.	S.
Aiguebelle tp., 90 ch. from north boundary, 4·65 mi. from west boundary	B.S.B.	F	East	Undet.	S.
Aiguebelle tp., 2¼ mi. from north boundary, 3¾ mi. from east boundary	B.S.B.	F	East	70° N.	S.
Aiguebelle tp., from west boundary, 170 ch. from north boundary, to point 3 mi. from west boundary, 165 ch. from north boundary (one flow)	B.S.B.	E	East	Undet.	S.
Aiguebelle tp., from last point to point 3¾ mi. from north boundary, 1¾ mi. from east boundary, one flow traced	B.S.B.	E	N. 70° W.	Undet.	S.
Clericy tp., 210 ch. from north boundary, 180 ch. from east boundary	H.C.C.	E	N. 60° W.	75° S.	SW.
Clericy tp., south side Kinojevis river, near Clericy station	H.C.C.	P	N. 60° W.	Vert.	NE.

Locality	Observer	Value	Strike	Dip	Face to
Clericy tp., about 40 ch. south of Clericy station	H.C.C.	E	N. 35° W.	Vert.	NE.
Clericy tp., opposite Clericy station	H.C.C.	F	N. 50° W.	Vert.	NE.
Joanne tp., Kinojevis river, west shore, just south of plaque 72	H.C.C.	E.	N. 20° W.	70° E.	E.
Joanne tp., about 10 ch. west-southwest of plaque 72	H.C.C.	E	N. 40° W.	Steep	NE.
Joanne tp., Davidson cr., west shore, 55 ch. northeast of plaque 72	H.C.C.	G	N. 60° E.	50° N.	Undet.
Joanne tp., Davidson cr., west shore, 100 ch. northeast of plaque 72	H.C.C.	G	N. 45° E.	45° NW.	SE.
Joanne tp., Davidson cr., west shore, 120 ch. northeast of plaque 72	H.C.C.	E	N. 80° W.	65° N.	S.
Manneville tp., range I, lot 24, near Kinojevis r.	H.C.C.	G	N. 55° W.	70° N.	SW.
Manneville tp., range I, lots 13-20, near Kinojevis river	H.C.C.	....	N. 60-80° W.	Undet.	Undet.
Manneville tp., range II, lot 22, 4,300 ft. north of Kinojevis river	H.C.C.	F	N. 80° W.	Vert.	S.
Manneville tp., range III, lot 43	J.B.M.	P	East	Vert.	N.
Manneville tp., range III, lot 43	J.B.M.	F	N. 85° E.	Vert.	N.
Manneville tp., range VI, lot 2, south end	J.B.M.	F	N. 85° W.	Undet.	S.
Bousquet tp., 2 mi. from north boundary, 1¼ mi. from east boundary	J.B.M.	G	N. 80° W.	Vert.	S.
Villemontel tp., range IV, lot 28-29.	W.F.J.	F.	East	80° N.	N.
Preissac tp., islet, about 36 ch. from west boundary, and just south of range-line V-VI	H.C.C.	P	N. 20° E.	80° W.	E.
Figuery tp., range VIII, lot 27	H.C.C.	G	N. 85° W.	Vert.	S.
Figuery tp., range IV, lot-line 35-36.	J.B.M.	P	N. 75° W.	65° N.	S
Figuery tp., range II, lot-line 21-22.	J.B.M.	G	N. 65° W.	70° N.	S.
La Motte tp., range VI, lot 47	J.B.M.	F	N. 45° W.	70° SW.	NE.
Malartic tp., range V, lots 29-30 (several determinations)	H.C.C.	E	N. 70-75° W.	Vert.	S.
Malartic tp., range VI, lot 17	J.B.M.	E	N. 45° W.	Vert.	S.
Malartic tp., range VII, lot 20	J.B.M.	E	N. 63° W.	Vert.	S.
Landrienne tp., range IX, lot 10	J.B.M.	G	N. 77° E.	Vert.	N.
Landrienne tp., range III, lot 13	J.B.M.	G	N. 80° W.	50° N.	S.
Barraute tp., range-line IV-V, lot 30-31	J.B.M.	F	N. 60° W.	70° N.	S.
Barraute tp., range-line IV-V, lots 28-29	J.B.M.	F	East	55° N.	S.
Barraute tp., range I, lot 56-57	J.B.M.	P	N. 45° W.	45° NE.	SW.
Dubuisson tp., range VII, lots 40-41, east shore Demontigny lake	H.C.C.	F	N. 72° W.	Vert.	S.
Dubuisson tp., range VII, lot 43, east shore Demontigny lake	H.C.C.	F	N. 70° W.	Vert.	S.
Dubuisson tp., Siscoe island, Demontigny lake	H.C.C.	....	N. 70° W.	Undet.	Undet.
Dubuisson tp., range VIII, lot 53, Stabell property	H.C.C.	G	N. 82° E.	Vert.	S.
Dubuisson tp., range VIII, lot 53, Stabell property	H.C.C.	G	N. 87° E.	Vert.	S.
Dubuisson tp., range VIII, lot 55, Stabell property	H.C.C.	G	N. 84° W.	Vert.	Undet.
Dubuisson tp., range VIII, lot 51, Legault property	H.C.C.	G	N. 82° E.	Vert.	S.

TIME OF FOLDING

The time when the Timiskaming series, with the underlying Keewatin series, suffered the intense deformation now exhibited, is fairly closely fixed with respect to the different periods of igneous intrusion. On Renault bay, Dasserat lake, the Keewatin has been invaded by a large sill of diorite porphyry differentiated in place, and now turned up on edge. The arrangement of the rock types in the sill indicates that differentiation took place while the sill was horizontal, and, therefore, that intrusion occurred before the Keewatin was folded.

The Timiskaming series is cut by dykes of what has been termed hornblende lamprophyre in some reports, amphibolite in others. The dykes are highly schistose, and have, apparently, been metamorphosed as strongly as the sediments they cut. They also may be presumed, accordingly, to have been formed before the series was folded.

The lamprophyre and diorite porphyry are the only intrusives that afford direct evidence of having been intruded before the folding. Some doubt exists as to the exact age of the quartz diorite or older gabbro, and granodiorite, as will be shown later in this report. The remaining, as yet undiscussed, intrusives are known to be younger than the folding, as they are not schistose, and they cut at all angles across the highly folded or sheared older rocks. The oldest of the later intrusives is the syenite porphyry; and folding, therefore, took place between the intrusion of the diorite porphyry and that of the syenite porphyry.

FAULTING OF THE KEEWATIN

Faults in the Keewatin areas are probably for the most part of post-Timiskaming age. This is indicated by the fact that many of them cut dykes of syenite porphyry and later gabbro. Faults that displace the later gabbro cannot be accurately dated, as a rule, because throughout most of the region under discussion the later gabbro is the youngest rock present.

Information about the faulting is scanty. Most of the known faults are in Dubuisson and Rouyn townships, where mining claims have been examined in detail. The securing of definite information regarding fault movements in the Keewatin is normally rather difficult, on account of the paucity of dykes or other markers that can be identified with certainty on both sides of the fault.

ROUYN TOWNSHIP

A wide and continuous belt of schist, formed by faulting, crosses Pelletier lake from east to west, and is of some interest because on it gold was discovered early in the spring of 1923. The shear zone has an average strike of north 80 degrees east and a dip of 75 degrees south. The strike varies, however, from north 60 degrees east to south 80 degrees east, and the dip also varies. At one point on the south shore of the lake, where the strike swings to north 80 degrees west, the dip changes to 85 degrees north. The sheared zone outcrops on the south shore of the west arm of the lake, and crosses from there to the east shore, appearing on two small islands between. In places it splits to form two or more belts of schist separated by good-sized horses of massive rock. One of these subsidiary faults cuts and displaces a 2-inch dyke of basaltic diabase, and also a contact between lava and quartz diorite (older gabbro), on a small island close to the east shore of the lake. The displacements show that the north side of the fault moved west relative to the south side; the displacement is about 3 feet on the branch fault observed, but this is, of course, only a small part of the displacement of the whole fault. A later fault was observed on the same island, striking north 52 degrees west and dipping 85 degrees south. Where it cuts the older fault, here striking north 60 degrees east, it has dragged the older schist strongly to the west, indicating that the north side of the later fault has also moved west relative to the south side. The amount of the movement is unknown.

Throughout the sheared zone of the earlier fault there is a certain amount of vein material, introduced between the leaves of schist in strings and nodular veinlets. It consists of quartz, with some iron-bearing carbonate, sericite, and pyrite; and the schistose wall-rock is also somewhat enriched with pyrite. Free gold has been found on the surface in places, but it is not yet known whether it is a primary constituent, or is residual from the weathering of pyrite. On the south shore of the west arm of the lake, where the strike of the shear zone changes suddenly from north 65 degrees east to north 80 degrees west, a lens of quartz some 5 feet in width is found at the bend.

On Block 60, at the east end of Héré lake, a fault cuts the Powell vein at a point about 2,000 feet from the north boundary of the claim. The fault, which is marked by a steep cliff some 50 feet high, strikes north 80 degrees east and dips vertically or steeply north. Striæ on the fault-plane dip about 45 degrees toward the west end of the fault. The vein north of the fault has been shifted about 40 feet westward; and the direction of the striæ indicates that the north side has also moved down.

Faults with similar displacement were also observed cutting veins on the claims northeast of Héré lake.

On the Chadbourne claim, Block 1, a small fault was observed striking approximately northwest. It cuts across the contact between a rhyolite breccia and a massive basic lava, shifting the northeast side toward the northwest a distance of 6 or 7 feet.

The valley of Horne creek has long been supposed to be a fault valley. This conclusion was drawn from the topography; the valley may be traced for about 3 miles, and is perfectly straight for the whole of that distance; the sides, particularly on the south, are steep and in places cliffed. However, no direct evidence of faulting could be obtained until the United Verde Extension Mining Company (now the Quemont Mining Corporation) sank a shaft for prospecting purposes on the south shore of the bay into which Horne creek empties. From the 100-foot level, workings were driven northward, and eventually cut large widths of faulted rock at several points over a total length of 1,800 feet. At the time the property was visited, near the end of August, 1927, the workings had not yet entered the fault, but Mr. A. J. Anderson, who was in charge of the development, kindly furnished the following description of what was later found.

"As has been generally supposed, there is a fault occupying the Horne Creek valley. We cut the fault first in the crosscut running north from the shaft, and later in the west drive near the southwest corner post, also in a diamond drill hole west of the dyke (of later diabase). In the north crosscut the fault consists of a zone of crushed diorite about 150 feet in width, the trend of which seemed to be north 80 degrees east, and dipping 75 degrees north. The crosscut was still in the crushed material when it was stopped, but a drill hole proved the width to be about 150 feet. Within the crushed zone there were several small ($\frac{1}{4}$-inch to $\frac{3}{4}$-inch) seams of plastic gouge, and one seam about $3\frac{1}{2}$ inches. Adjacent to this larger seam is 5 feet showing more intense crushing than the remainder of the zone. All the crushed material is diorite, and the crushing is in various degrees of intensity, but all of it is crushed.

We encountered the fault in the west drive about 100 feet east of the southwest corner. We did not cross the fault but ran alongside of it for 50 feet. About $2\frac{1}{2}$ inches of plastic gouge was on the north wall of the drive for 25 feet. Here the fault strikes north 80 degrees east and dips 75 degrees south. (This also lines up with the drill hole and the north crosscut, at north 80 degrees east.) The crushed material is rhyolite with a decided pink tinge, and fairly well mineralized with pyrite. The diamond drill hole checked the north crosscut very well."

Specimens of the various types of faulted material were forwarded by Mr. Anderson. The " plastic gouge " is material that has been crushed to a fine-grained, dark grey clay, containing no fragments large enough to be recognized as such by the naked eye. The material from the 5-foot crushed zone is extremely friable, falling to pieces at a touch, and consists of fragments, most of them smaller than a pea, in a matrix of clay. The remaining specimens, of rhyolite and of diorite, though not so badly crushed, are much shattered, and split readily along cracks to reveal slickensided surfaces.

There are as yet no data from which the direction and amount of the movement along this fault can be directly determined. A large number of smaller faults are found, however, in the Horne mine workings directly to the south. Most of them strike northeast at various angles, so that they appear to be branches of the main fault. They cut and displace dykes of red syenite porphyry, and also fracture the later gabbro. Along all of them the north or northwest sides have moved westward. It seems probable, therefore, that the north side of the Horne Creek fault also moved west.

BEAUCHASTEL TOWNSHIP

A large shear zone, presumably formed by faulting, runs almost due east and west across MacDonald lake, along the south shore of Fortune lake, and disappears under the waters of Renaud lake. The shear has created a belt of chlorite schist 6 to 8 feet wide on the average, but widening to 300 or 400 feet between Fortune and Renaud lakes. The fault is certainly post-Timiskaming, for in one place on the property of the Lake Fortune Mining Company it has rendered schistose the syenite porphyry which is intrusive into the Timiskaming series.

A large dyke of later gabbro, striking northwest, crosses the northwestern quarter of Beauchastel township. It cannot be traced continuously because of lack of outcrops. The observed outcrops do not fall on a single straight line, but are arranged as if, in at least three places, the dyke had been broken by faulting. In all three cases the part of the dyke north of the supposed break is situated as if it had been shifted eastward.

DUFRESNOY TOWNSHIP

No faults of importance have yet been observed in Dufresnoy township. On claim A 2039, northeast of the Amulet property, a large dyke of later gabbro striking nearly north is displaced in the interval between two outcrops. Again the part on the north is east of where it would appear if the southern part continued north without change of strike. The amount of the apparent displacement is about 800 feet. Here again there is suggestive evidence of comparatively late faulting.

DUBUISSON TOWNSHIP

On the Stabell and Legault claims, lying between De Montigny and Blouin lakes, a number of faults have been detected. The largest, in which the Stabell vein lies, strikes north 60 degrees west and dips steeply north; the north side has moved east about 400 feet. Striæ indicate that the movement was nearly horizontal. A smaller fault on the Legault claims strikes north 75 degrees east and dips vertically or steeply south. It cuts across the contact between two lava flows, and this contact on the north side of the fault is about 25 feet east of its position on the south side of the fault. Four smaller faults, with displacements of only a few inches, were also seen. Two are approximately parallel to the Stabell vein, the other two parallel the described fault on the Legault claims. The north side of all four has been shifted east. These faults are cut by dykes of granodiorite porphyry.

At the Martin mine, on the south shore of De Montigny lake, two faults cut the vein. Each strikes about north 77 degrees east, and in both the north side is shifted toward the west. The amount of displacement is about 20 feet in one, and about 40 feet in the other. Striæ indicate that the movement was nearly horizontal. These faults cut and displace dykes of grey syenite porphyry.

On the St. Germaine-Gale claims, on the east shore of the narrows between De Montigny and Lemoine lakes, three faults have been observed. One strikes north 40 degrees east, is vertical, and its northwest side has moved about 20 feet to the northeast. The strike of the second varies from north 30 to 60 degrees east, the dip is 55 degrees northwest, and the faulting has sheared the country rock intensely over a width of 6 feet. The third strikes north 80 degrees west, dips 75 degrees north, and its shear zone is 2 to 3 feet wide. These faults are of different ages. The first two are cut by dykes of grey syenite porphyry like the porphyry found at the

Martin mine. The third cuts a dyke of similar rock and renders it schistose. The first two are, therefore, earlier than the porphyry intrusion, the third, later.

On the Sullivan claims, on the east shore of De Montigny lake, small faults cut a knob of granodiorite, strike north 75 degrees east, and dip almost vertically. The amount of displacement is unknown, but is small. The fractures are filled with quartz and tourmaline carrying a little free gold.

These and other minor observations indicate that in Dubuisson township there are at least two sets of faults, one older than the dykes of syenite porphyry, the other younger than the syenite porphyry and granodiorite, but older than dykes of granodiorite porphyry. The trends of the older set are north 40 degrees east and north 40 degrees west; those of the later set are north 75 degrees east and north 60 degrees west.

FAULTS IN THE TIMISKAMING SERIES

There are undoubtedly many faults in the Timiskaming series, as the strata could hardly have been closely folded as they are without developing fractures. The heavy cover of drift, however, prevents the fractures from being seen and recognized.

A fault with a general north-south trend runs through the western end of Kekeko lake, and presumably may continue southward through Evain and Albee lakes, accounting for the trench in which these lakes lie. The west side of this fault has moved north a distance of about half a mile. This is indicated by the displacement of the band of Timiskaming conglomerate at Pelletier creek; an outcrop of this conglomerate was found on the north side of the band of Cobalt series, a short distance west of the creek. The south edge of the conglomerate band, again, appears on the east shore of Kekeko lake, but not on the opposite shore; and the bedding on the east shore strikes northwest instead of nearly west, a change that may well be caused by the drag of the fault movement. Several small subsidiary faults were observed on the east shore of the lake.

At the south end of Albee lake the boundary between the granite and the sediments on the west side of the lake is about a quarter-mile farther north than on the east side. The relations suggest that the fault may extend as far south as this, but the inference is by no means certain, as an irregularity may readily occur in an intrusive boundary without being caused by faulting.

The fault must have been formed before the intrusion of the big dyke of later gabbro that crosses Kekeko lake, as the dyke itself is not faulted.

Another strong fault strikes about north 40 degrees east in western Joanne township, underlying the bed of Davidson creek and of Kinojevis river below the mouth of the creek. This fault has displaced the Timiskaming-Keewatin contact about 3 miles, measured along the fault; the southeast side has been shifted toward the northeast. Although the great part of the faulted zone is concealed beneath the stream beds, the numerous subsidiary faults along the shores, the strong shearing, and the twisted and contorted bedding close to the fault, yield plenty of direct evidence of faulting, in addition to the displacement of the contact.

Almost opposite the mouth of Davidson creek the fault splits, and a large, if not the larger, branch runs off westward on a strike of north 82 degrees east. This fault dips about 60 degrees to the north, and has already been described, page 80. A second branch has been inferred (page 80) to run off to the west a little north of the Joanne centre line, near the axis of the northernmost syncline of the Timiskaming series. The northernmost branch may strike west to connect with the fault crossing Pelletier lake. The second branch may follow the Keewatin-Timiskaming contact more or less closely.

A fault striking almost due north displaces the Clericy band of sediments where Kinojevis river crosses it in eastern Clericy township. The east side of this fault has been moved north about 2,000 feet. The line of this fault, projected north, passes through Caste lake, Abijevis lake and the creek draining it, Eileen lake, the east end of Lois lake, and Robertson lake. Projected south, it runs through the lake-like expansion of Kinojevis river, Parfouru lake, Wabuskus and Vaudray lakes, Gendron lake, and Kinojevis river south of Vaudray lake for at least 3 miles beyond the boundary of the region under consideration. This line of depressions has a total length, therefore, of at least 52 miles, and its existence suggests the presence of a through-going fault, although actual faulting has been proved only where the line of depressions crosses the Clericy sediments.

The strike of the Davidson Creek fault would carry it through Clericy lake and into the last-mentioned fault near Parfouru lake. In both faults the east side has moved north. Possibly, therefore, the Davidson Creek fault is a branch of the Clericy fault.

Another large fault is known on the O'Brien claims, about $\frac{3}{4}$ mile from the west side of Cadillac township, and $1\frac{5}{8}$ miles north of the centre line. Its existence has been definitely proved by underground exploration. On the surface it has been eroded to form a valley occupied in part by a small tributary of Blake river. The fault zone consists of talc-chlorite schist 150 feet or more in width; it strikes approximately east, and dips almost vertically. The fault zone has been traced by drilling for about a mile.

In many places in the area of Timiskaming series, peculiarities of outcrop suggest faulting, but definite evidence is lacking.

CHAPTER VI

INTRUSIVES

INTRODUCTION

The intrusives of the region are of several different types and ages. A mass of red feldspar porphyry in Duparquet township is clearly earlier than the Timiskaming series. A mass of diorite porphyry and some dykes of lamprophyre or amphibolite are later than the Timiskaming, but earlier than the great post-Timiskaming folding. Bodies of diorite, granodiorite, syenite, porphyry, granite, and gabbro are later than the Timiskaming folding, but earlier than the deposition of the Cobalt series. One dyke of Nipissing diabase cuts the Cobalt series east of Olier lake.

Localization of the larger igneous masses was evidently determined by the regional structure. The Dufault and the Flavrian granites, the Palmarolle granite, the Robertson Lake granite, and the immense granite mass occupying a great part of Preissac, La Motte, and La Corne townships, all lie on or near the summits of anticlines in the Keewatin series. Intrusive bodies may and do occur also in the synclinal areas, but are of small size and few in number. The presence of the intrusive masses in the anticlines, however, does not indicate that the pressure of the upwelling magmas caused the folding. On the contrary, there is abundant evidence to show that folding occurred before intrusion, and controlled it. The axes of the folds have a regular arrangement, in that they are very straight over long distances, and for the most part trend in one direction, east-southeast. These features must be the result of stresses that acted with uniformity over the whole region. Had folding been due primarily to the upwelling force of intrusive masses, the elongation of the intrusive would determine the direction of the axis of the fold above it; and it would scarcely be expected that a number of widely separated intrusives would all be elongated so as to yield a structure as regular as the region exhibits. Again, if an intrusive forced its way into comparatively flat-lying strata and domed them, the intrusive should be found approximately in the centre of the anticline thus formed, and the strata should dip away from it on all sides. The centres of the intrusive masses under consideration, however, do not coincide with the centres of the anticlines; on the contrary, most of the masses lie largely to one side or the other of an axis, as if they had stoped their way irregularly into the fold. In some instances, one of the intrusive boundaries may extend almost to the succeeding synclinal axis; this is true of the granite injected into the La Motte anticline. In other instances the intrusive may cut completely across synclinal axes, as does the great southern granite. These intrusive bodies, in addition, are not shattered and sheared as if they had been folded, nor are the strata around them unusually deformed, as would be expected had the intrusives acted as unyielding buttresses during folding. All the evidence at hand, therefore, indicates that intrusion took place after folding was entirely or largely completed, and that the already established folds localized the intrusions.

PRE-TIMISKAMING INTRUSIVES

Red Feldspar Porphyry

A large mass of purplish red feldspar porphyry is exposed in Duparquet township close to the east-west centre line. This body of porphyry has a length of 3 miles and a maximum width of $\frac{5}{8}$ of a mile. It extends from $\frac{1}{2}$ mile east of the north-south line to within $\frac{1}{2}$ mile of Duparquet lake. In addition to this large mass a few small dykes of reddish porphyry were observed in the volcanics $1\frac{1}{2}$ miles to the east, and also to the south, of the sedimentary series, adjacent to the Destor-Duparquet boundary. A megascopic and microscopic similarity seems to indicate that the smaller intrusions are of the same age as the large body of porphyry.

The rock is highly porphyritic, with phenocrysts of feldspar up to 1 inch in diameter. These phenocrysts have good crystal form and vary in colour from grey or green to pink, depending upon the amount of alteration that they have undergone. The matrix is variable as regards texture, but is usually fine grained and under the microscope is found to be composed of a felted aggregate of small plagioclase and orthoclase laths with indistinct outlines and generally much altered. The alteration products developed are small patches of carbonate, flakes of sericite, and occasionally a small, irregular grain of epidote. All the phenocrysts are clouded with kaolin and flakes of sericite. Pyrite and magnetite in small grains and crystals are common. The composition of the feldspar phenocrysts as determined by oil immersion is anorthoclase.

Alteration of the porphyry has been particularly intense east of the north-south centre line. Here the rock is light green and is cut by a network of small stringers of milky white quartz, which carry finely crystalline galena, tetrahedrite, chalcopyrite, and arsenopyrite. The porphyry has been mashed and rendered schistose over considerable areas, and near the western end of the large mass silicification and mineralization have occurred along a number of these sheared zones.

As already described, the red feldspar porphyry is broken up on the south side to form the red feldspar porphyry conglomerate at the base of the Duparquet-Destor band of Timiskaming sediments. It is, therefore, pre-Timiskaming in age.

Quartz Porphyry

On the south side of the Duparquet-Destor band of sediments a quartz porphyry outcrops, and its debris forms the quartz porphyry conglomerate already described (page 62). There is some doubt whether this rock is an intrusive or a lava; the relationships are not found in the field, and it is petrographically not unlike coarsely porphyritic rhyolites, such as have been found in a few places elsewhere. Besides the occurrence at the base of the Duparquet-Destor band, there are several other bodies 2 or 3 miles to the east, crossing the Makamik road.

The rock is light olive-green to light grey in colour, and highly porphyritic in texture. The groundmass is a very finely crystalline aggregate of feldspar crystals, the composition of which was not determined partly because of the fine grain, partly because it is badly altered to sericite. The groundmass contains phenocrysts of quartz, feldspar, and mica. The quartz phenocrysts are numerous, large, and conspicuous, rather rounded, and of all sizes up to ½ inch in diameter. The feldspar phenocrysts are numerous but smaller, square to tabular in shape, and are chiefly albite, $Ab_{90}An_{10}$. In many of the outcrops they are inconspicuous, but in some places they attain diameters of ⅕ inch, and the rock thus becomes a feldspar or quartz-feldspar porphyry. The feldspar phenocrysts are also badly sericitized. Mica crystals are few, and badly altered to chlorite. A few grains of pyrite and magnetite are also present, and some irregular patches of chlorite.

Some small masses of a quartz porphyry occur on the Newbec claim, Block 8, northwest of Dufault lake, and on the claim north of it. The rock is rather dark grey, weathering to a light grey, and is highly porphyritic, with numerous quartz phenocrysts averaging about 1 mm. in diameter. There are also a number of phenocrysts of oligoclase, $Ab_{85}An_{15}$, of the same or slightly larger size. The groundmass is composed largely of oligoclase, with more or less quartz, up to 20 per cent, and a little white mica.

This rock was proved to be intrusive into the Keewatin lavas, as in the mine it cuts across the strike of the lavas, as determined from a flow top marked by a thick band of well-bedded cherty tuff; and likewise, on the 250-foot level, forms a contact breccia in which, over a width of 50 feet, fragments of lava are included in a matrix of the quartz porphyry.

The quartz porphyry is intruded, northeast of the shaft, by the diorite-aplite member of the Dufault granodiorite mass, and, in the mine and other places, by the two sets of dykes of quartz diorite, or older gabbro, that occur on the Newbec property.

POST-TIMISKAMING INTRUSIVES INJECTED BEFORE FOLDING

Diorite Porphyry

Diorite porphyry forms a single mass on the south side of Renault bay, Dasserat lake. The exposure is about 1½ miles long, 30 chains in maximum width, and strikes about north 60 degrees east. The true width is greater than the exposed width, as the south margin of the mass is overlain by Cobalt series. For the same reason, and also because the mass has been intruded on the north by syenite porphyry, the strike of the exposure probably does not represent the strike of the body.

The rock is very similar to the diorite porphyry occurring near the village of Larder Lake. It was, like that porphyry, intruded as a sill in the older rocks before folding took place, underwent differentiation in place, and was later folded with the older rocks and turned on edge. Accordingly, as at Larder Lake, it exhibits a variety of phases. The north side, originally the upper, is a rather acid feldspar porphyry, made up of numerous phenocrysts of albite feldspar averaging 1 mm. in diameter embedded in a fine-grained matrix consisting almost wholly of albite, with accessory magnetite. The diorite phase is more basic than the porphyritic phase. It is a fine-grained, brownish grey rock, with fewer and smaller feldspar phenocrysts, some biotite, and a good deal more magnetite than the more acid phase. The basic diorite phase of the rock found in Larder lake is here either absent or is covered by the overlying Cobalt series.

The age of the diorite porphyry is fairly definitely determined. The differentiation indicates that it must have been intruded and cooled before the folding of the Timiskaming series. It cuts only the Keewatin in Opasatika area, but it also cuts the Timiskaming in Larder area. Its age, therefore, may be definitely stated to be post-Timiskaming and earlier than the folding movements. It is cut by dykes from the adjacent mass of syenite porphyry, and hence is older than the syenite. It cuts the hornblende lamprophyre in Larder area, and may be supposed to possess similar age relations here.

This rock is not related to the quartz diorite, or older gabbro, and should not be confounded with it on account of the similarity of name.

Amphibolite

A considerable number of sill-like masses of a rather dark green, soft rock of micaceous appearance are found in the Timiskaming series, particularly in the western half of the mapped area. In width they vary from 2 or 3 feet up to 15 feet. They are commonly schistose, and the weathered surface in most places is covered with projecting nodules as big as a man's fist, which stand 2 or 3 inches above the surrounding surface, giving it a striking, warty appearance.

The chief constituents are hornblende, chlorite, and biotite, with interstitial feldspar and calcite. The nodular parts are much the same as the remainder of the rock, except that they seem to contain less calcite, the rapid erosion of which presumably accounts for the nodular weathered surfaces. The feldspar is mainly oligoclase, but microcline was found in some sections.

The composition of the rock is that of a basic intrusive, but if so it has been so completely recrystallized that all chilled edges have disappeared. The schistosity and recrystallization suggest that it was probably injected before the folding of the Timiskaming series. On Kinojevis lake it is cut by a dyke of granite; but it has not been found in contact with any other of the igneous rocks of the area.

LATER PRE-HURONIAN INTRUSIVES

Quartz Diorite (Older Gabbro)

The name "older gabbro" was first applied in 1922 to a large dyke that crosses the south end of Dasserat lake and runs northeast past the south end of Arnoux lake. It was definitely distinguished from the later gabbro, because a dyke of reddish syenite porphyry cuts it, whereas the later gabbro cuts the syenite porphyry. The so-called "older gabbro" was afterwards found to be of widespread occurrence, and to form numerous large masses.

The quartz diorite, or older gabbro, appears to be confined, in Quebec, to the area between Abitibi lake and the north end of Opasatika lake, and chiefly within an area extending 25 miles north of Opasatika lake. If basic masses associated with the Lake Dufault and Clericy granodiorites are classed with the quartz diorite, the eastern boundary of the quartz diorite zone lies slightly more than 30 miles east of the Ontario boundary. It is not known how far west into Ontario these bodies extend. The masses are most numerous in Montbray, Duprat, and Beauchastel townships. None has yet been found within the Timiskaming sediments.

On fresh surfaces the rock is very dark grey, with a greenish cast in places where alteration to epidote has occurred. The weathered surfaces are dark green, unlike those of the later gabbro, which are characteristically brownish. In the larger dykes and masses another distinguishing characteristic is the long needle-like hornblende crystals freely sprinkled through the rock. The later gabbro never displays this texture. A third characteristic, particularly useful for distinguishing this rock from the later gabbro in mine workings, is the rather light grey or greenish grey shade of the chilled edge. The chilled edge of the later gabbro is always very black and glassy, with a sort of resinous lustre difficult to describe but readily recognizable by the light of a miner's lamp.

The quartz diorite almost everywhere is greatly altered. Originally it apparently consisted of hornblende and feldspar in about equal amounts, with accessory quartz. In some thin sections feldspar exceeds hornblende, in others the reverse is the case. The feldspar is rather completely altered to micaceous aggregates and some epidote. Remnants were found in several thin sections, however, and vary from oliogoclase, Ab_{75} An_{25}, to labradorite, Ab_{50} An_{50}. Much of the hornblende has altered to chlorite.

The texture of the rock varies much. Some masses, and, in certain instances, parts of masses, are fine grained and exhibit gneissic and flow textures, indicating that movement took place after the rock had partly cooled and become viscous. The normal texture, however, is like that of an ordinary gabbro, the grain medium to moderately coarse except in the smaller dykes. A characteristic feature in the larger masses is the occurrence of rounded masses of pegmatite that grade into the normal quartz diorite at their edges. The pegmatites, which are thus clearly acid differentiates, are much coarser than the average rock, and are composed of long crystals of black hornblende in a matrix of sodic plagioclase with a good deal of quartz. In places the hornblendes are as long and thick as a man's finger, and give rise to a rock of very striking appearance.

A rather general characteristic of the rock is a sort of acid veining. Joint cracks are filled with a mixture of quartz and pyrite, and the rock on each side is bleached for distances up to an inch, through the replacement of the rock materials by quartz and epidote.

The rocks classified as quartz diorite, or older gabbro, are of more than one age, though petrographically alike. On claim A 2746, Dufresnoy township, northeast of the Waite-Ackerman-Montgomery mine, a sill of quartz diorite with a low dip cuts through a larger mass of almost identical appearance and composition. North of Dufault lake, on the line between claims 14923 and 14932, two bodies of quartz diorite or basic granodiorite are in intrusive contact. On the Robb-Montbray property, basic intrusives of at least three ages are present; fine-grained dioritic rock is cut by a coarse-grained diorite dyke, in turn cut by small dykes of somewhat similar composition. On the Oriole property in Montbray township two dioritic intrusives have been observed, though their relations have not been determined.

Apparently the same conditions prevail on the property of the Mining Corporation of Canada which adjoins the Noranda property on the north. In April, 1928, the mine was examined by Warren H. Emens for the Mining Corporation, and Mr. Emens kindly forwarded his results, with numerous specimens, to the Geological Survey. In the workings, according to Emens, there are diorite dykes of at least two ages, the later cutting the earlier and chilled against them. The two are very similar in composition, but Emens believes they can be distinguished texturally. The texture of the earlier dykes appears to be that of a gabbro, with the hornblende or augite crystals about as broad as they are long, whereas in the later dykes the hornblendes are thin and needle-like.

On the Waite-Ackerman-Montgomery property, the rocks in the neighbourhood of the shaft are almost all basic dykes and irregular intrusive masses, all of which may be considered as varieties of older gabbro. The detailed description of these will be found in the section dealing with this property. At least three, and possibly four, gabbros have been distinguished in this locality, each of which cuts the earlier ones, exhibiting well-chilled edges at the contacts. They are so much alike, however, that it is impossible to differentiate them in the field, except where contacts are well exposed.

It is evident, therefore, that the quartz diorite, or so-called older gabbro, is of three, or perhaps even more, different ages. The intrusives of the different periods can be distinguished in the exceptional cases where one cuts another, but such distinction is usually impossible because, as a rule, only one type occurs in any one place, and the different types cannot as yet be diagnosed by composition or texture. Eventually some minor textural difference such as Emens reports may prove to be a regional characteristic; but until then the only practicable course is to group these intrusives under one name. So far as known, all are approximately of the same age, that is, all intrude the Keewatin series, and are older than the syenite porphyry and later intrusives.

None of the quartz diorite bodies invading the Keewatin is in contact with the Timiskaming series. In the west, the only area where such contacts might possibly occur, the base of the Timiskaming is hidden by the overlying Cobalt series. Farther east, where the base of the Timiskaming is exposed, no masses of quartz diorite have been found. No quartz diorite is known within the area underlain by Timiskaming series. A small mass of basic intrusive outcropping at the south entrance of Moose bay, Opasatika lake, was at one time believed by the senior author to be a differentiated variety of the quartz diorite, but comparison of specimens of this material with those of basic phases of the granite to the south makes this body seem to be, more probably, a basic variety of the granite.

The quartz diorite exhibits a strong tendency to form sills in the Keewatin series, though many dykes also occur. Particularly is this sill-forming tendency evident in Montbray and Duprat townships, along the crest of the Dufault anticline, presumably because fracturing, in these flat-lying flows, occurred more easily along flow contacts than any other plane. Accordingly, most of the quartz diorite masses in this area have a northerly strike, and dip east at low angles.

There seems to be little doubt that many, if not all, of the quartz diorite masses were intruded after the folding of the Keewatin and Timiskaming series. The large dyke that cuts across the south ends of Dasserat and Arnoux lakes runs in almost a straight line across the axis of the Dasserat syncline, and is not crushed or sheared as if it had suffered folding. It seems necessary to conclude, therefore, that it was injected after the folding. On the Noranda property the lavas are contorted by a large drag-fold, and are intruded by many bodies of quartz diorite. Some of these are more or less parallel to the contorted bedding, others cut across it, but none is rendered schistose or otherwise deformed. The aggregate amount of quartz diorite, also, is much larger within the drag-folded area than outside of it. Although none of these facts is absolute evidence, they point to intrusion occurring after folding rather than before it. Again, the tendency of the quartz diorite, when intruded into flat-lying flows, is to form sills, as is seen in Duprat and Montbray. Had intrusion occurred before folding, therefore, most of the masses should appear as sills infolded with the lavas. Outside of the anticlinal Duprat-Montbray area, however, there are many that cut across the folded structures, instead of being parallel to them.

The quartz diorite is cut by dykes of red syenite porphyry. A large sill of it in Duprat township is cut off at each end by the Flavrian granite, and near the contact fragments of it are broken away to form an intrusive breccia with a granite matrix. It is also cut in many places by dykes of the later gabbro. It is, therefore, the oldest of the intrusives that were injected after the folding.

Granitic and Syenitic Intrusives

A large number of intrusive masses, of granitic to dioritic composition, have been found in the region. Little is known of their age relations, except that all appear to have been formed after the intrusion of the quartz diorite, and before that of the later gabbro. It seems best, therefore, to describe these masses individually, without attempting to group them according to age. In general these rocks fall into two main classes, the syenites and syenite porphyries, and the granites and granodiorites.

SYENITE AND SYENITE PORPHYRY

The syenites and syenite porphyries form, principally, dykes and small masses. In general they are confined to Keewatin areas, and to the northern part of the Timiskaming area. North of Opasatika lake, a block about 12 miles square includes most of the larger masses that occur in the western part of the region. East of this there is a gap about 15 miles across, in which porphyry masses are few and small. A second area in which syenite bodies are fairly numerous begins in the eastern part of Destor and Dufresnoy townships, and extends east about 25 miles, over a width of about 7 miles. Some dykes and small masses have also been found in Dubuisson and Bourlamaque townships.

The western group of syenite porphyry masses, including the Hub Lake syenite, are considered to be closely related. They are, commonly, reddish in colour, very coarsely porphyritic, and rich in soda. The eastern group, to which the name syenites is better applied, are thought to be allied in origin to the granite masses. Some of them are porphyritic in texture, but the phenocrysts are surrounded by a groundmass of granitic texture, so that the rocks are porphyritic syenites rather than syenite porphyries. In addition to these larger masses, there are dykes of grey syenite porphyry and granodiorite porphyry here and there throughout the region. The relationship of these to the reddish syenite porphyries or the syenites is not known.

Hub Lake Syenite

The Hub Lake syenite forms a mass about 1½ miles in diameter, to the south and southwest of Hub lake near the centre of Montbray township. Outcrops are not very numerous.

The rock near the centre of the mass is a rather ordinary variety of syenite of coarse, granitic texture. It consists largely of finely twinned pink albite with a well-developed zonal texture. Smaller quantities of orthoclase and hornblende are present, and a very little quartz. The hornblende is of the ordinary variety with refractive index ranging from 1·640 to 1·655, but associated with it is a bluish, presumably soda-rich, hornblende in small fragments and patches that suggest intergrowth or replacement. The presence of the soda-rich hornblende is considered to indicate a relationship between this mass and the soda-rich porphyries about to be described. In addition to these principal minerals, epidote, titanite, zircon, and apatite occur as accessories.

Here and there throughout the normal syenite patches of more basic rocks are found. These likewise contain pinkish albite, but have a larger proportion of ferromagnesian minerals, and the latter include augite, biotite, and magnetite in addition to hornblende. The augite is colourless, and partly altered to hornblende. The biotite is always in contact with augite. In places compact masses of hornblende crystals are found.

Near the margin of the mass the syenite exhibits well-developed flow textures. Flow movements, occurring apparently when the rock was almost consolidated, gave the feldspar crystals a parallel arrangement, and more or less fractured the hornblendes so that the fragments now fill the spaces between the feldspars.

Aldermac Syenite Porphyry

Aldermac syenite porphyry forms a mass in western Beauchastel township, about 1½ miles in length from north to south, and a mile in width. It has been studied in detail by H. C. Gunning (*See* Bibliography). The body is not a single intrusive, but is composed of a large number of more or less regular dyke-like masses of widely varying though related composition. The different dykes exhibit intrusive relations one to another, the more basic being the earlier, the more acid the later. Contacts, however, are rarely much chilled, and in many cases the relative ages of two dykes in contact are only determinable by the occurrence of flow textures in the margin of the younger. The general impression gained during examination is that the various dykes succeeded one another rather rapidly, so that in many cases the earlier dykes had not cooled completely before they were intruded by those following.

The dykes may be arranged in a series of which each member differs but slightly in composition from the members preceding and following it. For convenience of reference, Gunning has broken this series into four sections, termed the acidic, intermediate, trachytic, and basic types. It must be remembered, however, that this division is an artificial one, and that the most acid members of one section differ little from the most basic members of the next section.

The acid types are small dykes made up, in general, of a rather fine-grained groundmass of quartz and feldspar, with a few shreds of amphibole. The groundmass may or may not enclose feldspar phenocrysts, which, when present, are commonly not more than ¼ inch in length. Phenocrysts are mainly orthoclase and microcline, with albite in some dykes; the feldspar of the groundmass is predominantly albite, with a little orthoclase.

The intermediate types have feldspar in large phenocrysts as their principal constituent. Many of these rocks are very striking in appearance, made up as they are of large brown feldspars, 2 or 3 inches long, packed closely together. Other varieties have smaller feldspars, half an inch in length and upwards. Some of these rocks consist almost wholly of phenocrysts, others have fairly large amounts of a greyish matrix. The mineral composition is approximately 75 per cent or more of feldspar, a very small amount of quartz, and the remainder hornblende and pyroxene.

In some varieties the amount of the latter is small, in others it may amount to 10 or 15 per cent. The phenocrysts of the intermediate types consist almost wholly of orthoclase, microcline, and microperthite. The feldspar of the matrix, on the other hand, is fine-grained albite, which has attacked and partly replaced the feldspar of the phenocrysts. The ferromagnesian minerals include muscovite, green biotite, ægirine, and amphiboles high in soda.

The trachytic types are very similar in appearance to the intermediate, except that the lath-like feldspars are commonly all parallel to one another and to the trend of the dyke, as if the molten rock had flowed just before its final crystallization. In composition they are somewhat more basic than the intermediate types. Feldspar laths an inch or more in length and $\frac{1}{4}$ inch in width form 50 to 75 per cent of the rock, and are set in a matrix of pyroxene, and biotite. Quartz is practically absent. The phenocrysts are orthoclase and microperthite. The amount of albite in the groundmass is small, and limited commonly to a rim of small grains around the phenocrysts. The ferromagnesian minerals are brown biotite and ægirine-augite, with a good deal of apatite and titanite, and some magnetite. Ægirine-augite is more or less altered to a soda-rich hornblende.

The basic types exhibit a rather wide variety. The most basic contain somewhat more than 50 per cent of pyroxene and biotite; and between this and the trachytic type, with 25 per cent of ferromagnesian mineral, there are all variations in composition. The most basic are either non-porphyritic or very slightly so; and in general none of the basic types has the very large feldspar phenocrysts found in the more acid. Many of the basic rocks would not be recognized as members of the porphyry series, except for their content of the peculiar high-soda pyroxenes that characterize the porphyry mass. The most basic variety examined consists of about 50 per cent feldspar, mainly albite with a little orthoclase; a small amount of quartz; augite, apatite, and biotite in grains about 1 mm. in diameter.

This porphyry mass cuts across a large dyke of the older gabbro, and is cut by a dyke of the later gabbro.

Duprat, Twin Lake, and Olier Lake Syenite Porphyries

The Duprat porphyry is a triangular mass about 1 mile long and $\frac{1}{2}$ mile wide at the base, lying about 2 miles west-southwest of the centre of the township. The Twin Lake mass is an oval body of about the same size, just south of Twin lake in the northwestern part of Beauchastel township. The Lake Olier porphyry lies between Olier and Renaud lakes, in southwestern Beauchastel. It is somewhat smaller than the others.

None of these masses has been studied in detail. All are like the Aldermac porphyry mass, in that they are composed of a number of dykes of varying composition, having intrusive relations one to another. All the observed types can be matched with types from the Aldermac mass, although any one of the bodies may not exhibit as many types as are found in the Aldermac mass. All, therefore, appear to have been extruded from the same magma basin, and undoubtedly were formed at about the same time.

Dasserat and Kekeko Syenite Porphyries

On the south shore of Renault bay, Dasserat lake, there is a mass of syenite porphyry about 1¾ miles in length, and somewhat less than ½ mile in its greatest exposed width. A rounded outcrop of rather similar porphyry, about a quarter mile in diameter, intrudes the Timiskaming conglomerates near the north end of Kekeko lake. It is not known whether these porphyries are related to those last described. They are like them in their red colour, coarsely porphyritic texture, and rather sodic composition, but on the other hand, they are masses of uniform composition, not a complex of dykes of varying compositions, and they do not contain the peculiar soda-rich amphiboles and pyroxenes of the Aldermac and similar masses.

Some of the feldspar phenocrysts are reddish, others white, but the reddish predominate and give their colour to the rock. They attain an average length of about 2 mm., though larger occur. They appear to be all albite, $Ab_{90}An_{10}$ to $Ab_{80}An_{20}$. Many of them are badly altered to kaolin. Hornblende phenocrysts up to 1·5 mm. in length are present, though fewer in number than the feldspar phenocrysts. In thin section the hornblende is almost colourless; it is largely altered to chlorite. The total volume of the phenocrysts is about 15 per cent of the rock mass. The groundmass is composed almost entirely of small feldspar crystals, averaging 0·2 mm. in diameter. It is more or less replaced by calcite. Some accessory titanite is present.

Grey Syenite Porphyries

In addition to the syenite porphyries described, which are all of a reddish colour, many dykes of grey syenite porphyry occur, scattered here and there throughout the region. Whether they are magmatically related either to the red syenite porphyries or to each other is not known. It is known, however, that the general term "grey porphyry" includes rocks of quite different ages. Thus in the Dubuisson area there are two "grey porphyries", both rather alike, which were distinguished in that area because they are separated by a period of faulting. Again, on the O'Brien, Thompson-Cadillac, and Graham-Bousquet properties in Cadillac and Bousquet townships there are undoubtedly porphyries of two ages, because one porphyry is sheared by the great fault there and the other is not. The places where such distinction can be made are few, however; and until the country has been examined in much greater detail about all that can be done is to class the "grey porphyries" together.

They are light grey to dark grey rocks, composed of phenocrysts of white feldspar in a dark grey groundmass. For the most part the phenocrysts are small, but instances have been noted in which they attain lengths of about an inch. All the grey porphyries occur as dykes—most of which are of small or medium size, but in some places they attain widths up to 100 feet. The increased size, however, is not accompanied by a corresponding increase in grain. Commonly they are more altered than the red porphyries.

In general, the grey feldspar porphyries appear to contain less potash feldspar and more soda feldspar than the red porphyries. They likewise appear to lack the great variation from quite basic to highly siliceous types that the red porphyries exhibit.

In Dubuisson township the earlier type of grey porphyry has been termed syenite porphyry, to distinguish it from the later, which is known as granodiorite porphyry. The syenite porphyry is a grey rock, with an altered appearance, and is composed of white phenocrysts of albite with a few of orthoclase, in a fine-grained, grey groundmass. The phenocrysts make up 10 to 20 per cent of the rock, vary from 1 to 4 mm. in diameter, and are much altered to kaolin, sericite, and calcite. The groundmass consists of fine-grained albite with 10 to 15 per cent of hornblende and a little biotite. The ferromagnesian minerals are largely altered to chlorite, and in some places the chlorite has been recrystallized to form long needles and laths of actinolite which cut through the phenocrysts and groundmass in all directions.

The granodiorite porphyries are rather fresh-looking grey rocks, containing many medium-sized phenocrysts of feldspar and hornblende in a fine-grained grey groundmass. The feldspar phenocrysts are andesine or oligoclase-andesine (about $Ab_{60}An_{40}$), and may form up to 20 per cent of the rock. The hornblende phenocrysts rarely form more than 1 per cent. In the most siliceous dyke examined, a few phenocrysts of biotite were also found. The groundmass is mainly albite feldspar ($Ab_{90}An_{10}$), with about 5 per cent of hornblende and biotite, and varying amounts of quartz. Most of the dykes examined carried less than 1 per cent of quartz, but one, on the Legault claim, carried about 15 per cent.

The granodiorite porphyries thus carry more silica and lime, and less soda and potash, than the syenite porphyries. A set of faults striking north 75 degrees east is found in this township, and faults with this strike cut and displace the dykes of syenite porphyry, but are themselves cut by the dykes of granodiorite porphyry. This fact suggests that the syenite porphyry is probably the older. Dykes of the granodiorite porphyry cut the larger masses of granodiorite in this district, but the relations of the syenite porphyry dykes to any of the rocks of the region except the lavas are unknown.

On the Thompson-Cadillac property, in Cadillac township, a porphyry occurs within the highly schistose zone of a large east-west fault. The porphyry is not itself sheared, hence was evidently intruded after the faulting. It is white in colour, and composed of phenocrysts of plagioclase up to 2 mm. in length in a fine-grained groundmass of acid plagioclase with a few quartz grains.

Porphyries sheared by the faulting or folding movements are widespread on these and adjoining claims, but are now too schistose and too much altered to carbonate for any satisfactory determination to be made of the original composition.

On the Bathurst claims in Rouyn township a number of grey porphyries intersect the Timiskaming conglomerates and greywackes. The different dykes exhibit rather large variations in composition, and both in this and in the coarseness of their phenocrysts resemble somewhat the red porphyries. They were not studied in detail, but one that was examined consists of numerous white phenocrysts of oligoclase-albite ($Ab_{85}An_{15}$), up to an inch in length, embedded in a dark grey matrix whose grain varies from 0·05 to 0·5 mm. The matrix consists of albite, biotite, and a little quartz and zoisite.

Dykes of grey feldspar porphyry were found by Buffam to cut the Palmarolle granodiorite mass. They are composed of grey tabular phenocrysts of albite and orthoclase, with a few of quartz, in a fine-grained groundmass of feldspar laths. The phenocrysts are badly altered to kaolin, sericite, and epidote. Some patches of chlorite present may represent original amphibole.

In Bourlamaque township there is a rather poorly exposed mass of dark greenish grey porphyry, about 1½ miles in diameter, the centre of which is about a mile southeast of the central point of the township. The rock consists of numerous greenish, earthy crystals of altered feldspar up to ½ inch in length embedded in a fine-grained, greenish grey groundmass. The microscope shows the feldspar to be completely altered to epidote, mainly, with some calcite, chlorite, and white mica. Faint traces of albite twinning remain to indicate that the feldspar was once a plagioclase. The groundmass likewise consists largely of the same alteration products, but quartz, albite, microcline, apatite, and magnetite were identified as probable original constituents.

Clericy Porphyritic Syenites

A body of porphyritic syenite about 2 miles long and 1½ miles wide occurs in the northwest corner of Clericy township, and another, of smaller size, about 2 miles to the northwest, in Destor township. The rocks are mauve or pink, and coarsely porphyritic, with numerous phenocrysts, up to an inch or more in length, of orthoclase, zoned acid plagioclase, and some microperthite. Orthoclase forms about 40 per cent of the rock. The groundmass is coarsely crystalline, with an average grain of about 4 mm. It is made up of feldspar grains, a little quartz and titanite, and a deep green pyroxene. The latter forms 10 to 20 per cent of the rock.

Another mass of porphyritic syenite about a mile in diameter is found just south of the middle of the north boundary of Clericy township, and three smaller bodies occur in the northeast quarter of the township, and extend a short distance into Aiguebelle. Another small body is in Manneville township, just northeast of Cascade rapid. They are pinkish rocks containing pink feldspar phenocrysts ¼ inch or more in length. Otherwise the composition is similar to that of the rocks described in the previous paragraph.

A somewhat similar, but more basic, rock outcrops about a mile south of Clayhill portage, Kinojevis river. It consists of phenocrysts of orthoclase, zoned plagioclase, and microperthite, up to ¼ inch in length, embedded in a dark groundmass of which augite is the chief constituent. The augite forms about half the rock. It is colourless under the microscope, and is partly altered to greenish hornblende. Titanite, apatite, zircon, and biotite are accessory.

La Pause Syenites

In La Pause township there are three small masses of syenite, arranged approximately on a line running north-northwest from La Pause lake. A fourth body of similar composition occurs on the centre line of Bousquet township about 1¾ miles from the north boundary. The rocks have the general appearance of quartz-augite syenites, but, owing to the presence of a considerable amount of calcic feldspar with the acid plagioclase and microcline, are augite-quartz monzonites. The rock is pink, with a grain up to 4 mm. Ferromagnesian minerals compose 20 per cent to 30 per cent of the rock, the remainder being feldspar and a little quartz. The larger feldspar crystals show a tendency to idiomorphism and have zonal structures. Their centres are reddish brown and are surrounded by a lighter zone and this by one almost white. Under the microscope the central zone is seen to be much altered to calcite. It was probably originally basic plagioclase. Microcline is interstitial to the plagioclase individuals. Stumpy crystals of augite are also interstitial to the feldspar. The augite is partly altered to green hornblende and chlorite. Grains of glassy quartz are sparingly present. Small grains of white mica and calcite have apparently developed as alteration products of the plagioclase. Magnetite and epidote are present as accessories.

Preissac Syenites

In the northwestern corner of Preissac township a few small bodies of porphyritic syenite intrude the metamorphosed sediments. They are petrographically similar to the small masses, already described, in the northeastern part of Clericy township.

GRANITES AND GRANODIORITES

Granite and granodiorite form by far the largest masses of intrusive in the region. The southern border is underlain throughout a great part of its length by granite, which is merely the edge of an immense mass that stretches indefinitely south and east. Another great mass underlies most of Preissac, La Motte, La Corne, and Varsan townships; and smaller bodies of all sizes are numerous.

In the following pages the attempt has been made to subdivide these intrusives into granites and granodiorites. The attempted subdivision is not wholly satisfactory, partly because the speed at which the field work had to be carried forward forbade any very detailed study of the bodies, and partly because many rock specimens taken for examination proved too badly altered for satisfactory determination even when great care had been exercised in selecting them. It is felt, however, that real differences in petrography and perhaps also in age exist between the granites and the granodiorites, so that something is gained by the attempt at classification even though subsequent workers in the region may fail to agree with the writers on the correctness of the classification of a given mass.

One of the more prominent differences between the granites and granodiorites is found in the relative proportions of pegmatite to which each gives rise. Pegmatite dykes, grading in composition from siliceous granite to almost pure quartz, are very numerous in and near the granites. The detailed mapping of the St. Maurice claims, Preissac township, showed more than 16,000 linear feet of these pegmatite veins in less than a square mile, some of the veins as much as 16 feet wide. Again, large areas within the great southern mass of granite are underlain entirely by coarse pegmatite. The granodiorites display no such wealth of pegmatite. On the contrary, pegmatite dykes in them are so small and so widely scattered that they may almost be said to be lacking. This difference must imply an original difference in the composition of the magmas. The granite magmas would seem to have contained a much larger proportion of water and other volatile constituents by which quartz and other materials were held in solution after the body of the rock had crystallized.

Another petrographic difference is found in the extent of alteration. The granodiorites are so much altered that little of the original feldspar remains; and this is true not only of specimens taken from the surface, which might be affected by weathering, but also of specimens from deep, newly-opened rock cuts along the Rouyn Mines railway. The granites, on the other hand, have suffered but slight alteration, even in specimens taken close to the surface. The cause of this difference can be only a matter of speculation; but the difference itself appears to be fairly characteristic.

Still a third difference is found in the composition of the feldspars. The feldspar of all the rocks in the so-called granodiorite subdivision is nearly all plagioclase; only rarely can orthoclase or microcline be found in thin section. The plagioclase varies in composition from albite in the more siliceous types to oligoclase $Ab_{75}An_{25}$, in the more basic varieties. The feldspar of the so-called granites, on the other hand, includes much potash feldspar, mainly microcline, with some orthoclase. In certain varieties two-thirds of the feldspar is microcline and orthoclase. On the other hand, the normal granite of the southern batholith carries little or no potash feldspar, but the feldspar is nearly all albite and the rock, in consequence, is indistinguishable from the siliceous varieties of " granodiorite." However, the augite-hornblende syenites, porphyritic syenites, and pegmatites of the southern batholith are rich in potash feldspar. If composition is to be considered a distinction between the two classes, therefore, it must be that of the bodies as a whole rather than that of individual specimens or varieties.

It may be noted that the " granodiorites " are found for the most part in the western end of the region, where also occur the bodies of quartz diorite and the soda-rich syenite porphyries. It is possible that these three rock types are magmatically related to one another, so that this district may form a little " petrographic province."

Granodiorite Subdivision

The Dufault granodiorite mass underlies an area of about 10 square miles bordering the north part of Dufault lake, Dufresnoy township. It is of interest from a petrographic viewpoint, because of its unusual differentiation.

The mass, considered as a whole, is made up of two separate bodies of intrusive rock (*See* Figure 10). The western body extends from the western margin of the mass to the middle of Dufault lake. The eastern body underlies the eastern half of the lake, and extends north half a mile beyond the centre line of Dufresnoy township. The line of separation between the two bodies is approximately marked, on the south, by a long, narrow point of Keewatin rocks, that projects north 22 degrees west for more than

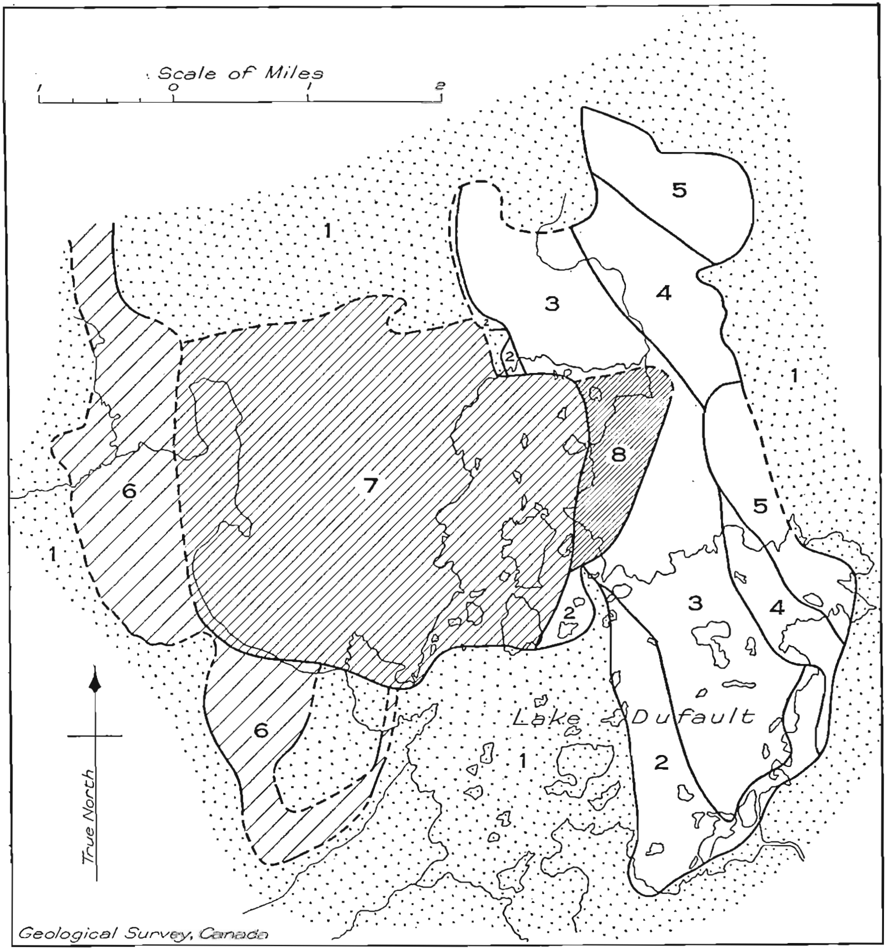

Figure 10. The Dufault granodiorite mass. The western body consists of diorite (6), granite (7), and very siliceous granite (8); the eastern body, of quartz diorite (2), aplitic and feldspathic diorite (3), chloritized graphic granite (4), and granite (5). The surrounding rocks (1), are mainly Keewatin lavas.

half a mile from the main body of the Keewatin; and on the north, on the Newbec claims, by a right-angled point of Keewatin rocks, and a large inclusion of Keewatin, nearly 2,000 feet long, which has been cut off from the point by the intrusives. Between these two points, over a distance of 1½ miles, the two intrusives are in direct contact, and the western has cut into the eastern for at least a mile.

The eastern body is roughly rectangular in shape, 1½ to 1¾ miles wide, and about 5½ miles long. The long axis strikes approximately north 20 degrees west. This body is made up of three distinct varieties of rock, which exhibit a strong tendency to a banded arrangement, the bands parallel to the long axis of the body. The westernmost band (represented on Figure 10 as consisting of two bands) consists of a coarse, feldspathic diorite, made up on the average of about 70 per cent of white feldspar and 30 per cent of hornblende, and with an average grain of 5 to 10 mm. The exact composition of the feldspar is not known, as all the specimens collected were too greatly altered for precise determination. In many places, particularly toward the east side of the band, the feldspathic diorite passes into a white aplite, made up of feldspar, with more or less quartz, and practically no ferromagnesian mineral. One specimen from the railway cut just north of Dufault siding consisted entirely of albite-oligoclase, $Ab_{85}An_{15}$; a second, from isle 16, of nearly pure albite with some 25 per cent of quartz. On the west side, and near all its contacts with the Keewatin, the band of feldspathic diorite becomes more basic, and passes finally into a normal quartz diorite of fine to medium grain. Specimens of this rock are again too altered for determination, but megascopically it is estimated to consist of approximately equal parts of feldspar and hornblende; and the microscope shows that 2 or 3 per cent of quartz is also present. The whole width of the diorite-aplite band varies from ¾ mile to 1¼ miles.

Within the diorite-aplite band, banding on a smaller scale is common, and the strike of the smaller bands is always parallel to that of the main band. The aplite, for example, always occurs as a band or bands within the coarse, feldspathic diorite, and diorite bands carrying varying proportions of feldspar are apt to alternate with one another. In spite of this, however, a progressive general increase in the feldspar content takes place from west to east, so that the rocks on the west, on the whole, are so basic as to approach the composition of a gabbro, whereas those on the east approach or attain that of an aplite.

In many places there is no sharp contact between the more feldspathic and the less feldspathic varieties, but an insensible gradation in composition which indicates either that differentiation of the two occurred in place, or that the older was still hot, possibly even fluid, when the latter was injected beside it. In other places definitely intrusive phenomena were found, indicating that the more feldspathic varieties are later than the less feldspathic and invade them. Thus, on the large island near the south shore of the lake, across which passes the centre line of Dufresnoy township, there is a 2-foot dyke of feldspathic diorite cutting through the more basic diorite, and exhibiting slightly chilled edges. On the east shore of isle 11 there is an intrusive breccia composed of fragments of fine and coarse-grained, basic diorite in a matrix of somewhat more feldspathic diorite. The fragments are sharp-angled, and of all sizes up to a foot or more in diameter. On the west shore of isle 12, only a few hundred feet to the east, there is a similar breccia, but the fragments are about as acid as the matrix on isle 11, and the new matrix is still more feldspathic.

Intermediate in character between the gradational relationships commonly seen, of which an excellent example will be later described, and the somewhat rarer intrusive relationships, may be placed those observed in a railway cut a little beyond the north end of Dufault Lake siding. Here a coarse, white, highly feldspathic diorite contains large, irregular masses, some of which become bands, of dark, coarse-grained, less feldspathic diorite. No sharp boundaries between the basic and the acid varieties are to be found, and the relations suggest, either that the darker masses are basic segregations within the lighter, or that the more feldspathic material was injected into the less feldspathic, and broke it up, while the latter was still hot.

To the east of the diorite-aplite band there occurs a band of chloritized granite or micropegmatite, which varies in width from three-eighths to three-quarters of a mile. The greatest width is at the north end, where that of the diorite-aplite is narrowest; and least at the south end, where the diorite-aplite is widest. The two bands thus form complementary wedges.

In hand specimen the chloritized granite is a dark green rock of very basic appearance. It appears at first sight to consist entirely of chlorite, but on closer inspection is seen to be filled with little crystals of quartz up to 1 mm. in diameter. In some specimens remnants of feldspar are also visible, and, in one place, on the east bay of Dufault lake, the rock grades into very coarse material somewhat like a feldspathic quartz diorite. Thin sections reveal the fact that this rock is the result of an astonishing alteration. The freshest specimens obtained are made up of masses, 3 to 6 mm. in diameter, of graphically intergrown quartz and feldspar. Within each such mass all the quartz exhibits crystal continuity by simultaneous extinction under crossed nicols, and all the feldspar does the same. The feldspar was identified as albite $Ab_{90}An_{10}$ to Ab_{100}. Little or no ferromagnesian mineral appears to have been present, except for a few grains of ilmenite and an occasional grain of apatite. Quartz and feldspar are nearly equal in amount. The rock has thus the composition of a graphic granite.

In other sections the proportion of quartz is much smaller. One showed as little as 2 per cent. All, however, are characterized by the graphic intergrowth of the quartz with part or all of the feldspar.

In the least altered specimens the feldspars are laced with cracks filled with chlorite and some sericite, and a lesser number of these cracks also cut through the quartz crystals. In both quartz and feldspar the veins have irregular replacement edges, and in the feldspars aggregates of chlorite have developed like a fungus in the areas between veinlets. The non-chloritized parts of the albite crystals are spangled with minute grains of sericite or paragonite. In other thin sections various more advanced stages of alteration can be seen, up to the final stage in which all the feldspar is converted into chlorite and sericite, and even the edges of the quartz crystals are attacked. In these sections the only indication of the original composition is the simultaneous extinction of groups of quartz crystals in the chloritic matrix.

This strong chloritic alteration, and the large size of the rock bodies so altered, inevitably calls to mind the widespread alteration to chlorite that accompanies copper deposition in the neighbouring district. Such striking similarities are not common; so that, although proof is lacking, one cannot help but feel that both may have a common cause.

The relations of the chloritized graphic granite to the aplite and diorite appear much the same as those of the more feldspathic diorites to the less feldspathic. They are best seen on the south shore of the east bay of Dufault lake, on a high, rocky point south of island 31, where there are good clean exposures between high and low water-levels. Near the low water-level the rock consists of medium-grained diorite, composed roughly of equal parts of white feldspar and hornblende. This grades upward, within 4 or 5 feet of vertical distance, into much coarser and somewhat more feldspathic diorite, upon which a flat, glaciated platform up to 15 feet in width is developed. A low knob, about 15 feet long, 8 feet wide, and 10 inches high, rises above the general level of this platform, and is composed largely of white, aplitic diorite. The contact between the two is a band about an inch wide, within which the one variety grades into the other. The contact dips north at a very low angle, about 5 degrees.

The aplite is cut, in this place, by a 2-inch dyke of the chloritized granite. The plane of the dyke is almost parallel to that of the diorite-aplite contact; but instead of being perfectly flat, the dyke is slightly bowed downward, so as to make a very shallow bowl. Erosion has cut away all but the bottom of this shallow bowl; so that the outcrop now consists of an oval mass of aplite, lying above the dyke, surrounded by a ribbon of chloritized granite, the edge of the bowl, and outside of this again is the main mass of aplite that lies below the dyke.

About 20 feet away, chloritized granite lies directly in contact with coarse, greenish, feldspathic diorite. The contact, like the previous one, dips about 5 degrees north. The contact is not a very sharp line, but neither does it appear to be gradational. The chloritized granite is quite coarse at the contact, though not so soarse as a few inches farther away. There are no flow textures at the contact.

The relations indicate that the chloritized granite was later than the diorite-aplite rocks, but probably very little later, as there is little chilling and no flow texture in the granite at the contact. The parallelism of the contact with that of the structure within the diorite-aplite mass points to the latter as having had a controlling influence on the later intrusion.

To the east of the band of chloritized granite there lies a more normal type of granite. This does not form a band continuous from north to south, but occurs as two separate masses, one, about $1\frac{1}{2}$ miles long and 1,000 feet wide, toward the south end of the eastern body, the other, about the same length but somewhat wider, at the north end. Between the two the Keewatin to the east is in direct contact with the chloritized granite.

This granite is a normal grey granite of medium to coarse grain, made up of quartz, white feldspar, and badly chloritized hornblende. In no place was it found in contact with the chloritized granite.

A chemical analysis of this granite was made by the writer's assistant, J. F. Henderson, in carrying on thesis work at Queen's University. The analysis is as follows:

	Per cent
SiO_2	70·41
Al_2O_3	15·41
Fe_2O_3	1·01
FeO	2·60
MgO	0·99
CaO	1·29
Na_2O	6·87
K_2O	1·48
CO_2-H_2O	0·97
	101·03

The shape of the eastern body of the intrusive mass appears to be that of a laccolith, dipping toward the east. This is indicated partly by the petrographic changes, and partly by direct determinations. In a flat-lying sill or laccolith differentiated into acid and basic types, the more acid varieties are invariably found at the top, the more basic at the bottom. When such a mass is tilted and eroded, the position of the acid types with respect to the basic indicates the direction of tilting. In this instance diorite lies to the west, followed by aplite to the east, then by chloritized graphic granite. The arrangement, therefore, indicates an eastward dip.

In the east bay of lake Dufault the dip is very flat. This is indicated by direct observations on the diorite-aplite and diorite-granite contacts south of isle 31, which show a northward dip of 5 degrees; and also by the presence, along the same shore, of numerous outcrops of the Keewatin lavas, which presumably represent bits of the roof of the intrusive, the surface of which is undulating. To the west the dip becomes steeper. This is indicated by the banding within the mass, which dips at steeper angles, and also by direct observation of the dip of the base, obtained about 1,000 feet northeast of the Newbec shaft, claim T 1291 (Block 8). Here the base of the sill dips eastward at an angle of 50 degrees.

The sill-like structure at first suggested the view that the whole eastern intrusive body had been a single mass of magma that had differentiated in place. Although this conclusion is still possible, there are some objections to it which are brought out in the following discussion.

The mass of diorite and aplite appears, undoubtedly, to be one that has differentiated in place under the influence of gravity. The uniform occurrence, along the west side of the mass, of the more basic types, and the general increase of feldspar content toward the west, together with the presence of relationships such as were seen south of isle 31, indicate this conclusively. At the same time, the presence of banding, and the intrusive relationships observed here and there between the more and the less feldspathic types, suggest that before consolidation was complete there occurred important disturbances in the mass, which resulted in a partial intermingling of the basic and acid forms, and the injection of the more liquid, feldspathic materials into the solid, or partly solid, basic parts.

It seems likely that the now chloritized graphic granite may have been a true differentiate of the diorite mass. It was, before alteration, still more siliceous than the aplite portion, and its feldspar was more sodic in composition. Some parts of it, those containing less quartz, differ from the aplites only in their graphic textures. The relations observed south of isle 31 suggest that there was no great difference in age. The data at hand, therefore, seem to justify the conclusion that the diorite, aplite, and chloritized graphic granite represent a single body of intrusive magma differentiated since coming into its present position.

The bodies of normal granite lying to the east of the chloritized graphic granite would seem, however, to represent a separate intrusion entirely. It is less siliceous than the graphic granite, and also contains a considerable proportion of original hornblende. It cannot, therefore, be a differentiate of the diorite body, because the differentiates of the diorite become progressively more acid eastward. It is unfortunate that no contacts between the normal granite and the chloritized graphic granite were found; but the manner in which the normal granite swings westward north of the lake, so as to isolate the northern and southern bodies of chloritized graphic granite from each other, suggests that the normal granite is later than the chloritized graphic granite, and has been injected into it.

Tentatively, therefore, the conclusion is here drawn that the eastern part of the Dufault mass is composed of two intrusive bodies, a western and an eastern. The western is a differentiated sill or laccolith, varying in composition from quartz diorite on the west to graphic granite on the east. The eastern is a granite of fairly normal composition and appearance, probably intrusive into the sill. Its shape is not known, although the length and comparative narrowness at the surface suggest that it may also be sill-like.

The western half of the Dufault intrusive is a body about 2½ miles in length from north to south and 3 miles from east to west. It is divisible into a western, dioritic part and an eastern granitic part (represented on Figure 10 as consisting of two parts). The contact between the two is almost completely hidden by a belt of swamp. On claim A 3496, Dufresnoy township, the granite type can be seen intruding the dioritic type; but one outcrop is not sufficient to decide the relations between the two. In the eastern mass, as shown, more feldspathic diorite intrudes the less feldspathic in places, yet the two are undoubtedly differentiates of a single body of magma. The same may be true of the diorite and granite of the western mass.

The diorite body on the west of the granite exhibits the following changes in composition. The rock near the contact with the Keewatin is medium grained and very basic, consisting of about equal parts of greenish hornblende and labradorite feldspar (Ab_{50} An_{50}) with a few grains of quartz and magnetite and occasionally a little pyrite. Rock of this composition, however, forms a band only a few feet wide around the edge of the mass, and the average basic phase is composed of some 25 to 35 per cent hornblende, 55 to 65 per cent feldspar which varies in composition, in different specimens, from Ab_{50} An_{50} to Ab_{75} An_{25}, and quartz varying in amount from a few grains up to perhaps 10 per cent. The texture is granitoid and moderately coarse, 2 to 3 mm. on the average, but very coarse, pegmatitic phases occur here and there, with crystals up to 2 or 3 inches long. The dioritic rock forms a band about three-quarters of a mile wide on the west side of the granite.

To the east of the diorite band there is a body of granite about 2 miles wide. It is a rather ordinary grey granite, varying somewhat in composition from place to place, but averaging perhaps 20 per cent quartz, 10 per cent hornblende, a little magnetite, and the remainder highly altered feldspar which appears to have been largely albite.

On the east, the normal granite passes gradationally into a granite of highly siliceous composition. A typical specimen is composed of about 30 per cent quartz, 1 or 2 per cent chloritized hornblende, and the remainder badly altered albite and oligoclase-albite. It is considered probable that some orthoclase may be present, but none was identified.

An analysis of a specimen of this granite was made by J. F. Henderson in the course of thesis work at Queen's University. The analysis shows less silica than the thin sections indicate as normally present, so that it is possible that the specimen is hardly representative of the average composition.

	Per cent
SiO_2	67·02
Al_2O_3	16·41
Fe_2O_3	0·23
FeO	3·36
MgO	1·06
CaO	4·68
Na_2O	4·02
K_2O	1·79
CO_2-H_2O	2·77
	101·34

In 1926, when the western half of the Dufault intrusive was first studied, the variations in composition suggested that all the rock types had been formed by differentiation in place of a single body of magma. Under this hypothesis the mass would be flat and sill-like with a gentle dip toward the east. Accordingly, contacts were sought on the west side of the mass, from which the dip could be directly observed. Two of these were found. In the northeast corner of M.L. 1890 the Keewatin-diorite contact is exposed for 50 or 60 feet, and dips eastward at an angle of 22 degrees. Again, in the northeast corner of claim A 2746 the dip is even lower, in the neighbourhood of 10 degrees. The sill-like nature of the mass and the flat, easterly dip may, therefore, be considered established, but in view of the complex nature of the eastern half of the Dufault intrusive mass, it is probably better to await further evidence before concluding that the granite and diorite portions were both formed by differentiation of a single magma. Quite possibly they may represent separate injections.

The relations between the eastern and western parts of the Dufault mass are intrusive. The base of the eastern intrusive mass presumably extended at one time in a more or less direct line across the gap between the observed base in the southern part of the lake, and the observed base on the Newbec claims north of the lake. The granite of the western body has broken across this line, and extends east of it more than a mile into the area that would otherwise be occupied by diorite and aplite. In addition, direct evidence of the intrusive relations was obtained on the shore and islands at the southern contact of the granite and diorite. In several places intrusive breccias were found, consisting of numerous fragments of diorite and feldspathic diorite in a matrix of the normal granite.

Thus the Dufault granodiorite mass, according to the evidence, is made up of a series of sills or laccoliths piled one upon the other. The oldest is that which now occupies the centre of the mass, and which has differentiated into diorite, aplite, and graphic granite. At some later date the magma, or magmas, that consolidated into the granite and diorite of the western half were injected. This, or these, differentiated to form various basic and acid diorites, on the west, and a normal and a highly siliceous granite, on the east. The granite invaded the diorite laccolith, and stoped up into it for a considerable distance. At some time during the igneous history, after the intrusion of the central laccolith, the normal granite of the east side of the mass was injected, but its age relations to the western laccolith are unknown. Finally the whole mass was tilted so as to acquire an easterly dip, and warped so that the dip varies from almost flat in some places to 50 degrees in others.

Clericy Granodiorite. The Clericy granodiorite underlies an area about 1 mile wide and 7 miles long, striking about north 30 degrees west. It lies mainly in the southwest corner of Clericy township, but extends some distance into Joanne on the south and Dufresnoy on the west. Like the western part of the Dufault mass, it is made up of both dioritic and granitic rocks. The diorite part forms a band with a maximum width of ½ mile along the western side of the body, extending from the north end of lake Savard southwest for nearly 4 miles. The remainder of the body is for the most part a reddish granite of normal appearance, but toward the south end it becomes white and apparently more siliceous. The greater part of the area underlain by the Clericy mass is heavily covered with drift, so that conditions are not favourable for the study of relationships between the different varieties.

The diorite types are dark rocks of medium grain, without the great variation in composition and grain that marks the Dufault diorites. The resemblance between them and the diorites of the western end of the Dufault mass is, however, reasonably marked. They contain usually some quartz—in places as much as 10 or 15 per cent; 30 to 40 per cent of hornblende, with a little augite, apatite, and titanite; and the remainder a white feldspar too altered for precise determination.

The siliceous varieties are like those found in the granitic part of the western half of the Dufault mass. Quartz forms a large proportion of them—in places 50 to 60 per cent. Feldspar, which constitutes most of the remainder, is mainly albite-oligoclase much altered to sericite, but some microcline is present, and perhaps some orthoclase. The ferromagnesian minerals are totally altered to cloudy masses of epidote, chlorite, and iron oxide.

The granite at the south end of the body is white and highly quartzose, full of quartz phenocrysts 1 mm. or more in diameter. The same material composes a small mass about five-eighths of a mile to the southeast of the end of the main mass.

The granitic varieties are distinctly younger than the dioritic varieties, and intrusive into them in certain places. These relationships may be due, of course, to disturbance during the consolidation of a differentiating magma.

On the whole, there is a very marked resemblance between the diorites and granites of the Clericy mass and those of the western half of the Dufault mass; and it is considered that in all probability the two originated from the same source and were injected about the same time.

Flavrian Granite. The Flavrian mass is, in composition, a highly siliceous granite. It is classed with the granodiorites because of its lack of pegmatitic phases and the alteration of its feldspars. So far as known, no dioritic rocks like those of the Clericy and Dufault granodiorites are associated with this granite mass.

The Flavrian granite underlies an area of about 25 square miles in southern Duprat and northern Beauchastel townships. A smaller mass between it and the railway in northern Beauchastel is considered to be part of the same intrusion. The main body is cut almost in two, in Duprat township, by a band of Keewatin rocks about three-quarters of a mile wide. These are everywhere so highly altered and recrystallized that they were concluded to be merely a very thin remnant of the original roof of the intrusive body; and the presence of such a wide and long remnant suggests that the granite to the north and south has not been eroded much below the original top. A sill-like mass of quartz diorite intrudes the roof-remnant, and dips gently eastward at angles that vary locally from 10 to 30 degrees. It is believed that this probably corresponds to the original structure of the flows, and, if so, it is likely that their flat structure controlled and localized the intrusive, giving it a flat or gently dipping upper surface not far above the present land surface.

The rocks consist of a variety of coarse-textured pink or white granites. A considerable range of specimens was obtained, illustrating the different types observed, but they proved to be rather monotonously alike in composition. The chief difference was in the percentage of quartz, which varies between 25 and 50 per cent. Almost all the remainder is albite, though a little orthoclase was identified in some thin sections. The feldspar is much altered to sericite. A few shreds of dark green biotite, and the chloritized remnants of another ferromagnesian mineral, probably a hornblende, are present in all thin sections.

The Keewatin rocks near the Flavrian mass have been severely altered, both by addition of quartz and feldspar, and by recrystallization. They have been converted, over large areas, into light grey to pure white, finely crystalline rocks, easily mistaken for the granite by anyone who has not traced the alteration through its various stages. The altered rocks always differ from the granite, however, in containing numerous, needle-like crystals of black hornblende, from one-eighth to one-half inch in length.

The Flavrian granite is cut in two or three places by dykes of the later gabbro. It cuts across a sill of quartz diorite just north of Flavrian lake, and a breccia is developed at the contact, of large fragments of quartz diorite in a granite matrix. Relations to the syenite porphyry have not been determined.

Powell Granite. The Powell granite is a mass about 3 miles long and ½ mile to 1 mile wide in the northwest quarter of Rouyn township. It is bounded on the south by the extension of the Horne Creek fault. It is a rather fine-grained, light grey or pinkish rock, with a tendency to porphyritic texture. The one thin section examined showed phenocrysts of quartz and albite up to 2 mm. in diameter, embedded in a finer groundmass of the same minerals. The phenocrysts form about 15 per cent of the rock, and those of albite are about twice as numerous as those of quartz. The total quartz in the section was estimated at 25 per cent, and albite formed the bulk of the remainder, although there were a few grains of chlorite, hematite, and pyrite.

The country rock around the borders of the mass is badly granitized in places, so much so that it is at times difficult to determine where the granite ends and the country rock begins. The alteration is similar to that caused by the Flavrian granite.

Noranda Lake Granite. A band of granite some 300 feet wide is found on the south shore of Noranda lake, Rouyn township, bordering the north side of the band of quartz diorite that runs east through Rouyn village. The granite maintains its position on the north side of the quartz diorite for about 2 miles, then, toward the east end of the townsite, turns slightly and cuts across the quartz diorite band at a small angle. The contact between the granite and the quartz diorite is not a sharply defined line, but rather a rapid gradation, the one rock grading into the other in a distance of 3 or 4 inches. The fact that the granite cuts across the quartz diorite indicates that the quartz diorite must have been injected and solidified before the intrusion of the granite; but the gradational nature of the contact suggests that the granite came in before the quartz diorite was cold, so that a little remelting took place at the contact, allowing a slight mingling of the two rocks.

The granite is light to dark grey in colour, medium-grained (1·5 mm.), and highly siliceous. The percentage of quartz varies locally from 10 to 50 per cent, and most of the remainder of the rock is albite, more or less altered to sericite and calcite. In places part of the feldspar is graphically intergrown with the quartz. Chlorite, probably secondary after hornblende, is the principal ferromagnesian mineral. Commonly only a few shreds of it are visible, but locally the rock may contain 5 or 6 per cent.

Moose Lake Granite. The Moose Lake granite is a mass about 2 miles long and ½ mile wide in the southern part of Hébécourt township. The northern part of the body is not well exposed.

The composition of the rock varies a good deal, and tends to be more basic near the margins. The more acid varieties are pink or light grey rocks of coarse, granitic texture, with an average grain of 3 to 4 mm. They are made up of about 25 per cent of quartz, 70 per cent of albite, $Ab_{95}An_5$, more or less altered to white mica, zoisite, etc., and 5 per cent of chlorite probably secondary after hornblende. The more basic varieties are darker in colour, and differ mainly in their larger content of chlorite.

Nelson Lake Granite. The Nelson Lake granite is a small mass about a mile in diameter on the east side of Nelson lake, in the southeast quarter of Montbray township. It is a light-coloured, very coarse-grained albite granite; containing albite crystals up to 8 mm., and quartz crystals up to 6 mm., in diameter. It is composed of about 30 per cent quartz, some of which shows wavy extinction; 65 per cent albite, $Ab_{95}An_5$, somewhat altered to calcite, epidote, and white mica; and about 5 per cent of chlorite. Magnetite, pyrite, and apatite are accessory.

Labyrinth Lake Granite. A small mass of granite a little more than 1 mile long and less than $\frac{1}{4}$ mile wide occurs on the northeast shore of Labyrinth lake, Dasserat township. It is in contact, on the north, with a large dyke or sill of quartz diorite, and its texture and composition suggest that the two are magmatically related.

The granite is coarse in texture, with an average grain of about 3 mm. It contains 30 to 40 per cent of quartz, some 5 per cent of hornblende in long, narrow crystals, largely altered to chlorite, 2 or 3 per cent of magnetite in large flakes, and the remainder chiefly albite, $Ab_{80}An_{20}$. The albite is much altered to carbonate. The long, narrow hornblende crystals make the texture rather similar to that of the pegmatitic phases of the quartz diorite; and the mineral composition is likewise similar to that of the said pegmatites, only the proportions of the minerals being different.

Palmarolle Granodiorite. The Palmarolle granodiorite underlies an area about 17 miles long and 4 to 12 miles wide, mainly in the townships of Palmarolle and Poularies. Throughout most of this area only scattered outcrops project through the mantle of clay; but there are some strong ridges in southern Poularies on both sides of the Makamik road. The mass is here termed granodiorite rather than granite, because dioritic types appear around its margins, as in the Dufault mass.

The central parts of the intrusive consist of a rather coarse-grained (3-4 mm.), white, or light grey granite of very uniform composition. It contains a large proportion of quartz, and the remainder consists of about equal parts of feldspar and ferromagnesian minerals. The feldspar is badly altered to aggregates of white mica, kaolin, and epidote, but most of the determinable remnants consist of albite-oligoclase. Some microperthite and a very little microcline were also identified. The ferromagnesian minerals include biotite and hornblende, of which the biotite is the more abundant. The biotite is rather badly altered to chlorite, and epidote, with separation of grains of dusty magnetite. The hornblende is also somewhat chloritized, but is much the freshest constituent of the rock. Apatite, zircon, magnetite, and, locally, titanite are accessory.

The dioritic marginal varieties are usually small in quantity, though one area $1\frac{1}{2}$ miles long and $\frac{1}{2}$ mile wide was found in ranges II and III, Palmarolle township, along the north-south centre line. The rock is dark grey, rich in hornblende, and carries patches of very coarsely crystallized hornblende and feldspar. It thus strongly resembles the dioritic types on the west side of the Dufault mass.

The granodiorite is cut by dykes of aphanitic quartz porphyry, feldspar porphyry, later diabase, dunite, and, in the western part, by a complex of "basalt" dykes. The quartz porphyries are composed of small phenocrysts of quartz in a fine-grained, light grey groundmass. They pass, according to Buffam, into the feldspar porphyries, which consist of white, tabular phenocrysts of feldspar and an occasional phenocryst of quartz embedded in a fine-grained, light grey groundmass of feldspar laths. The feldspar is mainly acid plagioclase with a little orthoclase, rather badly altered to sericite, kaolin, and epidote. Some chlorite occurs in the groundmass, probably secondary after hornblende.

A very coarse-grained gabbro or diorite outcrops within the Palmarolle mass on the boundary between Poularies and Royal-Roussillon townships, in lots 19 and 20. It is a dark grey rock of very coarse grain, 8 to 10 mm. On the surface the feldspar weathers out completely, leaving the hornblende in relief. The rock is remarkably fresh. The feldspar appears to be labradorite, and composes about half the rock. The remainder is practically all faintly greenish hornblende, with a few flakes of biotite. The freshness of this rock suggests that it may be one of the basic phases of the Robertson Lake granite, in which case it might afford evidence of the relative ages of the two granites. Unfortunately the contact of the gabbro and Palmarolle granodiorite is drift covered; and the only evidence available is the presence in the gabbro near the contact, of a well-defined flow texture. Such a texture is commonly found at the edge of an igneous mass that has been intruded when somewhat viscous; and its occurrence here, therefore, suggests that the gabbro is later than the Palmarolle granodiorite.

La Sarre and Guyenne Hornblende Syenites. Two bodies of rather basic intrusive occur at the extreme northern edge of the region under discussion, and extend northward beyond it. The La Sarre mass is 8 miles long, measured along the northern boundary of the map-area, and has a maximum width, within the mapped area, of 3 miles. It lies mainly in the townships of La Sarre and Royal-Roussillon. The Guyenne mass underlies an area of about the same size farther to the east, mainly in Languedoc and Guyenne townships. The La Sarre body is fairly well exposed in a series of high, rocky ridges, but exposures of the Guyenne mass are few.

The two intrusives are petrographically so similar that a single description holds for both. They are rather dark rocks, locally faintly gneissic in texture, with an average grain of about 2 mm. Glistening black, euhedral crystals of hornblende can readily be identified on fresh surfaces, scattered thickly through the feldspar, which is usually white. The hornblende is more or less altered to chlorite. The feldspar appears to be plagioclase, varying between albite and oligoclase-andesine, but orthoclase and microcline were also identified. All the feldspar is much altered to carbonate, white mica, and epidote. A little quartz is commonly present, and forms as much as 10 per cent of some specimens. Titanite, magnetite, and apatite are accessory.

The descriptions make it evident that these rocks resemble closely the quartz diorites forming the marginal facies of the Dufault intrusive mass. For this reason these bodies are classed with the granodiorites.

The La Sarre and Guyenne masses are both cut by narrow stringers of granite. Whether it is an entirely separate intrusion, or merely a marginal phase of the granite, which solidified before the more acid material, is not yet known.

La Reine Granite. The La Reine granite underlies an area about 6 miles from east to west in the extreme northwest corner of the region under consideration. It outcrops on the north shore of Abitibi lake, and extends northward into La Reine township beyond the limits of the accompanying map. Small, isolated outcrops of similar rock occur at the narrows between Nepawa island and the mainland in lots 11 and 12, range I, La Sarre township; and on La Sarre river, range X, Palmarolle township.

The rock of the main area is light grey to pink, medium to coarse in grain, and somewhat gneissic in texture. The rock is made up of about 25 per cent of quartz, perhaps 4 per cent of biotite, and the remainder mostly albite or albite-oligoclase, with a little interstitial microcline. Apatite, titanite, and zircon are accessory. The feldspars are badly altered to sericite and kaolin, the biotite to chlorite and epidote. Both the quartz and the feldspars are more or less crushed and granulated, and the quartz exhibits wavy extinction. The gneissic granite is remarkably free from inclusions of country rock, and the latter is not metamorphosed as it usually is near a granite mass. The lava flows near the intrusive strike parallel to the contact, apparently, although but few determinations of strike could be made in this heavily drift-covered district. These facts, it is believed, suggest that the batholith attained its present position by pushing the country rock bodily aside and upward, rather than by the method, more usual in this region, of stoping down blocks of the roof.

The granite is cut by narrow stringers of quartz and by a few pegmatite dykes, which show no evidence of crumpling by movement after consolidation. Near lot line 30-31, about ¼ mile north of the south boundary of range II, La Reine township, the granite is cut by a large dyke of grey feldspar porphyry, striking north 30 degrees east.

What may be a basic phase of this granite is exposed on the west end of Nepawa island. The rock is a hornblende granite, about as much altered as the La Reine granite. It is light pink, medium grained, and massive. Rosiwal analyses of thin sections indicate an average composition of 20 per cent quartz, 3 per cent microcline, 56 per cent albite-oligoclase, 17 per cent hornblende, and 4 per cent biotite, with accessory apatite and zircon. The similarity in composition to the La Reine granite, except for the hornblende, is apparent. The microcline is quite fresh, and evidently replaces, in part, the other partly altered feldspars.

Toward the northwestern end of the island this hornblende granite is in contact with a mica gneiss identical in composition and appearance with the La Reine mass. The contact is hidden by drift, so that the relationships could not be seen. Buffam was inclined to believe, however, that the fresh microcline in the hornblende granite may have seeped in from the mica granite and, therefore, that the mica granite is the younger.

Lake Robertson Granite. Lake Robertson almost bisects a mass of granite which extends across it in a northwesterly direction, with a total length of 9 miles and width of 4½ miles. On the north, south, and west, the mass is bordered by a wide "transition zone" of highly metamorphosed lavas through which are intruded large amounts of igneous rock of intermediate to basic composition. On the earlier maps much or all of this transition zone was mapped as granite.

The granite is light pink to white, rather coarse-grained, and usually porphyritic, with quartz phenocrysts up to an inch in diameter. These phenocrysts are extraordinarily clear, so much so that in polished specimens the minerals beneath half an inch of quartz may be distinguished. The mineral composition averages about 30 per cent quartz, 3 per cent biotite, and the remainder feldspar. The feldspar is nearly all albite-oligoclase, about $Ab_{90}An_{10}$, with a little interstitial microcline. The albite-oligoclase is moderately altered to kaolin, sericite, and epidote, but the microcline is fresh. Hornblende, magnetite, apatite, zircon, and titanite are accessory.

Toward the margins, particularly west of lake Robertson, the acid granite grades imperceptibly into more basic material, in which hornblende appears in amounts that locally equal those of the feldspar and quartz. The hornblende forms small, elongated, glistening black crystals which under the microscope are dark green and pleochroic. Microcline is small in amount or lacking in these marginal varieties.

The rocks of the transition zone around the intrusive are best exposed in lots 6 to 25, range IX, Privat township, and in the northeast corner of Poularies township, range X. They consist of Keewatin lavas invaded in a complex manner by a series of plutonic rocks. The lavas, in places, are intricately brecciated by the invading materials, and great numbers of fragments, more or less perfectly digested, occur in an igneous matrix. The intrusive rocks vary, in an irregular and patchy way, from hornblende syenite to amphibolite. The amphibolite is a very coarse-grained, dark grey rock that weathers with a peculiar pebbly surface. It is typically composed of light green, slightly pleochroic hornblende crystals, with little or no interstitial material. Some of the hornblendes attain lengths of 10 mm. In range X, Poularies township, and in some other places, amphibolite such as described was observed to grade imperceptibly into varieties containing a good deal of feldspar. The gabbro, diorite, hornblende syenite, and other basic rocks of the transition zone resemble each other and the amphibolite, in mineral composition, but differ in the proportions of feldspar each contains. They are so poorly exposed that their relations to one another were not determined. The different varieties occur in about the same proportions throughout the whole area of the transition zone. If they are marginal facies of the granite, as they appear to be, the approximately constant proportions amongst the different varieties must indicate that the granite lies at shallow depths below the whole zone.

The gabbro or diorite body, already described as occurring within the Palmarolle granodiorite mass, strongly resembles some of the basic intrusives of the zone about the Lake Robertson granite.

Bourlamaque Granodiorite. The Bourlamaque granodiorite is a mass about 6 miles in diameter from north to south. It lies chiefly in Bourlamaque township, but also extends north into Senneville and Pascalis, and east into Louvicourt, townships. The western side of the body is obscured by drift, but there are outcrops of petrographically identical granodiorite at the south end of Blouin lake and on the Sullivan claims on the east shore of De Montigny lake, suggesting that a long tongue may project westward from the main body. If this be true, the mass is 13 miles long from east to west. The body is rather poorly exposed, in low outcrops projecting through the lacustrine clays. It is a coarse-grained rock, pink to grey, granitic in texture, and distinguished in most localities by large, opalescent eyes of quartz. It is made up of 20 to 30 per cent quartz, 50 to 70 per cent oligoclase, Ab_{85} An_{15}, the remainder hornblende with a little biotite. The feldspar is much altered to epidote, zoisite, and kaolin, the hornblende to chlorite. Apatite and zircon are accessory.

Siscoe Granodiorite. The north part of Siscoe island, De Montigny lake, is occupied by a basic granodiorite or quartz diorite, that resembles the Bourlamaque granodiorite in containing eyes of opalescent quartz, though otherwise it is much darker and more basic. The mass may be continuous, beneath the lake, with that on the east shore. The grain varies from fine to very coarse. The original minerals appear to have been albite-oligoclase, hornblende, some biotite, and the opalescent quartz, but the rock now is very thoroughly altered to mixtures of epidote, carbonate, and chlorite. It is considered to be, probably, a basic marginal variety of the Bourlamaque granodiorite.

Unison Granodiorite. Two outcrops of quartz diorite in a heavily drift-covered area, one at the Unison mine, Dubuisson township, the other 1,200 feet southeast of the first, may indicate the existence of a small body. The rock is essentially identical with the Siscoe granodiorite.

Figuery Granodiorite. On the south shore of Figuery lake, Figuery township, is a body of granodiorite whose exposed length is somewhat less than a mile, and whose width is less than one-quarter mile. To the east, within a distance of 3 miles, are two outcrops of similar rock. The granodiorite is pink or reddish, rather coarse grained (3 mm.), and in places is sheared in an east-west direction, parallel to its strike. It is made up of a little quartz, about 20 per cent of chlorite probably secondary after hornblende, and feldspar, with accessory ilmenite and zircon. The feldspar, which is rather badly altered to white mica, is andesine, Ab_{65} An_{35}, with an unusually low index of refraction, which suggests that it probably contains a considerable percentage of dissolved potash. Quartz may form, locally, a fairly high percentage of the rock.

Malartic Granodiorite. A peculiar porphyritic granite outcrops on the points and islands along the south shore of La Motte lake, Malartic township, over a distance of about 5 miles. Though equigranular in places, it is commonly porphyritic, with phenocrysts of quartz and feldspar in a blackish or dark green groundmass. The rock is rather badly altered and is locally strongly sheared. The alteration and the shearing suggest that it is to be correlated with the granodiorite rather than with the granites; or it may well be even older than the granodiorites.

Normally the phenocrysts form about half the rock. To the east both quartz and feldspar phenocrysts occur, the feldspars predominating. Toward the west the quartz phenocrysts become fewer, until finally only feldspar laths remain. The quartz phenocrysts are 2 to 4 mm. long, and usually opalescent. Though some exhibit a normal crystal outline, the majority are rounded. The feldspar phenocrysts are larger, varying from 2 to 8 mm. in length, and are usually well crystallized. They are an acid plagioclase, much altered. Phenocrysts of hornblende much altered to chlorite are common, and biotite was seen in some specimens.

The groundmass is dark green on glaciated surfaces, so that the feldspar crystals and the bluish quartz phenocrysts show prominently against it. On freshly broken surfaces the groundmass is nearly black or dark greyish green. The grain does not exceed 0·5 mm. The ground is largely quartz and feldspar, but with a good deal of chlorite, epidote, carbonate, and limonite. What ferromagnesian minerals may have once been present are now entirely gone over to chlorite. On the northern shore of the large island in the southern bay of La Motte lake this rock is strongly sheared and largely altered to carbonate containing stringers of pyrite. Some prospecting has been done on the shear zone.

Fiedmont Granodiorite. In ranges I, II, and III, Courville township, three outcrops of granodiorite project through the clays, and may possibly be parts of a single continuous mass, with a possible diameter of 2½ miles. The rock is medium-grained (1 to 2 mm.), light grey or pinkish, and rather badly altered. It is composed of some 20 per cent of quartz, about the same amount of biotite, and the rest feldspar, Ab_{85} An_{15}, with accessory apatite and zircon. The feldspar is largely converted to a mat of white mica, and zoisite.

Granite Subdivision

Southern Zone. The southern border of the region is underlain throughout a great part of its length by granitic intrusives, which constitute merely the northern margin of an immense granite mass stretching away to the south and east. The average width of the granite zone within the area mapped is about 4 miles, but in places it increases to 8 or 10 miles. In addition, numerous small bodies of granite allied to the larger mass in composition pierce the Timiskaming greywackes north of the main granite body. These tend, on the whole, to become fewer and smaller northwards, and as it is probable that they are upward extensions of a single, large, underlying batholith, their arrangement suggests that the upper surface of the batholith dips steeply northward.

The granite intrudes the Timiskaming series in a most complex manner, sending long tongues into it, and filling irregular embayments. Blocks of greywacke from a few inches to several miles in diameter are entirely cut off and surrounded by the granite, and may be found within the granite area 10 miles or more south of the boundary of this map. In particular, granite very readily entered along the planes of bedding or schistosity, thus splitting off great plates of greywacke close to the main contact, and forming numerous sill-like dykes farther to the north.

The profound metamorphic effect of the granite on the greywacke has already been mentioned in the description of the Timiskaming series. The effect of the greywacke on the granite has likewise been very great. Fragments of greywacke floating in the granite exhibit all stages of melting and digestion. In some of them the edges and corners are still sharp and unaffected; others show more or less melting of these parts; still others are more extremely affected, until all that remains of an original mass of greywacke is a vaguely outlined, dark patch of granite more basic than that which surrounds it. Considerable masses of greywacke must thus have been digested by the intrusive, and the intermixture may have given rise to some of the basic marginal varieties about to be described.

The granites thus present every evidence of having advanced into their present position by stoping down blocks of the roof, which either sank in the liquid magma or were digested by it. There is little or no evidence that they advanced by forcing the roof rocks bodily aside and upward, for the irregular boundary of the intrusive cuts across the bedding of the sediments at all angles, and without inducing in the sediments any schistosity parallel to the contact.

Four main petrographic types have been found in the granite mass, normal granite, pegmatite, porphyritic syenite, and augite syenite. No evidence was obtained suggesting that there is any important difference in the age of these varieties.

Normal granite is far in excess of the other varieties in amount. It is light grey or pinkish, of medium to coarse grain, and commonly equigranular, though in places somewhat porphyritic. The composition varies considerably. Some specimens carry as little as 5 per cent of quartz, others up to 40 per cent. The ferromagnesian mineral is commonly biotite with or without some muscovite, but in places hornblende takes the place of biotite partly or completely. Although the ferromagnesian minerals rarely constitute more than 10 per cent of the rock, and commonly not more than 1 or 2 per cent, in some basic types they amount to 20 per cent. The remainder of the rock is mainly albite and albite-oligoclase, with or without a little orthoclase and microcline. Graphic intergrowths of quartz and feldspar are moderately common. Epidote, titanite, zircon, apatite, and garnet are accessory.

Porphyritic syenite forms a number of masses in Bellecombe, Vaudray, Surimau, and Fournière townships. The largest mass is 5 to 6 miles in diameter. The rock is essentially a syenite in which most of the feldspar crystals are idiomorphic and of considerable size. Many of them attain diameters of half an inch, though commonly they are somewhat smaller.

Microcline composes, roughly, about 40 per cent of the rock, oligoclase-albite another 40 per cent, and hornblende the remainder. Perthitic intergrowths of the feldspars are common. The hornblende crystals are usually small, and interstitial to the feldspars, but locally attain about the same size. Quartz, biotite, apatite, and zircon are accessory.

Augite syenite is confined mainly to Montanier and Bousquet townships, though some small bosses occur in Surimau and Fournière townships. The largest mass is a little more than 3 miles in diameter. The rock has a very striking appearance, as it is made up of black or very dark green augite and hornblende in a matrix of pink feldspar. The grain is coarse, averaging 4 mm., and the texture equigranular or slightly porphyritic. Augite composes about 30 per cent of the rock; it forms stumpy, idiomorphic crystals, and is partly or completely altered to hornblende. The chief remaining constituent is a mixture of microcline and albite or albite-oligoclase in varying proportions, with, probably, a little orthoclase. In some thin sections microcline forms half to two-thirds of the total feldspar, in others the amount of microcline is small. Quartz varies from a few grains to 5 per cent, and epidote, titanite, apatite, and biotite are accessory.

Pegmatite forms dykes and large masses within the granite area. In Montanier and Surimau townships the bulk of the granite is pegmatitic, and locally large areas are underlain by coarse pegmatite. One such area is just west of Lemoine lake. The pegmatite is characterized by very large crystals of quartz and feldspar, up to 6 or 8 inches in length. The feldspar is chiefly orthoclase. A good deal of white mica is also present, in crystals up to 2 inches in diameter. Dykes of fine-grained aplite are also rather numerous in places. They are principally composed of albite, with more or less quartz and orthoclase, and a little hornblende.

La Motte-La Corne Granite. The La Motte-La Corne intrusive underlies an area some 33 miles long and 10 to 12 miles wide, chiefly in Preissac, La Motte, and La Corne townships. West of it there are some small granite bodies in La Pause township which are probably offshoots of the main mass. To the east, in Fiedmont, Courville, and Pascalis townships, there are some large, poorly exposed masses which may also be offshoots of the same underlying body.

The La Motte-La Corne intrusive exhibits the same range of rock types as the great southern batholith, namely, granite, pegmatite, augite syenite, and porphyritic syenite, and also some still more basic, which are hereafter termed amphibolite. Granite and pegmatite underlie the greater part of Preissac and La Motte townships, and also occur in western La Corne township extending almost completely across the township from north to south, and about 4 miles from east to west. The areas between these two granite belts, and east and southeast of the last-mentioned body, are underlain chiefly by the augite-hornblende syenites, with minor quantities of amphibolite.

The granite facies is commonly very siliceous, and over large areas pegmatitic. It is white or light grey, medium to coarse-grained, and equigranular as a rule, though in places porphyritic. Quartz and feldspar make up the bulk of the rock, and biotite is the usual ferromagnesian mineral. Locally, however, hornblende or white mica take the place of the biotite. Garnet, epidote, and titanite are accessory. The mineral proportions, as estimated in thin section, are, roughly, quartz 40 per cent, feldspar 50 per cent, other constituents 10 per cent or less. In some sections nearly all the feldspar is orthoclase or microcline, with only a little albite-oligoclase; in others the chief feldspar is oligoclase, with only scattered patches of orthoclase. Intergrowths of quartz and acid plagioclase lie between grains of albite and microcline, and fill embayments in microcline. The granite is usually quite fresh. Slight alteration of the plagioclases has occurred, generally along the twinning planes.

In the vicinity of the augite syenite bodies, the normal granite passes into hornblende granite by substitution of hornblende for biotite, then grades, by gradual diminution of the quartz content, into a syenite rich in hornblende and augite. The syenite is essentially similar to that in the southern zone. It is thought, however, that some of the hornblende may be original and not secondary after augite as in the southern zone.

The following chemical analyses made by William Gerrie[1] of normal granite and hornblende syenite from La Corne township illustrate the composition of these rocks:

—	(a)	(b)	(c)	(d)	(e)
SiO_2	69·10	69·00	69·15	67·30	58·30
Al_2O_3	17·90	17·35	16·10	15·95	17·65
Fe_2O_3	0·72	1·23	1·30	1·75	2·00
FeO	1·38	1·22	1·50	1·30	3·98
CaO	3·44	3·40	2·95	3·68	6·24
MgO	1·14	0·75	1·18	0·70	3·60
Na_2O	1·16	1·33	1·88	2·88	3·22
K_2O	5·00	5·48	5·10	4·08	4·54
	99·84	99·81	99·16	97·64	99·53

(a) Granite from small sill on range I, lot 1, La Corne township.
(b) Granite from small mass, range I, lot 2, La Corne township.
(c) Granite from range X, lot 64, northeast corner of Malartic township.
(d) Granite from range II, lot 11, La Corne township.
(e) Hornblende syenite from range III, lot 44, La Corne township.

Dykes of pegmatite, aplite, and high temperature quartz are very numerous within the granite areas, and in the older rocks near granite contacts. They are locally of economic importance for their content of molybdenite and bismuthinite. Other minerals present in small amounts are muscovite, allanite, epidote, titanite, apatite, and zircon. Their general composition is like that of the pegmatites of the southern zone.

Masses of amphibolite are found in range IV, lots 40 to 44, La Motte township; on the boundary between La Motte and La Corne townships, in ranges VI and VII; and throughout an area about 6 miles in diameter southeast and southwest of Fiedmont lake. The rock is composed almost

[1] Gerrie, W.: "Molybdenite in La Corne and Malartic Townships, Que."; University of Toronto Studies, Geol. Ser., No. 24, p. 38.

entirely of large crystals of hornblende up to an inch in diameter, with a little interstitial quartz and feldspar. Some varieties contain more feldspar, and might properly be classed as basic varieties of the augite syenite, thus suggesting that the amphibolite is merely a basic differentiate of the augite syenite.

Age of the Granites

The granites were intruded after the post-Timiskaming folding, for bodies of granite varying in width from a few inches to several miles cut across the schistosity of the Timiskaming greywackes, and these bodies, whether large or small, are not fractured, crumpled, or rendered schistose. Small dykes, from a fraction of an inch in width upward, intrude the greywacke along the planes of schistosity and bedding, but have not been rendered schistose, as they surely would have been had they been intruded before the intense folding of the greywackes.

The relations of the granite to the red syenite porphyry are not known.

The granite is cut by some dunites, by the later gabbro, and by basaltic gabbro. It is overlain with great unconformity by the Cobalt series, and furnishes numerous pebbles to the basal conglomerate.

The granite was, therefore, one of the first rocks to be intruded after the post-Timiskaming folding. It is probable that the rise of the granite magma followed closely the processes of folding and uplift.

The granite and syenite pebbles in the Timiskaming conglomerates indicate that, in addition to the post-Timiskaming granites, bodies of pre-Timiskaming granite also exist. Some of the granites and allied intrusives described may, therefore, be pre-Timiskaming in age; but no data have been obtained whereby these, if they exist, are to be distinguished from the later granites.

Altered Peridotites

The following paragraphs describe a number of small rock masses which are all very basic in composition, but whose affinities and age relationships are imperfectly known. Some of the bodies may be basic, altered Keewatin flows; others are known to be dykes and to cut the Timiskaming series or the later intrusives. The grouping into one section, therefore, indicates only that they have a certain petrographic resemblance to one another, and does not imply that they are all of the same age or have any genetic relationship to one another. Some of the so-called peridotites are probably closely related to the quartz diorite or " older gabbro."

Most of these rocks are now highly altered. They fall into two main classes: (*a*) serpentine rocks, probably resulting from the alteration of rocks high in olivine; and (*b*) hornblende-chlorite-carbonate rocks, which are probably the alteration products of rocks high in augite or hornblende.

The typical serpentines are readily distinguished in the outcrop by their form of weathering. Although very dark green on fresh surfaces, they weather to a colour between white and light reddish brown. The weathered surface tends to be well-rounded and smooth, and has a peculiar soapy feel that is quite characteristic. The bodies are commonly cut by narrow veinlets of asbestos that weather silvery white. These have never been found, as yet, in sufficient quantity to be of commercial importance. The asbestos is usually of the flexible variety, but the brittle or non-flexible kind is also common. Slip fibre is locally found along planes of movement.

The hornblende-chlorite-carbonate rocks are lighter coloured than the serpentines, less massive, and less soapy in feel. Locally they may have a schistose appearance, due to parallel orientation of the chlorite and hornblende crystals.

Most of the known occurrences of peridotite occur in La Motte and Dubuisson map-areas, within a zone 5 to 10 miles wide and 50 miles long, which trends east through the central parts of Preissac and western La Motte townships, then swings southeast through eastern La Motte, northeastern Malartic, enters Varsan township and continues through the southeastern corner of Varsan and through Bourlamaque into Louvicourt. The principal occurrences lie within a zone a mile or more wide, which begins at the north end of Chassignolle lake, in Preissac township, skirts the northern shore of lake Kewagama, and trends southeasterly through La Motte township, widening on the eastern shore of La Motte lake (Malartic township) at the entrance of Harricanaw river. Three miles southeast of this point an outcrop of the rock is found on Harricanaw river, and others on the north shore, islands, and southeast shore of De Montigny lake.

Outside the general zone three dykes of peridotite are known, one on the southeast shore of Lemoine lake, one in the northeast corner of Senneville township, and one in northwestern La Corne township.

From the northwestern quarter of the region, Buffam has described three intrusive masses of dunite, and some serpentinized basic flows. One mass of dunite forms a small, isolated outcrop in range I, lot 29, Roquemaure township. The second mass is in Poularies township, range II, lots 37 to 40; it is a dyke-like mass 600 feet wide, and has been traced for 3,500 feet along the strike, north 20 degrees west. The third mass occurs in Destor township, 1½ miles east of the centre, on range line V-VI. It strikes nearly east, is 650 feet wide, and has been traced for half a mile. In addition to these, there are some small, scattered masses in Duparquet and Clericy map-areas.

POULARIES PERIDOTITE

The dyke-like body of peridotite in Poularies township, mentioned above, cuts the Palmarolle granodiorite, and its contacts with the granodiorite are sharp. The body of the rock consists almost wholly of serpentine, which appears to have been formed by alteration of olivine, since the serpentine retains the outlines of the former olivine crystals, and the mesh structure of the serpentine is characteristic of that derived from olivine. Rather numerous grains of light green spinel are also present, interstitial to the former olivine crystals. They are partly altered to a colourless or pale yellow, non-pleochroic mineral that is probably hydromagnesite. A few grains of chlorite, brown biotite, and magnetite, and some minute square or hexagonal crystals of unknown nature, constitute the remainder of the rock. In one thin section a small crystal of basic plagioclase was observed.

Close to its margins the peridotite differs notably from the composition described. At the southern contact with the granite it is light grey, massive, and medium-grained, with a granitic texture. In hand specimen it appears to consist wholly of hornblende crystals up to 3 mm. in diameter, but under the microscope a little highly altered feldspar is seen between the hornblende crystals. The latter are nearly all actinolite, ragged and irregular, but there are also a few crystals of a light reddish-brown amphibole, which are penetrated in many places by feldspar laths, giving an ophitic texture. The brown amphibole, which appears to be katophorite, tends to be bleached around the edges of the crystals, and to fade into colourless amphibole with the same optical orientation.

Within 2½ feet of this contact the above rock rapidly grades into one composed of augite crystals up to 6 mm. in diameter, embedded in a dense greenish matrix. The rock is composed largely of diopside, with about the same amount as before of brown amphibole; the actinolite and feldspar of the marginal facies have entirely disappeared. The remainder consists of zoisite, epidote, chlorite, and serpentine.

Four feet from the southern contact, hand specimens closely resemble the main body of the rock; they are greyish-black, and contain no crystals that can be identified with the naked eye. The microscope shows that its composition is intermediate between the normal serpentinized peridotite and the variety last described. Diopside is still abundant, but there is much more serpentine and chlorite present. Brown amphibole has disappeared.

At the northern contact the peridotite is finer grained than at the southern, and carries numerous inclusions of the granodiorite. The western end of the peridotite mass is cut by a dyke of later gabbro.

DESTOR PERIDOTITE

The large body of peridotite in Destor township is similar to that in Poularies township. It consists almost wholly of serpentine with a little augite. As in the Poularies body, the serpentine appears to be secondary after olivine, and the augite crystals are interstitial to the former olivines. The augite is remarkably fresh.

Three other small masses of serpentine rock occur in Destor township, two in the north part of range VI, 1 and 2 miles respectively from the centre line, the third in range IV, astride the Makamik road. They resemble closely the rocks just described. Buffam is inclined to believe that they are basic, serpentinized Keewatin lavas rather than intrusives.

DUPARQUET PERIDOTITE

In Duparquet map-area there are a few dyke-like bodies of peridotite, much metamorphosed and now forming narrow bands of schist in the volcanics. On a peninsula in the south part of Duparquet lake such bands are about 50 feet wide, and strike east to north 70 degrees east, paralleling the general strike of the lavas. In this locality, the most striking type is coarsely crystalline, almost black, and consists of large, shining crystals of amphibole embedded in a greenish matrix. The microscope shows the amphibole to be uralite, secondary after augite, and the groundmass as probably serpentine, although the refractive index is rather high for serpentine, 1·58 to 1·60. A little pyrite is also present in irregular aggregates. Other varieties are much lighter in colour, more schistose, and less coarsely crystalline. They carry numerous crystals of diallage only partly altered to uralite, in a matrix of serpentine.

CLERICY PERIDOTITE

A very few outcrops of peridotite have been found in Clericy map-area. One occurs on Kinojevis river below Cascade rapids, in lot 13, range I, Manneville township. They appear to be altered dykes cutting the Keewatin lavas. They consist for the most part of chlorite and serpentine, though in some varieties crystals of augite and hornblende are also present.

EASTERN PERIDOTITE

The peridotites of the 50-mile zone in La Motte and Dubuisson map-areas are of many different kinds and variously altered, but all exhibit a certain general similarity. They are generally green, varying from light to very dark, and all except the less altered are easily scratched. Some are much sheared. The rocks vary from coarse-grained types in which the individual constituents are visible, to very fine-grained varieties. Large flakes of mica appear in some of the coarser grained.

One peridotite from the vicinity of the St. Maurice mine, Preissac township, seems to be composed chiefly of talc and fine fibrous serpentine, with a little black iron ore. In others the principal mineral seems to be a pale pleochroic hornblende with talc and serpentine. Less altered varieties, made up principally of olivine, augite, and hornblende, also occur. Black iron ore is a prominent accessory in almost every rock, and locally brown mica is important. Carbonates are nearly always present, and form a large proportion of some of the rocks.

Later Gabbro

The term "later gabbro" has been applied to a large number of gabbro dykes younger than the Timiskaming sediments. The rock is called gabbro rather than diabase because, although the texture is generally ophitic, in some instances it is not markedly so. Diabase is here considered as merely a textural variety of gabbro. Dykes of later gabbro are widespread, and have been found in every township mapped. In many parts where outcrops are scanty, it has proved impossible to trace the dykes for any great distance, but where exposures are better many of the dykes have proved to be very long. A dyke crossing Opasatika lake, for instance, has been traced for about 50 miles into Manneville township, and may extend 50 miles farther, for outcrops in Trécesson township, about 3 miles west of La Ferme, and other outcrops a mile west of Obalski lake, lie approximately on the same strike. Two dykes cross the narrows between La Motte and Okikeska lakes, and have been followed for about 30 miles southwest, into Montanier township; in the opposite direction, one of them apparently extends for 20 miles into Barraute township. In Montbray and Beauchastel townships a dyke has been followed for nearly 30 miles.

The occurrence of dykes so long, so straight, and so constant in width is interesting, more particularly as there is a pronounced parallelism between them over wide areas. They fall naturally into two sets, one set, which includes the greater number of dykes, striking about north 50 to 60 degrees east, the other about north to north 20 degrees west. These characteristics imply that the dyke fissures were formed by general regional stresses, probably quite gentle, as they merely opened the dyke fissures without causing any notable amount of faulting along them.

The later gabbro dykes comprise both olivine and quartz gabbros. Quartz gabbro is the more common, and forms most of the smaller dykes. Olivine seems to occur more commonly in the larger dykes.

In hand specimen it is difficult to discriminate between the two varieties. Both are composed chiefly of augite and plagioclase and neither the quartz nor the olivine is conspicuous. Both, at the contacts, are dense, black rocks which in some instances display tiny phenocrysts of feldspar. This fine-grained rock within a short distance of the contact passes into a coarsely crystalline phase in which the crystals of augite and plagioclase may be readily distinguished. In the weathered phases, the olivine gabbro has a slightly more rusty appearance than the quartz gabbro, probably as a result of the weathering of the olivine.

The quartz gabbro is of variable grain, but in the coarser phases with crystals about one-quarter inch in diameter. It is mottled grey and black, the black colour being due to the augite crystals. The grey feldspar crystals have in many cases a greenish cast, due to alteration. A black, flecked appearance is given by occasional flakes of biotite. The ophitic texture is more obvious in specimens of medium grain and not at all apparent in the extremely coarse phases. Microscopic examination shows that in some sections the augite is considerably altered to green hornblende. With some of this hornblende, brown biotite is in parallel intergrowth. The plagioclase is almost always twinned and fairly basic in composition, approximating labradorite ($Ab_{50}An_{50}$). It shows ophitic relationships to the augite and is in lath-shaped crystals. Quartz is present in micrographic intergrowth with the feldspar and in vermicular as well as in irregular-shaped grains. It is apparent that this quartz is much later in crystallization than the other minerals. Magnetite, probably titaniferous, apatite, epidote, and zoisite are accessory minerals. The finer phases of this rock appear very much like fine volcanics. They are composed of a mat of fine feldspar crystals which jut into small augite crystals and are of quite even grain, except for a few larger crystals of feldspar.

The olivine gabbro attains a coarser grain than the quartz variety and on the weathered surface tends to have a more rusty appearance, but as mentioned above is otherwise similar in appearance. The feldspar is basic in composition, in one section being determined as basic andesine (Ab_{55} An_{45}). It probably is more basic locally. Olivine forms large grains, much altered and carrying in the cleavage cracks considerable quantities of grains of black iron ore. The olivine and the plagioclase crystallized prior to the augite, whose outlines are adapted to these older crystals. Some brown biotite which encloses apatite crystals and grains of black iron ore is also present in small amount. The augite is almost colourless, but with the faint purplish tinge said to indicate titanium. It is somewhat altered to green hornblende.

The age relations of the later gabbro are not very satisfactorily determined, because throughout the greater part of the region it is the youngest existing rock. Only in the southwest corner of the region, where the Cobalt series appears, can it be determined whether the later gabbro is pre-Huronian or post-Huronian.

In the adjoining Ontario region there are dykes petrographically identical with the later gabbro, of two widely different ages. The later is the Nipissing diabase, which intrudes the Cobalt series and is generally considered of Keweenawan age. The earlier were first recognized in Matachewan district. They form part of the basement on which the Cobalt series rests, and furnish boulders to the basal conglomerate of that series. The dykes classified as later gabbro in the Quebec region may include intrusives of both ages.

Some of the Quebec dykes exhibit a texture found only in some of the pre-Cobalt dykes at Matachewan. They contain numerous large phenocrysts, up to 2 or 3 inches in diameter, originally of labradorite feldspar, but now thoroughly altered to kaolin and sericite, so that they have a waxy appearance. These phenocrysts lack good crystal boundaries, and usually are rather irregular lumps. Phenocrysts such as these have, as yet, been found only in the pre-Cobalt diabase, and the Quebec dykes characterized by such phenocrysts may be correlated as pre-Cobalt with reasonable certainty.

The number of dykes with this unusual porphyritic texture is small, however, and definite data as to the age of the others can be obtained only in the southwest corner of the region, where Cobalt series occurs. In that corner, one dyke was found cutting the Cobalt series near the Angliers road, east of Renaud lake, with a strike of north 70 degrees east. The dyke is about 100 feet wide, weathers to a brownish tint, and is otherwise identical with the later gabbro of the region. No other dyke cutting the Cobalt series was observed. On the other hand, the large dyke crossing Opasatika lake on a strike of about north 60 degrees east was traced westward to its contact with the Cobalt series, and there definitely observed to pass beneath the Cobalt series. In one place the Cobalt series has been worn away above the dyke, forming a small "island" of diabase completely surrounded by conglomerate. Again, the diabase dyke running north along the west side of Opasatika lake was traced to within 200 feet of the Cobalt contact, at which point it passed under drift; but no dyke was found to cut the well-exposed Cobalt series near where the dyke, if projected, should cut it. It was concluded, therefore, that this dyke also passed beneath the Cobalt series.

There is, therefore, but little direct evidence to indicate whether the Quebec dykes belong, in the main, to the older series or the younger. It is a very interesting fact, however, to which attention never seems to have been drawn, that the activity of the Nipissing diabase intrusion died away quite suddenly at approximately latitude 47° 54′ north, or about the middle of the tier of Ontario townships extending from Mulligan on the east to Midlothian on the west. The area south of this line, as far as the north shore of lake Huron, is liberally streaked and dotted with dykes and sills of Nipissing diabase intrusive into the Cobalt series. North of this line practically none is found with this relation, although considerable areas are underlain by Cobalt series. In Matachewan area there are large areas of Cobalt series, but a fairly detailed geological examination failed to disclose the presence of any masses of gabbro cutting it. In Flavelle, Burt, and Bompas townships there is a large mass of Cobalt series, a tongue of which extends east into Grenfell township; but the only diabase found to cut it was a couple of dykes in Bompas township. In Larder area, Cobalt series underlies the greater part of Mulligan, Rattray, and McFadden townships and extends eastward into Dufay and Dasserat townships, Quebec; but M. E. Wilson, who mapped this area in 1909, found no diabase cutting this series except one dyke on Raven lake, McFadden township. In Dufay, Dasserat, and Beauchastel townships no diabase has been found cutting the extensive area of Cobalt sediments, except a single dyke in Beauchastel. On this account, therefore, the bulk of the later diabase in Quebec is considered to be pre-Cobalt in age.

The olivine gabbro of Quebec has no similarity whatever to the late Keweenawan olivine diabase found in the region between Gowganda and the north shore of lake Huron, and which cuts the Nipissing diabase and Killarney granite. The characteristics of the late Keweenawan diabases of Ontario are, first, an extraordinary degree of freshness, and, second, a porphyritic texture, both of which are quite unlike anything found in Quebec. The late Keweenawan diabase, under the microscope, exhibits almost no trace of alteration in any of its minerals, which makes it almost unique among Precambrian rocks. Further, all dykes more than about 5 feet wide are characterized by rather numerous, well-formed phenocrysts of white feldspar varying from $\frac{1}{4}$ inch to 1 inch or more in diameter. They weather into shallow pits on exposed surfaces, and are so conspicuous that they can be seen from a considerable distance. No dyke of this type has yet been found in Quebec. It is most probable that the olivine gabbros of Quebec are merely basic variants of the quartz diabases.

Basaltic Dykes

Here and there throughout the Keewatin areas basic dykes occur, which are distinctive because of their very fine grain, even in those of considerable width. They have, therefore, been termed basaltic dykes, because their composition and texture is like that of basalt. Some of them cut dykes of later gabbro, and are, therefore, the youngest known intrusives of the region; but in most instances they cut rocks older than the later gabbro, and, accordingly, the dykes that do this can not be definitely placed as to age, except so far as to say that they are younger than the rocks they cut. Some basaltic dykes in Palmarolle township are cut by a dyke of later gabbro. It seems better at present, therefore, to consider the rocks described in this section as merely petrographically similar to one another, without implying that they all belong to a single period of extrusion.

The basaltic dykes range from a few inches to more than 20 feet in thickness. They are particularly noticeable in Palmarolle map-area, along a zone 3 miles long and ½ mile wide extending from range III to range VI, throughout lots 23 to 27. Many also occur in Duparquet map-area. On Beattie island, in the northern part of Duparquet lake, small basaltic dykes cut a schistose gabbro considered to be quartz diorite. In Montbray township basaltic dykes cut the Keewatin lavas in the extreme southwest corner of the township, on the Robb-Montbray property in the southeast corner, and near the eastern boundary just north of the centre line, as well as in the adjoining part of Duprat. On the Noranda property small basaltic dykes cut the large dyke of later gabbro. Similar dykes occur around Pelletier lake, Rouyn township. In La Corne township, in the centre of lot 24, range III, a basaltic dyke at least 100 feet wide cuts across the strike of the biotite schist. In Barraute township basaltic dykes occur in range III, lot 18, just north of the railway; in range II, lot 25; and a quarter mile southwest of Barraute station.

The basaltic dykes of Palmarolle township are the only ones that have been studied in detail. They are dark grey to black rocks, fresh in appearance, and not foliated. In general they are equigranular and very fine-grained, but locally they are porphyritic, and carry small phenocrysts of plagioclase and hornblende. Four types were observed, cutting each other in an order of increasing basicity.

The oldest and most acid dyke contains numerous tabular phenocrysts of plagioclase, so much altered to zoisite with some carbonate as to be indeterminable; a few phenocrysts, up to 2 mm. in diameter, of light green hornblende; all embedded in a groundmass of small feldspar laths, some reddish flakes of biotite, and microlites and small aggregates of hornblende. The feldspar laths are about ½ millimetre in diameter, and are clear and unaltered. They were determined to be andesine-labradorite, $Ab_{55}An_{45}$.

The next dyke in the succession likewise contains small feldspar phenocrysts up to 1·5 mm. in diameter, and hornblende phenocrysts up to 0·5 mm. As in the last, the feldspars are completely altered to epidote, carbonate, and sericite, but the hornblendes are fresh, and much more numerous than in the previous type. The groundmass is an aggregate of fresh feldspar, some quartz, needles of hornblende, and biotite flakes.

The next dyke of the series is not porphyritic, and is composed of about equal amounts of hornblende and fairly fresh labradorite. Considerable magnetite is present.

The youngest of the dykes is made up of 70 to 75 per cent of hornblende, with small, interstitial laths of fresh anorthite feldspar. In addition, remnants are present of original feldspar phenocrysts, now completely altered to saussurite.

The basalt dykes observed in Montbray and Duprat townships vary from a few inches to 20 feet in width, and are very difficult to distinguish from the fine-grained, massive lavas. Some are quite straight and long, whereas others are very irregular. The general strike is from 15 to 35 degrees east of north; some, however, strike east.

The dykes in Barraute township are more altered than most of those noted elsewhere, and very possibly were "feeders" of Keewatin lava flows.

CHAPTER VII

COBALT SERIES

The Cobalt series occurs only within Opasatika map-area, and is made up entirely of the lower beds of the series, grouped by Collins[1] under the name Gowganda formation. It includes large quantities of conglomerate interbedded with greywackes and impure quartzites, together with some fine-grained, blackish greywacke or argillite. The thickness of the series here, between 500 and 1,000 feet, represents only a fraction of the original thickness, for the greater part has been removed by erosion.

The Cobalt series was laid down on a relatively flat surface that truncates all the older rocks. The nature of this surface is well exhibited in Opasatika area. It appears to have consisted of knobs and short or long ridges alternating with valleys of moderate width, and to have had a relief, probably, of 200 to 300 feet. The topography varied no doubt with the nature of the underlying rock; in areas of Timiskaming series structure can be seen to have controlled the topography so that the pre-Cobalt valley and ridges had a general east-west direction.

A beautiful section is obtainable between Opasatika and Dasserat lakes, where the entire removal by fire of all vegetation has exposed all details clearly. The contact of the Cobalt and Timiskaming series at the north end of Opasatika lake is on a hill of the Timiskaming series that rises about 100 feet above the lake. Lake-level is 869 feet above sea-level, so that the old Timiskaming surface here has an approximate elevation of 970 feet. The contact may be seen on the cliffed shore to fall away rapidly northward, so that this part of it was evidently the south side of an old valley of some depth. The depth is not known, but was more than 100 feet, for the contact passes below lake Opasatika.

At the south end of Ogima lake (elevation 913 feet), one mile due north of the contact described in the last paragraph, low outcrops of lava rise a few feet above the lake, corresponding to an elevation in the old surface of more than 40 feet. Half a mile farther north, on the west side of the lake, the old surface rose into a considerable ridge, as the Keewatin-Cobalt contact is high on the hillside, 100 feet or more above lake-level, i.e., with an approximate elevation of more than 1,000 feet above sea-level. Farther to the north, the old surface evidently fell away again into another valley, which was about a mile wide, and, since the Cobalt series once more outcrops at the low-level surface of Dasserat lake (913 feet), must have been more than 100 feet deep. The northern contact is on the ridge on the south side of Renault bay, Dasserat lake, about 100 feet above lake-level. Figure 11 shows a cross-section of the old surface described.

Similar observations, though less complete, were made at many places in the area. Thus the outcrop of syenite porphyry to the north of Olier

[1] Geol. Surv., Canada, Mem. 95, p. 63.

lake is a pronounced ridge of pre-Cobalt age, that now rises 150 feet or more above Olier lake, and must have risen higher above the floors of the old valleys to the north and south, since these are now filled with Cobalt series at lake-level, and for a farther depth unknown.

The origin of the Cobalt series has been extensively discussed in past years, in view of the theory advanced by Prof. A. P. Coleman that the Gowganda formation represents the deposits of an early glacial period. The similarity of the thick boulder conglomerates of the Cobalt series to boulder moraines, of the unstratified greywackes to boulder clays, and of the thin-bedded argillites containing scattered boulders to the bedded clays of post-Glacial lake deposits, has been repeatedly pointed out by various geologists working in northern Ontario and Quebec. Coleman has discovered scratched and soled boulders in the conglomerate at Cobalt,

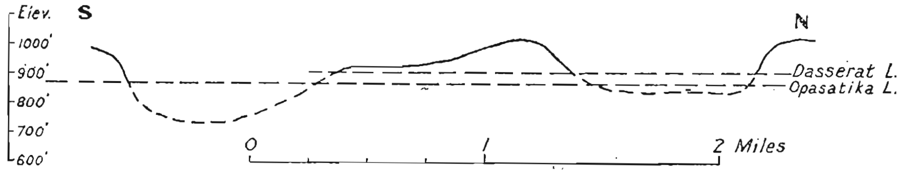

Figure 11. Profile of surface on which the Cobalt series was deposited, between the north end of Opasatika lake and Renault bay, Dasserat lake.

Ont., identical with those to be found in the deposits of the last Ice age. The evidence appears conclusive, but many geologists have not considered it so because up to the present a glaciated surface has never been found beneath the Cobalt series; that is, a smooth, polished rock surface covered with the grooves and striations made by boulders gripped by the moving ice, such as may be observed almost everywhere in northern Canada today.

Without going further into the controversy, it may be said that in 1922 two pieces of evidence were obtained that strongly support the theory of the glacial origin of the Gowganda formation. These are, the discovery of a conglomerate that could not have been formed by other than glacial means; and the discovery of a striated surface beneath the Cobalt series.

On the south side of the creek draining Olier lake, at a point about 30 chains east of the Dasserat-Beauchastel line, there is a cliff of the Cobalt series consisting for the most part of grits and quartzites, in beds 4 inches to 2 feet thick that maintain their thickness very uniformly along the strike. The strike here is north 80 degrees west, the dip 10 to 15 degrees north. Interbedded with the sandstones is a bed of conglomerate about 15 feet thick. It is made up for the most part of boulders 2 to 4 feet in diameter, with many of larger size. One boulder more than 15 feet in length and at least 8 feet high was seen; its full thickness is more than 8 feet, but its base is hidden by the soil at the foot of the low cliff; and many boulders 8 to 10 feet in diameter were observed. The boulders are crowded together, and cemented by a small amount of greenish-grey, clayey matrix that possesses a crude and highly irregular bedding near the base of the conglomerate bed, but is entirely without bedding in the upper two-thirds. Most of the boulders are subangular, though not soled; a number are sharply angular, with little signs of wear. About 80 per cent of them are of a white, highly quartzose granite containing very little ferromagnesian mineral. The remainder are mostly basalt and other lavas, with a few of the Timiskaming greywacke.

There are only two known ways by which such a coarse boulder conglomerate may be formed. One of these is by torrential streams descending from a mountainous area; the other is by glacier ice. The theory of torrential streams must be at once abandoned, because, as has been shown, the relief of the surface was very low when the Cobalt series was deposited; and also because the well-bedded sandstones both above and below the conglomerate bed indicate that the area was covered with comparatively still, though shallow, water. The conclusion, therefore, is unavoidable that the boulders were brought to their present position by ice, probably by a comparatively thin, glacial tongue pushed out into a shallow lake from some larger body at a distance, during a temporary advance of the ice-sheet. The ice tongue was evidently so buoyed up by the water that it exerted little pressure on the unconsolidated sediments beneath, for they show no signs of having been disturbed, at the point of observation at least.

The composition of the conglomerate affords further support to the glacial theory. It is 5 miles from this point to the nearest outcrop of granite on the southwest, much more to the nearest outcrop in any other direction. It would be impossible for any agent except ice to carry boulders of the size described across 5 miles or more of relatively flat country.

South of the west end of Renault bay, near where the south boundary of Renault's westernmost surveyed claim crosses the east side of the small stream valley, the contact of the Cobalt series and the diorite porphyry is well exposed at an estimated elevation of at least 200 feet above the lake-level. The valley, which cuts down across the plane of contact, here runs north 20 to 30 degrees west. The area has been so thoroughly burned that every trace of moss and vegetable matter is gone, and the rocks are magnificently exposed, except for thin deposits of talus. Attention was first directed to the contact by its unusual shape; instead of being flat, jaggedly rough, or gradational, it is a sharp line, but wavy, in smooth, flowing curves, the "waves" having a depth of 6 inches to 1 foot, roughly, from the top of the crest to the bottom of the trough. The appearance is precisely similar to a cross-section of a glacially gouged rock surface covered with soil.

Accordingly, this unusual contact was further searched for places where the Cobalt series had been lately so broken away as to expose a bit of the surface on which it had been laid down. If this were truly a glacially gouged surface, there ought to be finer striations on it, paralleling the larger grooving. There proved to be about 4 or 5 chains of contact well exposed on the almost vertical rock face, and in this distance two places were found where small blocks of the Cobalt series had been recently cracked out by the action of the weather, exposing in each case a small area, roughly 4 inches by 6 inches, of the underlying surface. Each of these surfaces is smoothly polished, and is distinctly grooved by fine striæ running parallel to each other and to the main large grooving. The strike, taken as accurately as possible on the fine striations, was determined as north 60 degrees east on one bit of surface, north 62 degrees east on the other.

These observations seem to establish pretty conclusively that the deposition of the Cobalt series commenced under glacial conditions, and further, that the glaciers must have been continental glaciers or ice-sheets, for the general peneplained character of the country would forbid the formation of the valley glaciers common in mountainous regions. Further, the ice must have moved over Opasatika area from a centre that lay either to the northeast or the southwest. Although there is no definite method for determining the position of the ice centre more exactly than as stated, two of the observed facts lend themselves to the suggestion that the ice centre lay to the southwest, or, precisely, south 60 degrees west from Swinging hills. The first of these facts is the slope of the pre-Cobalt surface where the groovings were observed. The slope is gently upward toward the northeast, at an angle of 10 or 15 degrees, exactly like the gentle slope of the iceward side of a roche moutonnée—thus suggesting that the ice came from the southwest. Again, it will be recalled that the great boulders in the glacial conglomerate previously described consist almost entirely of granite. The large areas of granite in the region all lie to the south and southwest. To the northeast the nearest body of granite is 12 miles away and it and its neighbours form only a relatively small part of the total area. Had the ice moved down from the northeast, boulders of basalt and other lavas would naturally form a large proportion of the total load of the ice. Of course, the soft greenstones might be ground to powder during ice movement much more readily than the harder granites, so that during movement there would always be increase in the proportion of granite boulders in the load; but this consideration can hardly explain the composition of the particular bed of conglomerate under consideration, for the boulders in it show scarcely any signs of wear, some of them being sharply angular and the rest subangular. It seems reasonable, therefore, to conclude that these boulders were brought from the large granite area to the southwest, where a great quantity of granite, and very little of any other rock, was available to the ice during the process of gathering its load.

The age of the Cobalt series has been shown in previous papers, to which the reader is referred, to be post-Lower Huronian.[1]

[1] Geol. Surv., Canada, Mem. 131, pp. 40, 41.

CHAPTER VIII

POST-GLACIAL LAKES AND THEIR DEPOSITS

GENERAL DISCUSSION AND CORRELATION

The melting of the Pleistocene ice-sheet in eastern Canada resulted in the formation of vast lakes. These lakes resulted, not only because immense volumes of water were set free from the melting ice, but also because the slope of the land at that time was more northerly than at present, and the northward and northeastward drainage was blocked by the retreating ice-sheet or by drift. Thus, a lobe of glacial ice for a long time choked Mattawa and Ottawa valleys at Mattawa, forcing the drainage of the upper Great Lakes basin into roundabout courses by way of Niagara and Trent valley. Again, a great dam of morainal materials filled the valley at the lower end of lake Timiskaming, and presumably had to be cut away by the river before the waters to the north could attain their present low level.

Probably the most fertile cause of lake formation was, however, the attitude of the land surface, which differed widely from the attitude now. At the time the ice-sheets covered northern Canada, the land surface beneath them stood several hundreds of feet lower than at present. Since the disappearance of the ice the land has risen to its present level. Proofs of this are found in the occurrence of sands and clays containing sea shells far up the valleys of St. Lawrence river, Ottawa river, and the rivers entering Hudson bay; in the presence of raised beaches all around the coasts of Labrador and Hudson bay; and in the fact that the ancient beaches of the post-glacial Great Lakes now slope upwards towards the north.

The amount of post-glacial uplift has been in places at least 700 feet, and probably more. At Kingsmere, 8 miles northwest of Ottawa, marine terraces have been found (by Gerard De Geer) at a height of 690 feet above present sea-level. Moreover, sea-level at that time was lower than at present, owing to the vast amount of water taken from it and locked up in the continental ice-sheets. Antevs has calculated this lowering to be about 300 feet at the maximum extension of the ice-sheets. When the ice had receded past Ottawa much of the locked-up water had been returned to the sea by melting, perhaps half of it or even more; but assuming that two-thirds of it had been thus returned, sea-level would still be 100 feet lower than at present. The Kingsmere beaches, therefore, being formed by a sea lower than the present one, indicate a correspondingly greater uplift since glacial times, an uplift in all probability of at least 800 feet.

The beaches of the late-glacial Great Lakes have been studied by many observers throughout a period of more than 40 years, and have been found to be tilted toward the south. The highest of these beaches, the Algonquin beach, is only about 25 feet above the present lake level at the south end of lake Huron. It has been traced northward as far as Uphill, a village 22 miles northeast of Orillia, where its elevation is 344 feet above lake Huron. Near North Bay, a beach supposed to correspond to the highest Algonquin beach is 596 feet above lake Huron. As these beaches when formed were horizontal, they thus record an uplift of the North Bay region, relative to the south end of lake Huron, of at least 571 feet.

Further evidence, which cannot be inserted here for lack of space, has shown that the territory thus uplifted is confined to the area occupied by the ice, and that the territory beyond the limits of the ice-sheets has remained comparatively undisturbed. It has also been proved, from a study of the Algonquin beach levels, that the southern part of Lake Huron basin was unaffected, or only slightly affected, by the uplift of the region to the north.

It is possible, therefore, to calculate roughly the former position of the land surface. The south end of lake Huron is 581 feet above sea-level, and has remained at or near that level since inauguration of lake Algonquin. Rail level at North Bay station is 662 feet above sea-level, and this area has been uplifted at least 571 feet, so that its former level was only 91 feet above present sea-level. The height of land, where crossed by the Temiskaming and Northern Ontario railway is now 1,044 feet above sea-level; at its lowest point, between Dasserat and Opasatika lakes, it is 915 feet. If these points were depressed as much as Ottawa, as is probable, then before uplift they stood at most 354 and 225 feet above present sea-level, respectively, and probably at least 100 feet lower. These figures indicate that at the close of glacial time the general slope of the land surface was towards the north and northeast. Had drainage been free and not blocked by the ice it is even possible that direct drainage from the Great Lakes to James bay might have been established. The later uplift of the northern parts of the region caused a migration of divides towards the north.

In view of some theories that in recent years have been advanced, suggesting a connexion between the occurrence of mineral deposits and the position of the height of land, this modern example of the migration of divides through differential uplift is perhaps of interest; and this migration is only one of a whole series of such changes known to have occurred during earth history. Unless, therefore, mineral deposits are supposed to have moved with the divides, it is difficult to see how any connexion between the two can be maintained.

From the time that the ice front retreated north of the south ends of lakes Huron and Michigan, the drainage from it was ponded between the ice body and the divide to the south, and the lakes thus formed grew constantly larger as the ice front continued to recede. At their maximum extension, when the ice front had withdrawn north of the present Great Lakes, these lake bodies were united into one vast sheet of water that occupied the basins of lakes Superior, Michigan, and Huron, and covered large sections of adjacent country to a point about 50 miles north of lake Huron. This body of water has been termed Lake Algonquin, and it came to an end largely through differential uplift. The northern end underwent the great uplift mentioned above; the southern part remained stable. After the uplift had practically ceased, the ice dam in Ottawa valley at Mattawa broke, opening a new outlet down Ottawa valley, past North Bay. This, together with the uplift, reduced the lake to a size only slightly larger than that of the present Great Lakes. The name, Nipissing Great Lakes, is applied to the lake bodies during this stage.

As the ice front continued to recede northward two new lakes were formed. The westernmost, named Lake Ojibway, was ponded between the ice and the height of land north of lake Huron. The eastern lake, Lake Barlow, filled Timiskaming valley, and was ponded between the ice and a broad barrier of drift at what is now Long Sault rapids at the foot of the present lake. These lakes grew in size as the ice front retired, until they finally extended across what is now the height of land. Finally, when the ice front was somewhere within the 15 miles between the height of land and Ramore station, the two lakes united to form one great sheet of water, that persisted for many hundreds of years. It finally came to an end, rather suddenly, when the ice front stood, in Quebec, a little north of the National Transcontinental railway. It is probable that the water began to flow to James bay, across the thinning ice, and rapidly wore a channel down through it.

On the high ground near Haileybury, Hume[1] found gravel beaches at a height of 875 feet above sea-level, or 300 feet above the present low-water level of the lake. It is possible that these beaches do not represent the highest beaches of the ancient Lake Barlow, but they are the highest yet on record in this part of the region. On pages 155, 156 of this report the discovery is recorded of the uppermost beach deposits of Lake Barlow-Ojibway, on the Aldermac property in Beauchastel township, Quebec. They lie at 1,201 feet above present sea-level, and are 58 miles from Haileybury in a direction 20 degrees east of north. If the beaches found by Hume are the highest beaches of the old lake, the beaches in Beauchastel township have been uplifted, since glacial times, 326 feet above those at Haileybury. In other words, differential uplift has given this region a southward slope of 5·6 feet to the mile. If the Haileybury terraces were formed at some distance below the highest lake level, the tilting would be correspondingly less than 5·6 feet a mile. It is probable that the Haileybury beaches are not the highest, as Coleman reports sand and clay terraces at the mouth of Montreal river 811 feet above sea-level. This locality is 78 miles almost due south of the Beauchastel occurrence, and the difference in level between the two is only 390 feet, corresponding to a tilting of 5 feet a mile. In all probability the tilting is even less than this figure, as Coleman's terraces are not gravel beaches such as would be formed on a shore, but are sand and clay, suggesting deeper water deposition. Near Haileybury Hume found similar terraces to rise only to 782 feet above sea-level, or 93 feet below the level of his beach, which probably is not the highest. If we assume that the water-level at Montreal river was 100 feet above the

[1] Hume, G. S.: "The Palæozoic Outlier of Lake Timiskaming, Ontario and Quebec"; Geol. Surv., Canada, Mem. 145, pp. 6-8 (1925).

terraces found by Coleman, the post-glacial tilting is reduced to 3·7 feet a mile, a figure that more nearly corresponds with that determined for the Algonquin beach.

From the mouth of Montreal river it is 24 miles farther to a line drawn through the head of Long Sault rapids at right angles to the direction of uplift. If the water level of Lake Barlow at Montreal river is assumed as 910 feet, and the tilting, accordingly, 3·7 feet a mile, then the old water-level at Long Sault rapids must now stand 89 feet lower, or 821 feet above sea-level. If the Montreal River terraces were formed at or close to the old lake surface, and the tilting, accordingly, has been 5 feet a mile, then the old water-level at Long Sault rapids is now approximately 691 feet above sea-level.

The position of the shores of Lake Barlow-Ojibway is as yet very imperfectly known. From Long Sault rapids the west shore must have been very near the present west shore of lake Timiskaming, as the latter rises steeply from the water for some hundreds of feet. North of lake Timiskaming it ran northwesterly for about 45 miles into southern Flavelle township. Apparently a long point or a chain of closely spaced islands then extended east into the lake for nearly 60 miles, as clay is lacking, except in some of the lower stream valleys, throughout the area underlain by Cobalt series in Quebec, throughout Larder and Kirkland Lake areas, and westward into Matachewan district. The width of this point, measured along the line of the Temiskaming and Northern Ontario railway, was about 30 miles; the clays disappear a little north of Krugersdorp station, and reappear again a few miles south of Ramore. From Ramore the shoreline must have extended somewhat south of east to pass around the end of the body of Cobalt series in Beauchastel township, and west or slightly south of west, as no clay occurs in Ontario as far north as the middle of Cleaver and McNeill townships.

East of lake Timiskaming the shoreline of Lake Barlow-Ojibway was confined to the Timiskaming trench nearly to rivière Lavallée. It then turned to the east, passing south of Quinze lake and across to the north end of Grand lake Victoria. East of Grand lake Victoria it appears to have turned suddenly north, and to have run approximately parallel to Bell river and a few miles east of it.

The boundary of the clay belt passes through the southeast corner of Rouyn-Harricanaw area. It is marked by extensive plains of sand, some of which are wind-blown, and others are doubtless beach deposits. South of these the country passes into the ordinary rocky upland type commonly found in the Canadian shield outside of the clay belts.

It is interesting to note that the present elevation of Grand lake Victoria is 1,103 feet above sea-level. This lake is just outside the limits of the clay belt. In Beauchastel township beach deposits of the post-glacial lake were found up to 1,202 feet above sea-level. It would appear, therefore, that since the disappearance of the ice, Beauchastel township must have been elevated about 100 feet more than Grand lake Victoria. The question is an interesting one for investigation; better data as to the precise altitude of the beach deposits in the southeast are required before the amount and direction of the possible tilting can be determined.

The north boundary of the lake was the ice-sheet. At present practically nothing is known of it, except that at the time the lake was drained it extended in a general easterly direction from a point several miles north of Cochrane. This boundary is particularly difficult to determine, as the ice front subsequently readvanced to Iroquois Falls, Nellie Lake, and a point 3 miles north of Frederick House lake, depositing a bed of almost pebble-free boulder clay on top of the lacustrine clays.[1] Similar pebble-free boulder clay forms the surface deposit northwards to the southern limit of the marine silts and clays of the James Bay coastal plain.

LAKE DEPOSITS

Deposits of several types were laid down in these lakes or close to them. Bedded clays and silts were deposited in the deeper water, and form the great " clay-belts " now gradually being cleared for agricultural purposes. Around the former margins of the lakes, and on hills that were islands in the lakes, deposits of sand and gravel were formed in the shallower waters and on the beaches. As the waters began to recede, the drying silts and sands were attacked by the wind, which formed wide sand-plains and great dune areas.

The clays and silts, which overlie the greater part of Rouyn-Harricanaw region, were the fine rock flour formed by the grinding of the ice-sheet against the underlying rocks. This material was carried by streams from beneath the ice into the lakes, where it sank to the bottom in a series of thin layers known as varves. The individual varve is half an inch to an inch thick, as a rule, and is composed of two distinct layers. The lower layer is normally the thicker of the two, is coarser-grained and siltier, and somewhat lighter in colour; the thin, upper layer is very fine grained and clayey. These characteristics, it is believed, indicate that the varve is the material deposited in one year. Each summer, it is argued, the waters from the melting ice-sheet would pour a new supply of sediment into the lakes, whereas during the winter melting would cease, and, with it, the addition of sediment. The thicker, silty, lower layer of each varve, therefore, is the coarser sediment that settled rapidly during each summer; the clayey upper part of the varve, the finer material that settled only with great slowness, and probably represents winter deposition, when no new materials were coming in to the lake. It has been found that individual varves maintain the same thickness, relative to those above and below, over great distances; in other words, if a varve is, let us say, twice as thick as its neighbour in one place, it will be approximately twice as thick in every locality. Such a relationship should be expected, if the varves are annual deposits; for the thickness of a varve should be proportional to the amount of silt brought into the lake during the season, and the latter should be proportional to the total heat of the summer; which is constant over large sections of the earth's surface.

By making use of this relationship it has been found possible to correlate the varves from place to place, and to determine with remarkable

[1] Antevs, E.: Am. Geog. Soc., Research ser. No. 28, 1928.

accuracy how long a time was necessary for the melting of the ice cap, the direction of its recession, where the ice front remained temporarily stationary during periods of retreat, and how long the stationary condition lasted, together with many other problems of interest and importance.[1]

Clays, as already stated, overlie the greater part of the Rouyn-Harricanaw region. The waters of Lake Barlow-Ojibway, in Beauchastel township, drowned the present land surface up to an altitude of 1,200 feet above sea-level, or, approximately, 330 feet above the present level of lake Opasatika. Clay may, therefore, be found at any point below this altitude, although, as a matter of fact, the great bulk of it lies below the 1,100-foot level. Wave movement tended to prevent clay being laid down in the shallower parts of the lake, and also removed to lower levels, as the lake fell, much of what was first deposited. Most of the region, however, lies below the 1,100-foot level, so that clay is universal except on the more prominent uplands. The chief of these are Kekeko hills and the whole area underlain by Cobalt series, Abijevis hills, Smoky hills, Tenendo hills, some high ridges in southwestern Clericy township, and a few other places. In the southeastern corner of the region under consideration the clays also disappear, and their place is taken by shoreline deposits of various types.

Beach deposits have been observed in a few places, but have not been studied. One very pronounced beach was traced for a mile in a north and south direction, between ½ and 1½ miles north of Flat rapid, Kinojevis river, in the southeastern corner of Manneville township. The beach has a smoothly curving outline, and is about 40 feet above the low clay country to the east and south, and probably not more than 75 feet above Kinojevis river. The approach to the beach from the east is a steep 30-foot slope of fine, yellow sand; this is followed by a level stretch of sand about 100 feet wide, beyond which there is a gently sloping, smoothly packed, shingle beach, 6 to 10 feet wide, composed of pebbles up to 4 inches in diameter. Beyond the beach there is a 3- or 4-foot shore cliff cut in till.

Beaches not quite so well marked were noted in Aiguebelle township on the north, and on the south slopes of Abijevis hills. Some of these are probably at a higher elevation than the one mentioned above. Forest fires have destroyed all vegetation on the western part of Abijevis hills and permit close examination of the rocky ridges and the deposits on them. At the top of the northernmost ridge of these hills, 2 to 3 miles east of the west boundary of Aiguebelle township near its east-west centre line, there are gravel ridges connecting outlying knobs that must have been gravel bars when the level of Lake Barlow-Ojibway was at this level. No other shore phenomena were noted in the vicinity except that the adjacent rock ridges at this and higher and lower altitudes are generally bare, probably due to wave action. The gravel ridges mentioned are probably 300 feet above lake Lois which lies 5 miles to the north and 200 feet above the previously described beach in Manneville township; they must lie in the neighbourhood of 1,300 feet above sea-level.

A series of gravel ridges connecting outlying knobs, which were evidently gravel bars when the lake level was high, were found in Beauchastel township on the Aldermac property, claim M.L. 1953, on the site of

[1] Antevs, Ernst: "Retreat of the Last Ice-sheet in Eastern Canada"; Geol. Surv., Canada, Mem. 146 (1925).

the main camp and for a few hundred feet to the west. A line of levels was carried by transit survey from the railway line about a mile to the south, and the elevation of the bars thus determined accurately. The highest bar, or beach, lies 3 miles 1,270 feet from the west boundary of the township, and 550 feet north of the east-west centre line. It is composed of reddish, oxidized residual soil covered with 3 or 4 inches of poorly washed gravel. Its nature suggests that it represents the extreme high water-level of the lake. The crest stands at 1,202 feet above sea-level. The next bar, 800 feet due east of the last, is 1,175 feet above sea-level. It is composed entirely of well-washed gravel and grit, with no fine sand or soil. A third bar 200 feet farther east stands at 1,163 feet above sea-level, and is composed entirely of well-washed, coarse gravel. As the level of lake Opasatika a few miles to the southwest is 869 feet above sea-level, it is evident that Lake Barlow-Ojibway at its highest must have been more than 300 feet deep.

High-level beaches and bars have also been observed on Swinging hills in Dasserat township, on a high ridge about 2 miles southwest of Hub lake, Montbray township, and on the flanks of Smoky hills in the centre of Duprat township. The elevations of these have not been measured.

On the Amulet property, about 300 feet northwest of the shaft, there are beaches of well-washed gravel in a small gully. The level of the upper border was determined, by transit levelling from the railway spur, as 1,218 feet above tide.

North of the Harvie mine shaft, about a mile east of Savard lake, Clericy township, there is a high gravel bar almost at the summit of the hilly area there. The elevation of this was determined as carefully as possible with a hand level, by carrying a line of levels down to Savard lake, across the portage to Kinojevis river, and from the river to rail level at Clericy station. By this means the altitude of the bar was determined as 1,197 feet above sea-level, a figure which is probably correct within a few feet.

Sand-plains are numerous throughout certain parts of the region. Their elevations are usually a little higher than those of the clay areas. Probably the largest underlies a great part of Privat, Launay, Guyenne, and Languedoc townships, and, according to Tanton,[1] extends west into Desmeloizes township. A second, though much smaller, area extends westward from the nose of Abijevis hills through Destor township. A sand-plain about 2 miles in diameter occurs near the middle of Duparquet township, and another in the northeastern part of the township. An area of sand some 4 or 5 miles in diameter lies in the northeast quadrant of Duprat township.

To the south and east a small sand area was found around the corner of Clericy, La Pause, Joanne, and Bousquet townships. Others occur in eastern Vaudray, extending into Montanier. The northern flank of the rocky and hilly area passing through central Montanier, central and southern Surimau, and southern Fournière townships, is bounded by flat sand-plains through which protrude small rock outcrops and irregular ridges of till. A shorter belt having a width of 3 or 4 miles trends southeasterly

[1] Tanton, T. L.: "Harricanaw-Turgeon Basin, Northern Quebec"; Geol. Surv., Canada, Mem, 109, p. 50 (1919).

across central Cadillac into southeastern Malartic. A similar area of sand partly covers the rocky township of La Corne and extends northward into southern Landrienne, eastern La Motte, northern Varsan, northeastern Senneville, and western Fiedmont townships.

All the townships along the south and east boundaries of the mapped region contain areas of sand which in places cover a large part of the country. Southern Dubuisson and Bourlamaque, and central Louvicourt have extensive rolling sand-plains with occasional outcrops and till ridges protruding through the sand cover. Small, rolling areas or isolated hillocks of sand bounded by extensive muskegs are to be found in other parts of these townships and also in Pascalis, Courville, Carpentier, and Barraute townships.

Some of these sand areas appear to be outwash plains, particularly, according to Tanton, the large area from Desmeloizes township eastward. Outwash plains are composed of sands, grits, and gravels dropped by the multitude of streams and rivulets flowing from a melting ice-sheet.

The larger number of the sand areas, however, are not made up of mingled sands, grits, and gravels, but of extremely fine sand only. The average grain of sand, as measured under the microscope, is 0·2 mm. in diameter. Approximately 75 per cent of the grains are of this diameter, and the remainder are but slightly larger or smaller. One may traverse these sand areas for miles, or dig into them anywhere, without finding a pebble as large as a pea. This physical character, and the crescentic shape of the sand ridges, which is characteristic of dunes, indicates that the sand beds have been formed by wind action. Kettle-holes, some fairly large, have been found in many places within the sand areas. Some are dry, others form ponds or small lakes. Kettle-holes are commonly considered to have been formed by the melting of blocks of ice that had been buried in outwash plains or moraines. Their occurrence within the sand areas suggests strongly that the sand deposits formed by wind action on the surface of outwash plains. The sand deposits are usually on areas higher than the normal clay country. Many of them are on the flanks of ranges of hills, such as the long sand ridge that runs west through Destor from the end of Abijevis hills, and the sand area in northeastern Duprat, that lies between high ridges to the east and west.

There appears to be a tendency for the sand areas to develop on the west flanks of ranges, rather than on the east, south, or north. The best known example is the sand area west of Abijevis hills. This suggests that, at the time of the retreat of the ice-sheet, the prevailing winds must have blown from the east. Confirmation of this conclusion is found in the shapes of the sand dunes, which are now motionless owing to their protecting cover of vegetation, and have probably remained so ever since vegetation became established after the disappearance of the Glacial lakes. Dunes tend to develop convex shapes while forming, because here and there bushes or other obstructions arrest the movement of the sand; and the convexities always face toward the direction of prevailing wind. Airplane photographs of the sand areas in Quebec show great numbers of dunes, with this convexity very beautifully developed and in all cases facing almost due east.

CHAPTER IX

SUMMARY OF THE ECONOMIC GEOLOGY OF ROUYN-HARRICANAW REGION

Rouyn-Harricanaw region contains deposits of copper, zinc, gold, and molybdenum. Considerable quantities of silver and gold are found in some of the copper-zinc deposits, as well as in vein deposits of the ordinary type.

The copper-zinc deposits have as yet been found only in rocks of the Keewatin series, and the discoveries are confined to the western section of the region, within 30 miles of the interprovincial boundary. The fact that intrusions of quartz diorite, granodiorite, and a very coarsely porphyritic feldspar porphyry are also largely confined within the same area has suggested the possibility that the copper deposits are genetically connected with one or other of these rocks.

Gold deposits are known both in the Keewatin and Timiskaming formations. They fall into two zones, a northern and a southern. The southern zone, 7 to 8 miles in width, lies astride of the main Keewatin-Timiskaming contact, with its southern boundary 2 to 2½ miles within Timiskaming area. Some deposits of the northern zone lie close to the Keewatin-Timiskaming contact in Destor township, and others near Fisher station, almost due east of the Destor occurrences. These relations suggest that the gold deposits, for reasons yet unknown, tend to have formed near synclinal axes; and it is interesting to note, in this connexion, that the Porcupine deposits, and those of the field extending from Kirkland Lake to Larder Lake, also lie near the axes of major synclines.

Molybdenite deposits are known only in two small areas in the eastern part of the region. They were formed, apparently, as the siliceous end-product of the differentiation of biotite granite, and for some reason not yet understood are located only near the contacts of pegmatitic granite and biotite schist.

So far as the gold and the copper deposits are concerned, deposition appears to have been localized by structural factors chiefly. Other factors have undoubtedly been operative; the ore-bearing solutions must have come from deep-seated sources, presumably bodies of cooling igneous rock; and deposition may have been influenced chemically by the composition of the wall-rocks, and physically by their temperature, because temperature differences in the wall-rock would vary the distances solutions must travel before being cooled to the point of deposition. Very little information has been gained, however, about such possible relationships, and certainly nothing that would aid in the search for new deposits. On the other hand, a considerable volume of data is accumulating, to indicate the existence of a close connexion between ore deposits and structural disturbance. The general arrangement of gold deposits along the major synclines has already been mentioned. Fault fissures, large or small, and sheared zones are places where many deposits were formed. The Robb-Montbray, Lake Fortune, Graham-Bousquet, Thompson-Cadillac, and O'Brien ore-bodies, together with others of subordinate importance, are examples. Drag-folds have proved favourable, in places, for ore deposition, as on the Noranda and Chadbourne and probably on the Malartic properties. Structural features of this sort are readily recognized, and may thus become valuable " indicators " to the prospector.

SULPHIDE DEPOSITS

The sulphide deposits are of two general types, vein fillings and replacements. The vein fillings are comparatively small and economically unimportant, so that when the deposits are mentioned the replacements are generally to be understood.

The replacement deposits are of all sizes and degrees of replacement. Many are almost pure sulphide, with little or none of the original country rock; and these may vary from small masses 10 to 20 feet long and 1 or 2 feet wide up to great bodies several hundred feet long and up to 200 feet wide. Others contain unreplaced fragments of the original country rock in greater or less amount; and still others are merely country rock sprinkled thickly or thinly with grains of sulphide. None of the last mentioned has yet been found of economic importance.

The sulphides are pyrite, pyrrhotite, zinc blende (sphalerite), and chalcopyrite, and with them more or less magnetite is commonly associated. The proportions of the different sulphides vary greatly. Some bodies are almost pure pyrite, others largely pyrrhotite with a little pyrite. On one property the bulk of the sulphide is zinc blende, with lesser amounts of chalcopyrite and pyrrhotite; and some parts of the Noranda ore-bodies are nearly pure chalcopyrite. The usual sulphide body, however, is made up of pyrite and pyrrhotite with a larger or smaller proportion of chalcopyrite.

The shape of the ore-bodies is generally described as lens-like, because the length and depth are greater than the width; but in many instances the length is not more than two or three times the width, so that the lenses are very stout, and resemble cones or pipes rather than lenses. The use of any of these terms, however, conveys the idea of a more or less symmetrical shape, which but few of the bodies possess. The outlines of most of them, viewed in three dimensions, are quite irregular. One observer has described them as shaped very like potatoes; and, considering the general irregularity in the shapes of different specimens of this vegetable, the description can hardly be improved.

There appears to be a tendency for the lenses of ore to lie vertically below, and parallel to, one another. There are not yet sufficient data to generalize definitely in this regard, and it may be that the known occurrences do not illustrate a general rule. Nevertheless, instances of this behaviour are now known from three properties, the Noranda, Aldermac, and Waite-Ackerman-Montgomery; and such wide distribution is most suggestive of a general rule. If it is assumed that the metal-bearing solutions originally ascended through some fissure, as presumably they must have done, replacement might occur of successive beds of breccia or other easily replaceable rock, and would extend outwards from the fissure along the planes of bedding. Thus a series of roughly parallel bodies might be formed.

The rocks that have suffered replacement to form ore-bodies are all either acid lavas, of the composition of rhyolites and dacites, or breccias and tuffs of corresponding composition. Where breccia or tuff was available for replacement, it was invariably replaced in preference to massive lava; and most of the deposits lie within bodies of these fragmental rocks. The deposits of the Robb-Montbray, Aldermac, and Noranda mines, the Chance pyrite deposit, and most of the minor deposits of the area are all replacements of breccias, sheared rocks, or tuffs. Replacement of massive lava takes place on the Amulet and Waite-Ackerman-Montgomery properties. In these, the localization of the ore-bodies appears to have been determined by the structure.

Classified according to composition, the sulphide bodies fall into two classes, those composed mainly of iron sulphides, and those that contain important quantities of the copper and zinc sulphides. This grouping, although apparently purely an economic one, nevertheless reflects an important genetic difference, because the copper and the zinc sulphides are later than the iron sulphides and replace them; and in the case of the copper sulphide at least, the difference in age is considerable, as at least two separate periods of dyke intrusion intervened between the formation of the iron sulphide and that of the copper sulphide.

AGE OF THE SULPHIDES

It was determined at the Aldermac mine that the pyrite and pyrrhotite of the ore-bodies are younger than the oldest differentiates of the Aldermac syenite porphyry mass, and older than the later differentiates, because these sulphides replace the minerals of the older dykes, but are cut by the later dykes. The pyrite-pyrrhotite masses are, therefore, of about the same age as the porphyry intrusions, and presumably related to them in origin. Veinlets of chalcopyrite, on the contrary, cut and alter even the latest of the dykes, so that the copper was evidently introduced long after the formation of pyrite and pyrrhotite. On the Horne property (Noranda) chalcopyrite veinlets were observed not only to cut a dyke of syenite porphyry, but also to project, as tongues and stringers, into the fractured edges of the dyke of later gabbro. The chalcopyrite is, therefore, later than both these intrusives.

Polished sections show that the first sulphide to be introduced was pyrite. Where magnetite occurs, as it does in small amount in places, it was formed after the pyrite and replacing it to some extent. Pyrrhotite was the next mineral to be introduced, then followed successively sphalerite or zinc blende and chalcopyrite. Each of these minerals replaced the preceding ones to a greater or less extent.

Pyrite also appears to have formed as a late mineral, contemporaneous or almost so with chalcopyrite, in places. This is most evident at the Newbec mine, where pyrite and chalcopyrite form the matrix of a breccia, including boulders of pyrrhotite and magnetite.

ALTERATIONS ACCOMPANYING INTRODUCTION OF THE SULPHIDES

It has been found that, on many properties, large masses of the country rock have undergone profound alteration. The alterations are of two types, silicification and chloritization.

Silicification. On the Noranda and Aldermac properties, large volumes of the original rhyolite now contain no recognizable feldspar, although the proportion of recognizable feldspar is large in rhyolites at a distance from deposits. The place of the feldspar is taken by a colourless, fine-grained mineral which is either talc or sericite, and quartz. The formation of sericite or paragonite from feldspar would set free quartz at the same time, and it is probable the greater part of the quartz in these " silicified " rhyolites is the sum of the original quartz plus the quartz formed in this way; but some rocks, such as the highly siliceous " fluxing ore " on the Horne, and the fragments in the Aldermac breccia, contain so much quartz that they resemble quartzites. In such cases it appears highly probable that quartz has actually been introduced.

The rhyolite adjacent to the ore-bodies on the Robb-Montbray and Coniagas properties is even more siliceous than the silicified rocks at the Aldermac and the Horne. It contains so much quartz that detached specimens have been microscopically identified as quartzite. It can hardly be doubted that silica has been introduced into this rock in large amount.

Addition of silica is evident in specimens from the neighbourhood of the Waite-Montgomery ore-body. The rock, as shown in drill cores, is trachyte of normal composition, except for containing numerous, rounded, whitish spots about an eighth of an inch in diameter. The spots are irregular in shape and they grade into the matrix without any sharp line of contact, so that they are plainly little replacements. Under the microscope they are seen to be composed mainly of quartz, with a little pyrite and sphalerite; the rock they replace is composed of fine-grained oligoclase, $Ab_{75}An_{25}$, and needles of pale green actinolite.

Notable additions of silica are also evident at the Amulet and Newbec mines. At the Amulet, a dacite containing perhaps 2 or 3 per cent of quartz is altered to a rock carrying 35 to 40 per cent; the rhyolites, also, have part of the feldspar of the groundmass replaced by quartz. At the Newbec, quartz porphyry containing about 20 per cent of original quartz is altered so as to contain 40 to 50 per cent.

The reactions involved in the silicification of a rock may be roughly outlined. A trachyte like that found at the Waite would be composed, roughly, of some 60 per cent of silica, 18 per cent of alumina, about 10 per cent of soda and potash, mainly soda, and small percentages of lime, iron, and other constituents. It is evident that introduction of silica must imply the removal at the same time of other rock constituents, which in this case are mainly alumina and soda. The solvent, therefore, whatever it may have been, entered the rock laden with silica, and probably carrying also some iron and sulphur, because the silicified rocks are commonly sprinkled lightly with pyrite; and by reaction with the rock became depleted of part of its silica and iron sulphide, but richer in alumina and soda.

Chloritization. The silicified rock on the Robb-Montbray property is itself replaced by a solid mass of dark green chlorite. The relation of the chlorite to the silicified rock plainly shows that the chlorite is later than the silicified rhyolite. On the Horne some chloritization of many rocks has occurred, and it seems probable that the great bodies known as dacite and dacite breccia are really rhyolites that have suffered a greater or less degree of chloritization. On the Aldermac approximately one-quarter of the mass of the rhyolite breccia near the sulphide bodies consists of chlorite, and the manner of association of this material with iron pyrites makes it evident that the chlorite has been introduced. On the Amulet there are large bodies of dalmatianite, an alteration product of rhyolite; and near the ore-bodies this rock, which is rich in biotite, is converted into a mass of featureless chlorite dotted with nodules of cordierite. On most of the smaller ore-bodies the development of chlorite-rich rock may be observed in the vicinity and particularly around the edges of sulphide veins and masses.

Chlorite is silicate of magnesium and aluminium, in which iron commonly replaces some of the magnesium. Biotite is a silicate of magnesium, iron, aluminium, and potassium. Cordierite is a silicate of magnesium, iron, and aluminium. All of these minerals are of similar composition, and may, therefore, be the products of reaction of similar solutions acting under slightly differing conditions of temperature and pressure.

Chlorite and biotite are minerals that exhibit wide variations in composition, so that without chemical analyses it would be impossible to determine the exact composition of these minerals as found in Rouyn district. Something may be learned, however, from the consideration of average analyses, as shown in Dana's Mineralogy.

—	SiO_2 %	Al_2O_3 %	MgO %	K_2O %	Iron oxides %	H_2O %
Chlorite (clinochlore)	32·5	18·4	31	....	5±	13
Biotite	34–40	12–18	10–24	8–9	5–20	1–4
Cordierite	49·4	33·6	10·2	....	5·3	1·5
Rhyolite (average)	75	14	....	K_2O+Na_2O 7–8	1·7	....

It is obvious, therefore, that the conversion of an ordinary rhyolite or a highly silicified rhyolite into a rock rich in chlorite, biotite, or cordierite must involve the elimination of much silica, and the addition of large amounts of magnesia and some iron. Soda, if present, was removed, and where biotite was formed, potash was undoubtedly added. It is difficult without actual analyses to say what may have happened to the alumina, as almost enough is present in the original rock to satisfy the requirements of the new minerals. Where replacement of highly silicified rhyolite occurred, alumina must have been introduced.

The complementary nature of the reactions occurring during silicification and chloritization would appear highly suggestive of some connexion between them. During silicification iron sulphides and silica were added, alumina and soda removed. During chloritization silica was removed, and magnesia, iron, and probably alumina added. The silicifying solution was rich in silica and poor in bases, the chloritizing solution rich in bases and poor in silica. It is to be expected that some genetic relation exists between all the solutions causing alteration and sulphide deposition; in other words, that they emanated from a common source; and in such case it would be expected that gradual rather than rapid changes in composition would occur. The sudden change from a solution of high acidity and low basicity to one of high basicity and low acidity would be unusual and difficult of explanation; so that it is interesting to speculate whether the differing effects might not be produced by the same solution under differing conditions of heat and concentration.

If there emanated from a magmatic source a solution rich in bases, particularly magnesia, with some iron, potash, and alumina, such a solution, while still hot and concentrated, would take up silica and soda from the rocks it encountered, and as it cooled would deposit silicates such as biotite, hornblende, chlorite, and cordierite. Deposition might conceivably continue, with cooling, until the bulk of the basic constituents had separated in the solid form, leaving the aqueous remainder still fairly rich in silica and soda. As the solutions continued to be forced farther and farther from their source through the crevices and pore spaces of the cold country rock, their temperatures must ultimately drop below the saturation temperature for silica; and accordingly this constituent would tend to separate, causing the silicifications observed. Soda, being extremely soluble, would not separate; but part of it, being set free from the soluble compound sodium silicate by separation of silica, might attack the feldspar of the rock, converting part of it into the sodium mica, paragonite, and removing part of the alumina in the form of the soluble sodium aluminate. Some albite would probably also be formed, and this reaction may account for the " spots " of albite and oligoclase-albite in the dalmatianite at the Amulet, and for the small quantities of fresh albite in the altered rocks at the Horne and elsewhere. Meanwhile, as the magnesium-rich solutions continued to pour forth from the magmatic source, the outer boundary of the chloritized zone would continue to advance farther and farther outward until finally it encroached upon the belt of silicified rock; thus producing the phenomena observed today, of chlorite rock replacing silicified materials.

Such a series of reactions, although entirely supposititious, is yet in line with known sequences of deposition elsewhere. It is well known that as magmatic solutions cool, they first deposit their bases as oxides, sulphides, or heavy silicates; with further cooling silica separates, along with a further set of metallic sulphides; and in the final stages silica still separates, accompanied by carbonates and a variety of other minerals.

Are chloritization and silicification associated with the introduction of the iron sulphides or the copper sulphide? This question is one that it is impossible to answer with certainty, because as yet it is mainly the chalcopyrite deposits, and not those of the barren sulphides, that have been opened up and studied. However, a number of facts have accumulated which seem to point to the conclusion that chloritization and silicification, on a large scale at least, were associated with the formation of chalcopyrite and not of pyrite and pyrrhotite.

There appears to be a rough proportionality existing in each deposit between the amount of chloritization and silicification, and the amount of chalcopyrite and zinc blende. Zinc blende is tentatively assumed, until proof is found, to have been introduced locally with the chalcopyrite. On the Horne, where large bodies of chalcopyrite occur, great masses of rock appear to have been altered to chlorite and equally large or larger masses have been highly silicified. On the main zone of the Robb-Montbray property, where the ore is pure chalcopyrite, and pyrite and pyrrhotite are absent except for scattered crystals of pyrite, chloritization and silicification have both occurred on a large scale. The same conditions are present on a smaller scale on the Coniagas property. On the Amulet, where there are large masses of zinc blende and chalcopyrite, biotite, chlorite, and cordierite, all minerals of very similar composition have been formed on a large scale. On the Waite-Ackerman-Montgomery the extent of alteration has not yet been ascertained.

On the Aldermac, on the other hand, where chalcopyrite forms only about 6 per cent of the total sulphides, silicification, though pronounced close to the ore-body, is not effective to any great distance from it; and although chlorite has evidently been introduced, it does not compose more than one-quarter to one-third of the rock body, even close to the ore-body. This is notably different from the conditions on the high-chalcopyrite properties, where much of the rock is transformed into pure chlorite. On the Chance property, where large masses of pure pyrite occur, the rocks near the sulphide bodies, when studied in thin section, exhibit neither chloritization nor silicification. On the Horne property a mass of pyrite about 35 feet wide is found near the northwest corner of block 15. The rocks close to it have not been studied in thin section, but it is obvious to the eye that they have not been chloritized to any extent.

Still further light is thrown on this problem by the study of the alterations produced in the country rocks by small veinlets of pyrite and chalcopyrite, respectively. In studying these, however, great care must be exercised, because both sulphides are found in most of the deposits. In such places it is evident that if a lava were altered close to a pyrite veinlet there could be no certainty that the alteration might not have been due to subsequent action by copper-bearing solutions; or, in the case of a lava altered near a chalcopyrite veinlet, that the alteration might not have been accomplished long before chalcopyrite was introduced.

For this reason it appears safe to consider alteration adjacent to the pyrite veinlets of the Chance sulphide body, since near the surface at least it contains no copper. Of the chalcopyrite veinlets, those cutting the syenite porphyry dykes were selected, as this rock cannot have been affected by the pyrite-bearing solutions because it was formed after the pyrite bodies.

The veinlets on the Chance claims are composed of pyrite and magnetite, with quartz, epidote, actinolite, and an altered feldspar. They alter the rock slightly to a similar mineral association, but do not chloritize it or silicify it excessively. This, therefore, may be considered as a typical pyritic alteration, unaffected by later solutions associated with the copper mineralization; and veinlets and alterations of this type are found on many other properties. On the Aldermac the pyrite veinlets contain larger or smaller proportions of hornblende, and the hornblende appears always to be actinolite; they carry also varying amounts of quartz and epidote, and alter the adjacent rock but slightly. On the Horne property pyrite veinlets in many places alter quartz diorite to a mixture of quartz, actinolite, and epidote.

The manner in which chalcopyrite veinlets alter the syenite porphyry was studied on specimens from both the Aldermac and the Horne. In hand specimen the colour is changed from a reddish to a very dark grey, almost black tint. The microscope shows that the change is due to the conversion of the feldspar of the rock into chlorite, colourless mica or talc, and a little epidote.

It would appear, therefore, that the chloritization and silicification of the rocks are linked with the formation of the chalcopyrite and sphalerite rather than that of the iron sulphides. Very little alteration accompanied the formation of the iron sulphides, and that little was limited to the introduction of some quartz, epidote, and hornblende.

This conclusion explains the opinion formed during the reconnaissance survey of the ore deposits in 1925. At the time one of the writers noted that the chalcopyrite and sphalerite deposits appeared to be confined to the more basic rocks, whereas the deposits of pure pyrite were found in acid rhyolites, and considered this difference to be due to the original composition of the lavas themselves. The later study suggests that the present composition of the enclosing rocks is due to the reactions with the copper-bearing solutions. Where only pyrite was introduced, the containing rocks were altered slightly or not at all. Where chalcopyrite and zinc blende were introduced, there was widespread alteration to chlorite and similar minerals.

It is evident, however, that although the chlorite and chalcopyrite were closely associated, the chalcopyrite was deposited slightly later than the chlorite. This is shown by the fact that chalcopyrite replaces chlorite in many places, as on the Robb-Montbray property. Evidently there was a progressive change in the composition of the solutions, which were at first high in magnesia and the other chlorite-forming elements, and later, perhaps when cooler, contained less magnesia and more copper. That this change could take place is shown in the body of fluxing ore on the Horne property. In this body veinlets of chalcopyrite close to the "E" ore-body are edged with wide, black borders of chlorite, accompanied by pistacite and talc. Farther from "E" ore-body the chalcopyrite veinlets have no altered edges. Clearly, therefore, the solutions continued to carry copper out into the country rock long after their magnesia content was exhausted.

The formation of the "E" ore-body itself would seem to be entirely parallel to that of the little chalcopyrite veinlets last mentioned. This body has long been a curiosity, because unlike any other known body of copper ore in the district it is surrounded by highly siliceous rock. The numerous sulphide veinlets cutting the rock close to it have chloritized edges, but the remainder of the rock in which it lies is not chloritized. The description of the fluxing ore indicates, however, that chalcopyrite may be carried after the magnesia of the solutions is exhausted; and there can be little doubt, therefore, that the "E" ore-body was formed by solutions of this type.

NATURE OF THE SULPHIDE-BEARING SOLUTIONS

It has been shown that the veinlets surrounding the pyrite-pyrrhotite masses are composed of pyrite, quartz, epidote, actinolite, and in places a little albite and orthoclase. Quartz, of course, is pure silica. Common epidote is composed of about 38 per cent silica, 22 to 25 per cent alumina, 14 to 11 per cent ferric oxide, 24 per cent lime, and 2 per cent water. Actinolite consists of about 57 per cent silica, 13 per cent lime, and 29 per cent magnesia and iron, chiefly magnesia. Albite, a very minor constituent, is a sodium aluminium silicate.

Evidently, therefore, the solutions carrying the pyrite were high in iron and sulphur, and carried also silica, lime, and some alumina, magnesia, and soda.

Following the deposition of pyrite came the deposition of some magnetite replacing the earlier-formed pyrite. The amount of magnetite is not large, and only a little information on it is available. Replacement veinlets cutting pyrite bodies on the Horne were found to consist of magnetite, colourless hornblende close to tremolite in composition, and a little quartz. Such a composition would indicate a further increase of iron and decrease of silica, alumina, and sulphur, with probably little change in magnesia and lime.

The amount of magnetite in the deposits is small, and it is probable that its formation was nearly simultaneous with that of pyrrhotite. Little is known of the pyrrhotite, except that it replaces pyrite in many of the sulphide bodies to form the great masses of pyrite and pyrrhotite which have been found in so many places in Quebec. Its formation does not seem to have been accompanied by that of gangue minerals. If it be assumed that the pyrrhotite and magnetite were contemporaneous, it is evident that the solutions forming them must have been rich in iron but comparatively poor in sulphur. For the most part they combined with the sulphur-rich pyrite to form pyrrhotite; but where through such reaction the sulphur content became too much reduced, the formation of magnetite was inevitable.

The copper-bearing solutions were of quite a different type. It has been shown that they were rather closely associated with the chlorite-forming solutions, in fact a slightly later phase of them. The chlorite-forming solutions were at first high in magnesia and low in iron and lime; and as the magnesia content decreased, that of copper and sulphur increased. Eventually the composition changed so greatly that the solutions were able to dissolve chlorite and replace it with chalcopyrite. They also were able to attack and replace the iron sulphide deposits.

CAUSES OF LOCALIZATION OF THE SULPHIDE DEPOSITS

The formation of a body of copper ore, in all the known properties, takes place in two steps, first, the deposition of a body of iron sulphides or of chlorite, and second, the replacement of these substances by chalcopyrite. There are in the area some small veins where chalcopyrite and quartz have been directly deposited, as vein fillings; but these bodies so far as yet known are all small, and of no economic importance. It is necessary, therefore, to consider the two stages of formation separately, when describing the conditions that localized the ore-bodies.

Three factors at least have been operative in localizing the bodies of pyrite, pyrite and pyrrhotite, or chlorite. These are, the presence of suitable fissures through which the ore-bearing solutions might travel, the existence of readily replaceable rock in the path of the solutions, and the presence of dams restraining locally the movement of solutions and thereby causing more intensive local replacement. In addition, such other factors as proximity to some igneous source undoubtedly operated, but as yet the information as to these is scanty.

The existence of fissures controlling the deposition is clearly visible in a number of properties, such as the Robb-Montbray, Coniagas, Newbec, Chance, and in places on the Horne. The No. 2 ore-body on the Aldermac appears to have been also developed along a pre-existing fissure, from which alteration and sulphide deposition spread. The evidence in each of these places is the existence of the fissure or shear zone beyond one or both ends of the sulphide or chlorite mass, the general linear shape of the ore-body, and the more intense alteration or deposition along the line of the fissure. In other places, such as the Aldermac ore-body No. 3, the Amulet ore-bodies, and some of the Horne bodies, no original fissure has yet been found, although it must presumably have existed.

The controlling influence of the nature of the country rock is most strikingly shown on the Chance pyrite deposit (*See* Figure 18), where a mineralized fissure cuts across the bedding of interbanded flows and breccias, and replacement has extended for a long distance from the fissure in the breccias, and for only a short distance in the massive lavas. On the Robb-Montbray, Coniagas, Aldermac, and Horne properties the ores are likewise confined to bands of breccia. The only properties on which the rock replaced was not a breccia are the Amulet and Waite-Ackerman-Montgomery.

The breccias replaced are of two types, dynamic and original. Dynamic breccias are those formed by crushing of massive rocks during folding or faulting. The breccias on the Robb-Montbray, Coniagas, and some of the breccias on the Horne are of this type. Original breccias include flow breccias and ash beds, and possessed the brecciated texture from the time of their deposition. The breccias on the Aldermac, Chance, and most of those on the Horne fall into this class. Either type of breccia is very susceptible of replacement, the dynamic breccia probably more so.

The reason for replacement is undoubtedly to be found in the physical character of the rock. The breccias, particularly the ash beds and the dynamic breccias, were porous rocks, into which solutions could readily enter; and the fine powder of which they were in large part composed presented a very large surface to the attack of these solutions. For these reasons replacement was largely confined to the breccias, if they were present within the radius of action of the solutions.

Certain kinds of rock act in exactly the opposite manner toward the solutions, for whereas the breccias, by reason of their porosity and fine grain, concentrate the action of the solutions within themselves, these others, by reason of their density or coarse grain, resisted the movement of solutions and acted as dams. Several types of rock have functioned in this way. On the Aldermac flows of hard, glassy rhyolite wall in the ore-body, and by their resistance to replacement may have influenced the concentration of sulphide within the interbanded breccias. On the Horne, dykes of diorite form walls to the ore-bodies in many places, and in a few places glassy rhyolites, which are probably dyke rocks, act in the same way. On the Amulet No. 2 ore-body a dipping dyke of rhyolite appears to have influenced the concentration of ore beneath it. On the Robb-Montbray, the sericite developed along small slips tended to dam back the ore-bearing solutions. Many other instances will doubtless appear as development of the region advances.

The Amulet and Waite-Ackerman-Montgomery ore-bodies appear to have been localized by structural dams. These bodies occur, like oil pools, at or near the crests of open, gently plunging anticlines. Ore-bearing solutions, rising along fissures or through the flow-textured amygdaloidal tops of lava flows, could apparently rise no farther when they reached the anticlinal crest, presumably because they found themselves beneath some relatively impervious lava. They were, accordingly, forced to deposit their mineral content, in spite of the fact that no breccias or tuffs occur.

The deposition of the copper sulphide, which forms the second step in the formation of each ore-body, appears to have been dependent on two factors only, namely, the pre-existence of a body of easily replaced material, such as iron sulphide or chlorite, and the presence, in conjunction, of copper-bearing solutions. Copper mineralization is found in many parts of the area, in quartz-chalcopyrite veins up to 2 feet or more in width, filling pre-existing fractures or zones of shear, and in scattered veinlets and grains; but the only bodies of economic importance so far discovered are those in which iron sulphide or chlorite have been replaced by chalcopyrite.

As, therefore, the copper bodies have been formed by replacement of masses of iron sulphide or chlorite by cupriferous solutions, it might be expected that the outer edges of these older masses would be the parts first attacked, except in those instances where fissuring permitted the copper solutions to penetrate to the interior. In many instances, accordingly, one might expect to find one or both ends or the bottom of a lens of iron sulphide or chlorite altered to chalcopyrite, while the remainder was still unreplaced. In general, development has not yet advanced far enough on most of the properties to test the validity of this theory; but three of the ore-bodies on the Horne appear to support the conclusion.

ORIGIN OF THE SULPHIDE BODIES

It has been shown that the older sulphide bodies are composed of pyrite and pyrrhotite, and that magnetite, epidote, actinolite, and feldspar are commonly found associated with them. Such a mineral association is characteristic only with very hot and concentrated solutions; and it must, therefore, be concluded that the bodies of iron sulphide were formed at great depth, and from solutions which either emanated from cooling masses of igneous rock, or were heated by them and received a great part of their mineral content from them.

Similarly, the copper-bearing solutions have been shown to be intimately associated with chlorite-forming solutions, which carried large quantities of magnesia and smaller amounts of iron, alumina, silica, and so on. They were undoubtedly, therefore, of magmatic origin, although the fact that they formed chlorite suggests that they were much less hot than the pyrite-depositing set. Hotter solutions would tend to form biotite rather than chlorite; and the widespread formation of this mineral at the Amulet suggests that this area may have been closer to an igneous source than the others.

It has been suggested in past reports that the source of the sulphide solutions may have been the reservoir from which came the great bodies of quartz diorite, or older gabbro. This reservoir was evidently in existence for a long time, since at least four sets of dykes and sills, of differing age, are known to have been extruded from it. The chief evidence connecting the quartz diorite with the ore-bodies lies in the distribution of the two; both are confined to an area 30 or 35 miles in diameter adjacent to the interprovincial boundary. Any connexion between the two could, of course, be with the iron sulphides only, as the age of the copper sulphide is much later.

Observations made at the Aldermac mine in 1929 showed, however, that iron sulphides there replace some of the older varieties of the Aldermac syenite porphyry, and are cut by dykes of the later varieties of porphyry.

This observation definitely fixes the time of deposition of the iron sulphide masses within the period of porphyry extrusion, and also, probably, as later than the quartz diorite or older gabbro; because, so far as known, all the varieties of porphyry are later than the diorites. It is reasonable also to infer, because of the intimate age relationship, that the reservoir of magma from which the porphyries came also gave rise to the sulphide-bearing solutions.

Attention has already been drawn, in Chapter VI, to the fact that there are seven known masses of these peculiar porphyries in the western part of the area, grouped within an area roughly 15 miles square. The distibution is thus similar to, though more limited than, that of the quartz diorites; so that any argument based on distribution applies with equal force to either.

Nothing is yet known of the possible source of the copper-bearing solutions. The much later age of the chalcopyrite, and the fact that the chemical composition of the copper-bearing solutions was quite different from that of the iron-bearing solutions, both point to the conclusion that they were derived from separate sources. The general association of the copper deposits with the iron sulphide masses may be due in part to the fact that both sets of solutions made use of the same channels of escape. It is undoubtedly due in part to ready replaceability of the iron sulphides. The Robb-Montbray and Coniagas occurrences show, however, that it was possible under suitable conditions for the copper solutions to form ore-bodies where little iron sulphide was previously present; and it may eventually prove that many such will be found, even in areas outside of the sphere of influence of the older gabbro.

During the field work of 1929 it was observed that the central part of the Lake Dufault intrusive, a very coarse-grained diorite, grading into aplite, has so differentiated as to give rise on the upper, or eastern, side, to masses of highly siliceous micropegmatite; and further that the micropegmatite was later altered in some way, so that most of its feldspar is now replaced by chlorite. A rock of very basic appearance, but full of quartz, has thus been produced. The limitation of this chlorite alteration to the micropegmatite suggests that it was caused by solutions emanating from the cooling magma itself; and the similarity of the alteration to that occurring near the copper bodies hints at the possibility of some connexion between the two. The main objection to such an hypothesis, at present, is that no part of the Dufault intrusive, so far as known, is younger than the later gabbro; and the chalcopyrite was, according to the evidence given, formed after the intrusion of that rock.

As to origin, therefore, it is really known only that both the iron-bearing and the copper-bearing solutions ascended from greater depths and were highly heated. The iron-bearing solutions probably came from the magmatic reservoir that likewise supplied the various bodies of coarse-grained, very sodic syenite porphyry. There is little information as yet as to the source of the copper-bearing solutions.

GOLD DEPOSITS

The gold deposits of Rouyn-Harricanaw region may be classified in several ways. They may be grouped according to their position into a northern and a southern belt; they may be divided according to their physical characteristics into replacement deposits, fissure veins, and shear zone deposits; their mineralogical characters also afford a third basis of subdivision.

Up to the present time only one of these deposits, the Siscoe, has been brought to the producing stage, although a 10-ton sampling mill is operating on the Thompson-Cadillac, and some high-grade ore has been shipped from the O'Brien property. Some deposits have been tested and have proved too small or too low grade for mining. On others, development work is actively proceeding, but their ultimate worth is still to be proved. The most promising properties at this time appear to be the Siscoe, O'Brien, Thompson-Cadillac, Graham-Bousquet, and Granada.

The subdivision into veins and replacement deposits is possibly the most useful to the prospector. In the replacement deposits the ore consists of altered and mineralized country rock, with minor quantities of vein material. Replacement may be mainly by silica, as in the Malartic mine, or by carbonate with some silica, as on the Arntfield property. The replacement deposits tend to form large bodies of low-grade ore.

The veins may be further subdivided into fissure veins and shear zone deposits. The former consist, in the main, of a single tabular body of quartz and other vein minerals. The shear-zone deposits are composed of a series of approximately parallel veins or lenses of quartz separated by schistose, altered, and mineralized country rock. The fissure veins fill cracks where there has been little differential movement of the walls; the shear-zone deposits, as the name implies, were formed by infiltration of quartz and sulphides into a band of rock rendered schistose by faulting.

The gold deposits may be classified according to composition into six subdivisions, namely, high temperature veins, made up of glassy, usually dark, quartz, and in places some tourmaline or hornblende and free gold; quartz-chalcopyrite veins; quartz-tourmaline veins; quartz-pyrite veins; silica replacements; and carbonate-silica replacements.

The high temperature veins are found mainly in the Timiskaming series to the south. Quartz forms the great bulk of the vein material, and in nearly all cases is of a dark smoky colour and glassy texture. The quartz, under the microscope, is seen to contain gas and liquid inclusions, and a few small, dark needles that may be rutile. Where gold occurs it is always free, and some veins of this type have yielded very spectacular specimens of free gold; but most of them are barren. The wall-rocks, for a few inches from the veins, are commonly enriched with pyrite or arsenopyrite, or both, with iron carbonate, and in places a little tourmaline. The mineralized wall-rock commonly carries low values in gold.

Great numbers of these veins occur throughout the Timiskaming greywackes in Rouyn, Joanne, Bousquet, Cadillac, and Malartic townships. Wide zones of the schistose greywacke are netted with irregular veinlets injected parallel to the schistosity, and also cutting across the schistosity from one veinlet to the next. Many of these deposits have been staked and prospected, but none has as yet proved to be of permanent value.

Into the same class fall the Granada deposits in southern Rouyn township and the Clark-Reid veins in Bourlamaque township. In these, however, the veins are of larger size and hold some future promise. The veins of the O'Brien, Thompson-Cadillac, and Graham-Bousquet properties are also placed in this class, although in these veins sulphides are found in the quartz as well as in the wall-rocks.

Closely allied to the high temperature veins described are the quartz-tourmaline veins, of which the Unison, Sullivan, and Siscoe properties in Dubuisson township afford examples. They differ from those of the first class in containing abundant tourmaline. Many of them exhibit two stages of vein formation, the earlier a deposition of quartz with a little tourmaline, some calcite, and free gold, the later a deposition of quartz with much tourmaline, up to pure tourmaline in places, accompanied by some albite, calcite, pyrite, and gold. Where both stages are present, as on the Siscoe property, the later may cut across the earlier, or veins of the earlier type may be re-opened and the fissures filled with vein material of the later type. The quartz of these veins, both earlier and later, is white rather than blue or smoky; the gold is nearly all free, and is commonly associated with the tourmaline. The wall-rocks are altered for distances of an inch or two to fresh albite, with addition of a little tourmaline and pyrite.

Quartz-chalcopyrite veins occur on the Stabell property and also east of Fisher. The quartz, of the ordinary white variety, is associated with a good deal of chalcopyrite, which, though not the principal sulphide of the veins, is usually highly auriferous and carries the bulk of the gold values. High temperature minerals such as pyrrhotite and tourmaline may usually be found, and a good deal of carbonate is present. Free gold is entirely absent, except close to the surface where it has been released from chalcopyrite by weathering. In the Stabell vein the wall-rock is little altered, but many of the veins east of Fisher are bordered by wide zones of highly carbonated volcanics.

Veins of the quartz-pyrite type are found on the Martin, St. Germaine-Gale, and Russian Kid claims. The vein matter consists mainly of white quartz, in many places of a sugary texture, with more or less pyrite and a little calcite. The wall-rock is carbonated and enriched with pyrite for distances varying from 1 inch to 2 feet from the vein. No free gold appears, except in the weathered surface parts; the gold appears to be bound up with the pyrite. Values are usually rather low.

The siliceous replacement bodies are as yet exemplified only on the Malartic property, in Fournière township. The Timiskaming greywackes have been metamorphosed to glistening masses of fine-grained silica rather high in pyrite, netted with veins and stringers of quartz. Some free gold is present, and a little mica, feldspar, galena, and chalcopyrite. The silicification appears to be closely associated with the intrusion of small masses of a feldspar porphyry. Large widths of low to medium-grade ore have been formed.

Carbonate replacements are found on the Arntfield and Francoeur properties, and on claims held in 1925 by the Huronian Belt Company. The country rocks, which on these claims are Keewatin lavas and tuffs, are more or less completely replaced by carbonates and pyrite, and are netted with veinlets of quartz, carbonate, pyrite, and albite. Free gold is rarely seen, but the variability of the assays suggests that it is probably present, though in a finely divided condition. The alteration has produced fairly good-sized bodies of gold-bearing material, the tenor of which, however, appears to be somewhat too low for mining.

MOLYBDENUM DEPOSITS

Pegmatite veins carrying commercial percentages of molybdenite, the sulphide of molybdenum, are known in Preissac and La Corne townships. Those in Preissac have been known for many years, but the La Corne discoveries are more recent.

The principal use of molybdenum is for hardening steel. In the past the price of this metal has fluctuated widely because of the great variations both in the amounts produced and the quantities used; and this instability of price has been a chief obstacle in the way of mining. A second hindrance to mining has been that tungsten has been used for much the same purposes as molybdenum, and can be produced for about half the cost. Special uses for molybdenum are gradually being developed, however, which it is hoped will eventually stabilize the market. Molybdenum is commonly sold as the alloy, ferro-molybdenum, which contains 50 to 60 per cent of metallic molybdenum. In this form the metal brings, at present, about $1.25 a pound.

To be marketable, the ores must be reduced to a concentrate containing at least 80 per cent of molybdenite. Bismuth and copper, particularly the latter, are deleterious constituents. More than one per cent of copper in a high-grade concentrate renders the material unmarketable. A good deal of bismuth occurs with the Quebec ores, but may readily be got rid of by roasting the concentrates.

The molybdenite occurs in veins of quartz and pegmatite that are the end-products of the crystallization of granite masses. These veins traverse the granite, and the schists near the granite margin, in considerable numbers. The distribution of the molybdenite deposits is, therefore, coincident with that of the granites. A second factor necessary to the occurrence of these veins appears to be the presence of bodies of ancient sediments metamorphosed to biotite schist. No veins have as yet been found where the granites are in contact with Keewatin lavas or any rock other than the biotite schists. The reason for this peculiar relationship is unknown.

The principal constituent of the veins is quartz, which in many places has a rosy tint, but some feldspar is almost invariably present, and in places there is so much that the vein material becomes a pegmatite. Muscovite is another principal constituent, and is usually concentrated along the walls of the vein. Molybdenite, bismuthinite, chlorite, fluorite, and pyrite occur in smaller quantities, and beryl, chalcopyrite, native bismuth, zinc blende, and phenacite (beryllium silicate) have been identified.

The molybdenite-bearing veins range in size from a few inches to 15 feet in width. Some of them have been traced for considerable distances, but the length in general is not great. Many are quite irregular in shape and strike, and tend to break up by forking. In Preissac township the veins in the granite usually vary in strike from west to north 50 degrees west; but those in the schist tend to follow the strike of the schistosity, which roughly parallels the granite contact. In La Corne township the general strike is east-northeast.

Molybdenite occurs in the veins in hexagonal crystals and irregular flakes either irregularly disseminated through the quartz or, more commonly, associated intimately with the mica. On the property of the Height of Land Mining Company, crystals, in some places, are 1 to 2 inches in diameter and 1 inch thick; elsewhere they are usually much smaller. Weathering in places converts the molybdenite to molybdite, the oxide of molybdenum, and thus imparts a yellowish colour to the veins.

Bismuthinite, the other common mineral, tends to occur in long and very thin blades. The largest observed was 11 inches long, about ½ inch wide, and very thin. It is clearly a later product than the molybdenite, as it occurs in fracture-planes in the veins, has been observed to include minute crystals of molybdenite, and in one instance to form a pseudomorph after molybdenite.

Pyrite occurs as large cubes and irregular granular aggregates. Beryl, where found, occurs in large crystals up to 3 or 4 inches in diameter, in nests packed about by flaky muscovite. Deep purple fluorite appears as widely separated grains, or as a film on slickensided surfaces.

The deposits of molybdenite and bismuthinite are very erratic, occurring in pockets or streaks in the quartz veins. In general, the percentage of molybdenite is much higher in the micaceous parts of the veins. On the property of the Height of Land Mining Company some large pockets of comparatively pure molybdenite have been found, one of them said to contain 500 pounds of the mineral. On account of the wide variation of molybdenite content from place to place it is impossible to sample the deposits satisfactorily except by mill tests of large quantities. To be ore, the vein materials must average at least 1 per cent molybdenite; the veins now being mined in La Corne township average about 2 per cent.

CHAPTER X

SULPHIDE DEPOSITS

Aldermac Mines

LOCATION AND HISTORY

Aldermac Mines, Limited, own seven claims in the western half of Beauchastel township close to the east-west centre line. The claims are Nos. M.L. 1951, 1952, 1953, and T. 2986, 2987, 2988, 2989, 2990, with a total area of 747 acres. The mine itself lies approximately 3 miles 1,000 feet from the west boundary of the township, and 4 miles 3,300 feet from the north boundary.

The property originally belonged to the Towagmac Exploration Company, who discovered the ore-body by dip-needle exploration in the autumn of 1925. During development a 65 per cent interest was sold to N. A. Timmins, Incorporated, and this interest was later transferred by him to Noranda Mines. In 1927 the property was incorporated under the name of Aldermac Mines, Limited, of which Noranda Mines held 60 per cent of the stock, and the Towagmac Exploration Company 35 per cent. Up to 1929 the property was managed directly by Noranda Mines, with Alderson and MacKay of the Towagmac Exploration Company as consulting engineers. Toward the end of 1929 arrangements were made whereby control of the company reverted to the Towagmac Exploration Company.

Attention was first attracted to the area by a highly rusted belt of rocks about 500 feet north of the centre line of the township, on claim M.L. 1953. The rusty rock proved to be a well-mineralized rhyolite tuff, but no body of ore has yet been found in it. North of the tuff band, however, there is a body of dark lava somewhat similar in composition and appearance to the dalmatianite in which ore-bodies occur at the Amulet; and in this were discovered two small bodies of sulphides, known as Nos. 1 and 2. A careful dip-needle survey of the property was then made, by which an area of strong magnetic attraction was located in swamp near the north boundary of M.L. 1953. Drilling at this point resulted in the discovery of No. 3 ore-body, a large mass of sulphides that does not reach the surface. While exploring the extension of this body at depth, No. 4 ore-body was found vertically beneath No. 3.

A detailed examination of the mine and the surrounding area was made by Survey officers in 1927, and most of the information in the following pages was obtained then. At that time, however, only the 125-foot level had been explored. Brief visits have since been made in 1928 and 1929, but no detailed study of the deeper workings has been attempted.

Development has been extensive. An exploratory shaft was sunk to a depth of 1,125 feet, and levels run at 125, 250, 500, 750, and 1,125 feet. Up to October, 1929, approximately 600 feet of lateral work had been done at the 125-foot level, somewhat more at the 250-foot, and more than double this amount at the 500-foot. At the 750-foot level only the station had been cut. The bulk of the exploratory work had been carried on at the 1,125-foot level, where aproximately 3,300 feet of drifting was done. At this level not only has the ore-body been investigated, but a long exploratory drift was run northeast to the dyke of later diabase, near which, it was hoped, other ore-bodies might be found. These expectations, however, were not realized. A large amount of diamond drilling has been done, mainly from the various levels, and the whole property has been prospected by electrical methods.

GEOLOGY

The geology of the area round the mine, as mapped by Mr. W. Samuel, resident geologist, is shown in Figure 12 in a generalized form. The rocks consist of a variety of Keewatin flows and tuffs, mostly acid in composition, invaded by dykes of quartz diorite, syenite porphyry, and later gabbro.

The rock in which showings Nos. 1 and 2 occur is very dark grey, almost black, on the weathered surface, and filled in places with small, rounded nodules or "spots" averaging about one-eighth inch in diameter, with a maximum size of one-quarter inch. In a few places the spots are crowded together; more commonly they are $\frac{1}{4}$ inch to 1 inch apart; and there are also considerable areas in which no spots appear. The spots weather to a slightly lighter shade than the matrix. On a fresh surface the spots are rather difficult to see, but appear blacker than the matrix. The spotted parts tend to form rounded masses 3 or 4 feet in diameter, somewhat like pillows, and the material between either lacks spots entirely or contains only a few scattered spots.

In texture the rock is fine grained, equigranular, and amygdaloidal, the amygdules filled with quartz and pyrite. The whole body of the rock is also rather heavily mineralized with fine-grained magnetite and pyrite. It is composed mainly of biotite and quartz, the quartz forming perhaps 25 to 35 per cent. The biotite has been altered in part to chlorite, and other parts appear to have been bleached. No feldspar was found in any of the thin sections, nor could the spots be distinguished under the microscope. The composition thus suggests much alteration and silicification of the original rock.

ORE-BODIES NOS. 1 AND 2

The No. 1 showing in this spotted rock is a small shatter zone lying apparently almost flat, and filled with pyrite and some chalcopyrite. It is only about 25 feet across. About 25 feet to the northeast there is another spot of heavy mineralization. The No. 2 showing is about 200 feet to the north. It is a lens traceable on the surface for about 130 feet, and striking due east. The middle 2 feet of the lens is almost solid sulphides, and the surrounding rock is heavily impregnated with sulphides throughout a total width of about 15 feet. There is rather more chalcopyrite in this showing than in No. 1.

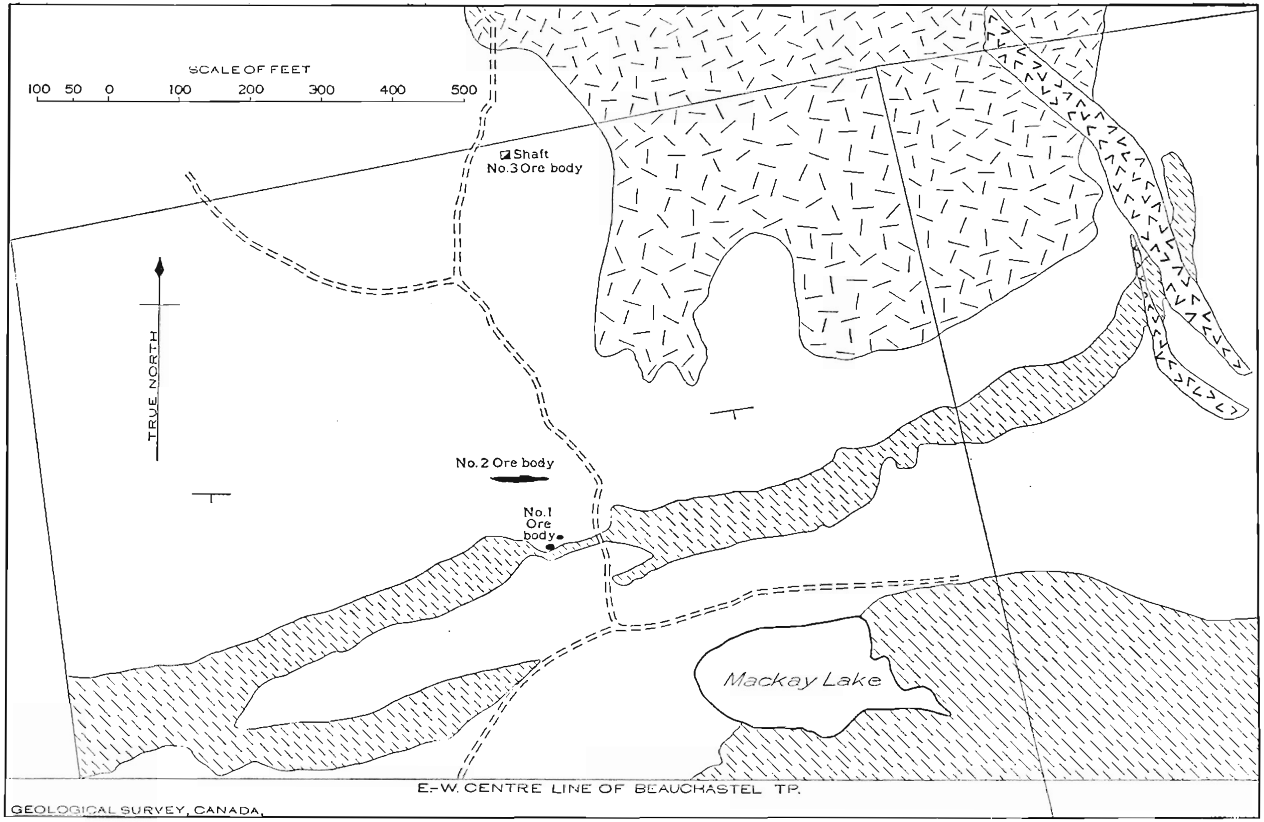

Figure 12. Surface geology, Aldermac mine, Quebec. Later gabbro shown by pattern of angles; syenite porphyry shown by pattern of angles; syenite porphyry shown by pattern of irregular pecks; quartz diorite shown by diagonal broken ruling; Keewatin flows and tuffs; dykes, shown by blank areas.

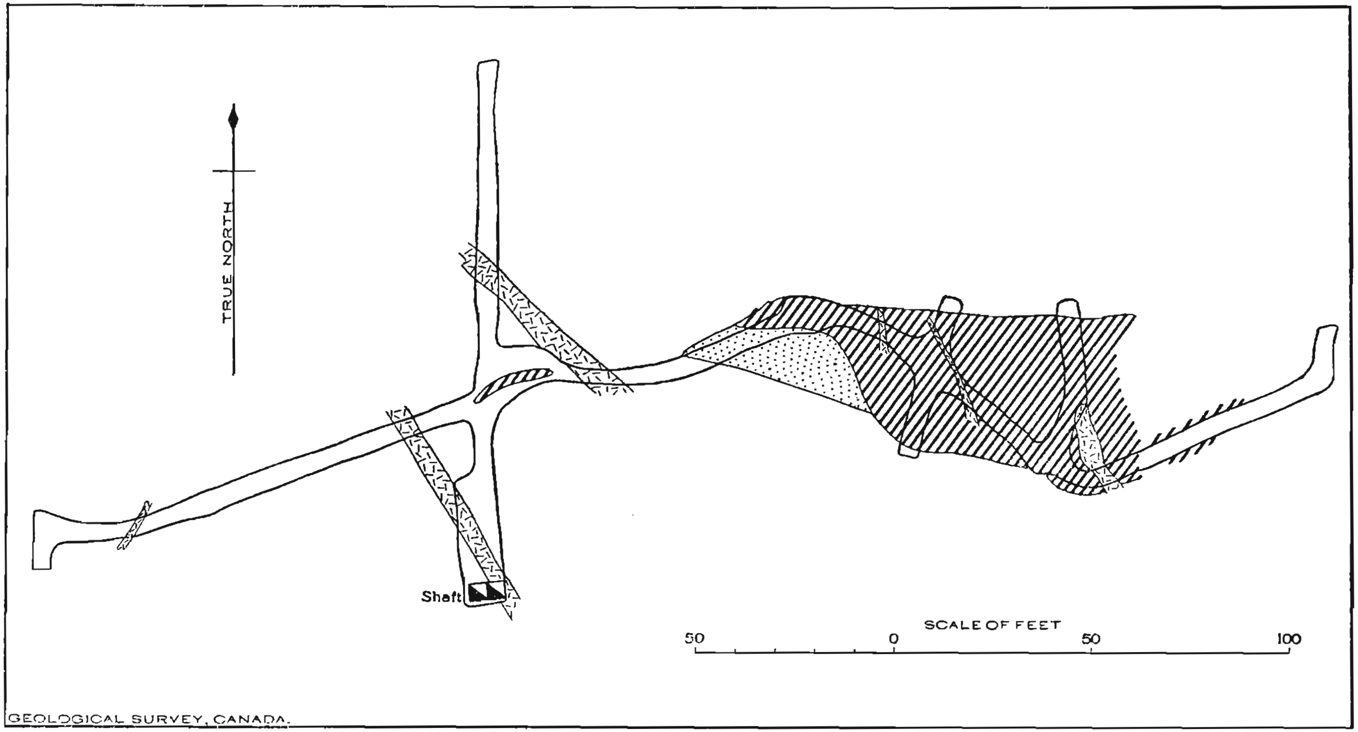

Figure 13. Aldermac mine, Quebec; plan of the 125-foot level, July, 1927. Syenite porphyry shown by irregular pecked pattern; breccia shown by stipple; ore shown by heavy diagonal ruling.

ORE-BODY NO. 3

Ore-body No. 3 does not come to the surface, but has been tapped by the underground workings at the 125-foot level (Figure 13) and the 250-foot level. It is a lens striking roughly east-west, and dipping about 60 degrees south. On the 125-foot level it has been proved for a length of 130 feet, and it has a maximum width of 40 feet of solid sulphide. On the 250-foot level, according to information received from Alderson and MacKay, it is more than 200 feet long and about 55 feet wide. The underground workings on the 500-foot level have opened up two lenses, one 60 feet long and 16 feet wide, the other 30 feet long and 10 feet wide, which are looked on as the possible downward continuations of No. 3 ore-body.

The rocks north and south of the lens of ore are hard, massive rhyolite lavas. In hand specimen the rhyolite to the south appears more chloritic than that to the north, but under the microscope little difference in composition is observable. Both consist of quartz and altered feldspar in about equal proportions, with a little biotite and muscovite; the feldspar is about altered to aggregates of sericite with some epidote. In places the rhyolite around the edge of the ore-body is filled with veinlets of varying composition. Some are reddish replacement veinlets composed of albite with a little orthoclase and carbonate. Others, in appearance very like the last, are composed mainly of carbonate. Still others are composed of black hornblende, with some quartz and calcite; and there are many made up of hornblende with much quartz, and carrying also epidote, pyrite, and some very fine-grained, highly birefringent material that may be mica. The rock for a short distance on each side of the latter type of veinlets has altered to a whitish product composed of quartz, some epidote, and much of a substance resembling leucoxene. The relationship of these veinlets to each other and to the ores has not been determined.

At the west end of the ore is a body of rhyolite breccia exposed in the drift for 30 feet. Like the ore, this breccia appears to lie between the rhyolite flows described in the last paragraph. It is made up of numerous, rounded and angular, light grey fragments of all sizes up to 3 or 4 inches in diameter, in a fine-grained, darker matrix. In thin section about 50 per cent of the matrix is seen to consist of quartz in grains averaging 0·02 mm. diameter, although a few of larger sizes are present; the remainder is mainly chlorite, with a little biotite, and a good deal of pyrite. The chlorite is in rather large, aggregated masses, and the pyrite is always associated with these masses. As the bulk of the pyrite is not an original constituent of the rock, but is known to have been introduced, and as the massing of the chlorite crystals is more characteristic of replacement than of an original constituent, it seems likely that the chlorite, also, in large part at least, has been formed by replacement.

The whitish fragments in the breccia have about the same grain as the matrix, 0·02 mm., but are so highly siliceous as to resemble a quartzite. Quartz composes 80 to 90 per cent of the thin section examined, the remainder being almost colourless mica.

At the most westerly point where the breccia appears in the drift, its matrix is rather thickly sprinkled with pyrite, but there is very little in the whitish fragments. The breccia is also cut by numerous veinlets up to an inch wide, some of them composed of pyrite only, others of pyrite and hornblende. Presumably these veinlets were the sources from which migrated the pyrite and hornblende or chlorite now scattered through the breccia. Toward the east the amount of pyrite becomes rapidly greater, and as this takes place, grains of pyrite begin to appear in the white fragments of the breccia as well as in the matrix. A few feet farther, and the matrix is completely replaced by sulphide, but the white fragments are still in part unreplaced. Finally the whole rock is converted to a solid mass of sulphide.

These facts made it appear that the sulphide mass was formed by replacement of a lens of breccia lying between two flows of rhyolite. To test the conclusion, search was made at all the visible contacts of the ore-body to see if remnants of breccia might be found. In three places such remnants were discovered. About 110 feet east of the shaft a crosscut has been run south from the main drift. The heavy sulphides extend to within 4 feet of the south end of the crosscut, and beyond them is rhyolite heavily sprinkled with pyrite. About 8 feet from the south end of the crosscut, the sulphide contains a number of light-coloured fragments identical with the fragments in the breccia. It was concluded, therefore, that the breccia had extended to this limit, and had been replaced, and also that the replacing agent had reacted with the massive rhyolite, converting it into sulphide for 4 or 5 feet beyond the edge of the mass of breccia. Again, on the south side of the main drift, at points 155 feet and 180 feet from the crosscut leading to the shaft, widths of 2 or 3 inches of the breccia were found at the edge of the ore-body. These facts, therefore, justify the conclusion that the ore-body was formed by the replacement of the breccia.

The sulphide mass is composed mainly of pyrite, pyrrhotite, and chalcopyrite. Practically no zinc sulphide is present. Pyrite formed at the outside edges of the mass where replacement of the original rock is incomplete. Pyrrhotite forms the bulk of the central part of the sulphide mass. Chalcopyrite forms irregular replacement veinlets and larger masses cutting the pyrrhotite and pyrite, and hence has evidently been introduced at some date subsequent to the formation of the iron sulphides.

A detailed examination of polished sections of the ore has been made for the mine by Dr. Ellis Thomson of the University of Toronto; and, through the kindness of Alderson, MacKay, and Armstrong, his report was made available. The conclusions reached by Dr. Thomson may be summed up as follows:

The deposit is a replacement. The evidence of replacement is very definitely shown by numerous pseudomorphs of the metallic minerals after rock-forming minerals like feldspar and hornblende. In most of the specimens examined, also, feldspars and hornblendes could be observed in all stages of replacement. The replacement of the feldspar was particularly well shown, the sulphides invading them along the cleavage and twinning planes.

Much of the feldspar present is secondary albite, formed after the introduction of the first-formed sulphide, pyrite. It will be recalled that fresh albite was found in some of the veinlets near the ore-body, so that Dr. Thomson's work may indicate when these veinlets were formed.

The metallic mineralization was the result of successive periods of deposition. Pyrite was the first mineral to be formed, then, in succession, magnetite, pyrrhotite, sphalerite, and chalcopyrite. Each of these minerals replaces to some extent those deposited earlier.

Some quartz was deposited throughout the whole period of metallic deposition, particularly along with the pyrite, after the chalcopyrite, and to a lesser extent after the magnetite. A little carbonate was formed at the very end of the period of deposition.

Relations of Ore to Porphyry Dykes. The ore-body is cut on the first level by three dykes of syenite porphyry, offshoots of the larger mass of these intrusives directly to the northeast. The dykes strike northwesterly along varying courses, and dip northeast at angles of 70 to 80 degrees. They are coarsely porphyritic rocks, made up of numerous, large, reddish, or brownish phenocrysts of feldspar in a darker matrix. The dykes cut through the ore-body, indicating either that the porphyry is intrusive into the ore-body, or that if it were there before the ore was formed, it resisted replacement. In the latter case some little replacement would have taken place around the edges, creating an irregular, embayed boundary. This is not the case, however; the edges are very clean cut, and as straight as if drawn with a ruler; the porphyry, therefore, is presumably intrusive into the ore-body. The edges of the dykes are strongly chilled over widths of 3 or 4 inches. The chilling is especially well shown in the reduction in size of the phenocrysts, which in the chilled edge average only about one-quarter of their size in the centre of the dykes. A number of measurements showed the average large feldspar in the centre of the largest dyke to be from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches in length and $\frac{3}{4}$ inch to 1 inch in width, and there are a number of still larger size, 2 to $2\frac{1}{4}$ inches in length. The largest phenocryst found in the chilled edge was only $\frac{1}{2}$ inch long and $\frac{1}{8}$ inch thick. Again, the porphyry in places sends small stringers into the mass of sulphides. One such stringer about 1 foot long was seen in the crosscut running north from the main drift 155 feet from the crosscut leading to the shaft. All these facts point to the conclusion that the dykes are intrusive into the sulphide masses.

In apparent contradiction to the above facts, veinlets of sulphide in places penetrate the porphyry dykes; and a 4-inch offshoot of the largest porphyry dyke is crossed in several places by veins of sulphide. The apparent contradiction disappears, however, when these veinlets are closely examined. They consist not of pyrite and pyrrhotite mainly, like the bulk of the sulphide mass, but of pure chalcopyrite. It has already been stated that the chalcopyrite is later than the pyrite and pyrrhotite, as it forms replacement veinlets in these sulphides. The relations of the chalcopyrite to the porphyry, therefore, are evidence that the chalcopyrite was introduced at some time after the intrusion of the porphyry dykes; whereas the general relations of the dykes to the sulphide mass indicate that the pyrite and pyrrhotite were formed before the intrusion of the dykes.

An interesting bit of evidence in support of this general conclusion was found in the crosscut running north from the main drift 155 feet east of the crosscut to the shaft. A dyke of porphyry at this spot bends sharply, almost at right angles. Several veinlets of chalcopyrite one-tenth to one-twentieth of an inch in width, cut the pyrrhotite close to the contact, and parallel the contact perfectly around the sharp bend. Evidently the forces that fractured the pyrrhotite so as to permit the entry of the porphyry magma, likewise produced a number of minor parallel fractures; and into these narrow channels the copper-bearing solutions were later able to enter, and form the little replacement veinlets observed. It must be concluded, therefore, that the chalcopyrite is later than the porphyry.

ORE-BODIES NOS. 4 AND 6

Ore-body No. 4 lies vertically beneath No. 3. It appears to dip somewhat more steeply southward than No. 3, and to rake somewhat to the west, whereas No. 3 rakes east. The outlines of the body are not yet fully known. Its top lies somewhere between 250 and 400 feet below the surface, but has not yet been located. The shaft enters it at a depth of 412 feet, and leaves it at 698 feet. The lower boundary, in the shaft, is a fissure that is probably a large flat fault. On the 500-foot level the body has a length of about 240 feet, and a maximum width of 140 feet. The ore differs from that of No. 3 body in containing a large proportion of pyrite, and comparatively little pyrrhotite; the percentage of copper is about the same.

On the 1,125-foot level the ore-body lies slightly northeast of the shaft, and is about 300 feet long by 200 feet wide. The size, shape, and mineralogical character render it probable that this mass is the downward continuation of the No. 4 ore-body; but it lies too far to the northeast for this to be true, unless the ore-body has been faulted, or has changed its dip and rake. It seems likely that the lower part of No. 4 has been shifted to the northeast by the fault that bottoms it in the shaft; but underground work is not yet detailed enough to prove this. In the meantime the management commonly refer to this ore-body as No. 6.

The average copper content of all three ore-bodies is somewhat less than 2 per cent. It has been found, however, that wherever a dyke of porphyry cuts the ore, the copper content is greater over widths of several feet on each side of the dykes. In such places the copper content may rise to 5 or 6 per cent. This interesting relationship was found due to the fracturing induced in the lean sulphides by the strains of dyke intrusion. The lean sulphides, for some distance on each side of a dyke, are fissured with little cracks parallel to the dyke walls, and these cracks have been filled with chalcopyrite. In some places the action has proceeded farther, and the lean sulphides are partly replaced by chalcopyrite emanating from the veinlets.

Relations of Ore to Porphyry. A relationship of unusual interest is displayed on the 500-foot level. A body of porphyry, instead of cutting the lean sulphides as usual, has been invaded and partly replaced by them, so that both pyrite and pyrrhotite, as well as chalcopyrite, are found within the porphyry.

The Aldermac porphyry mass (*See* page 112) is a complex of dykes of varying composition, not a single mass; and these dykes vary in age, the more basic being the older, the more acid the younger. The porphyry partly replaced by the iron sulphides proved, on examination, to be one of the older, more basic dykes. A younger, more feldspathic dyke in contact with it cuts through the sulphides in the usual manner, and is not replaced by them.

This occurrence, therefore, fixes with considerable accuracy the date of the formation of the pyrite and pyrrhotite bodies. They must have formed at about the middle of the period of porphyry injection; the middle, because the porphyry replaced by them is by no means the most basic of the series, and the porphyry cutting them is far from the most siliceous. The data also strongly suggest that the pyrite and pyrrhotite bodies are connected in origin with these peculiar porphyries; so close an association in age and in localization implies the probability of a common origin.

SUMMARY

The relations existing at the Aldermac mine, therefore: (1) date the pyrite-pyrrhotite bodies, as forming during the period of porphyry intrusion, and suggest a genetic relationship between the intrusions and the mineral bodies; (2) date the chalcopyrite as forming after the pyrite-pyrrhotite masses, and after the later varieties of porphyry. They are also of interest (3) because of the localization of No. 3 ore-body in a lens of rhyolite breccia; and (4) because of the nature and limitations of the alteration of the country rock. The latter is transformed into a highly siliceous rock with introduction of chlorite and pyrite, but this alteration is confined to a zone a few feet wide around the ore-body.

Noranda Mines

LOCATION AND HISTORY

The property of Noranda Mines, Limited, lies directly west of Osisko (or Tremoy) lake, in Rouyn township. It includes a block of sixteen full claims and a number of small fractional claims. Three discoveries have been made on the property, the Powell gold-quartz vein, the Chadbourne gold discovery, and the Horne copper-gold mine. The first two are described under "Gold". Attention will here be confined to the Horne mine, situated in Block 15 near the west shore of Osisko lake.

This property was staked in 1920 by Mr. E. H. Horne, acting for a small syndicate. The earlier discoveries, as seen in 1922, consisted of bands of rhyolite rather heavily impregnated with grains of pyrite and a little chalcopyrite, lying west and southwest of what is now shaft No. 2, and a wide vein of massive pyrites near Horne creek. Although assays from the surface showed high gold values, these proved wholly due to concentration of gold at the surface by weathering. Unweathered materials were later found to carry only about $2 in gold a ton, and a little copper. The heavy and widespread mineralization encouraged prospecting, however, and in

August, 1922, Mr. Horne and his associates optioned the property to the syndicate which shortly afterwards became Noranda Mines, Limited. As the exploratory operations of the syndicate were at first concentrated on the Powell vein and the Chadbourne discovery, little but assessment work was done on the Horne until late in 1923, when trenching disclosed the large body of copper and iron sulphides now known as "A" ore-body. After some preliminary drilling the company began the No. 1 shaft on this ore-body, at the same time continuing an active program of surface prospecting. The latter resulted in the discovery of "F" ore-body, a mass of iron sulphides containing low copper and rather high gold values; and this was further explored by No. 2 shaft, situated about 1,050 feet northwest of shaft No. 1.

The No. 2 shaft was carried only to the 100-foot level, where sufficient lateral work was done to outline the "F" ore-body on that level, and to cut a body of zinc ore lying a short distance to the north of "F" ore-body. The bulk of the underground exploration was carried on from the No. 1 shaft, which was sunk to a depth of 300 feet, and levels run at 100-foot intervals. A number of ore-bodies have been explored by these workings, and are distinguished alphabetically as "A", "B", "C", "D", "E", and "K" ore-bodies. Later, a long drift was run to connect the Nos. 1 and 2 shafts on the 100-foot level, known locally as the Montreal drift; and this drift cuts across the largest body of sulphides on the property, a band of pyrite and pyrrhotite some 150 feet wide, termed the "H" ore-body.

In addition to the ore-bodies outlined by underground exploration a number of others have been found on which little exploration has yet been done. These include a mass of copper ore some 200 feet in length, which was found about 225 feet east-northeast of the No. 2 shaft when removing gravel from the hilltop for use in construction of the smelter; a body of rich copper ore discovered in September, 1927, about 500 feet southwest of shaft No. 1 when excavating a drain; and a body or bodies of good copper ore stumbled on some 400 to 600 feet southeast of the smelter, when blasting out foundation for a water tank. Masses of iron sulphides have been found, also, on many parts of the property, on which further exploration may disclose spots enriched with copper. In fact, sulphide masses have been discovered in so many places where bedrock has been exposed for any purpose, that one is forced to conclude much may yet be found when systematic exploration is undertaken.

Development during 1927 was directed mainly to bringing the mine into production. The first 500-ton unit of the smelter was completed, and commenced operations about the middle of December of that year. Underground work was mainly confined to making changes necessary for rapid extraction of the ore. These included sinking shaft No. 3, a three-compartment shaft capable of handling 3-ton ore cars, to the 500-foot level; cutting large stations at the levels; enlarging the small development drifts for motor haulage; making raises in the ore-bodies, and installing loading chutes. In 1928 the No. 3 shaft was deepened to 1,040 feet, and as it was found to enter "H" ore-body somewhat above the 975-foot level, a new shaft, known as No. 4, was commenced. It is located 785 feet north and 397 feet west of shaft No. 3. By April 1, 1930, the No. 4 shaft had been deepened to 1,557 feet, and No. 3 shaft to 1,150 feet. No lateral work had been done up to that date below the 975-foot level.

Early in 1928 a small concentrator was erected for treatment of ores too lean for direct smelting, and experimental work was carried on throughout that year. The capacity of the concentrator was then increased to handle a possible 500 tons of ore daily, and in 1929, 51,691 tons of lean ore were treated, producing 11,553 tons of concentrates. At the annual meeting of the company held near the end of March, 1930, it was announced that the capacity of the concentrator is now being increased to 1,000 tons daily, and that the additions are expected to be finished in August, 1930.

PRODUCTION

On January 1, 1928, the smelter had been running only a few days, and construction work was still being done on various parts of the plant. During January an average of 409 tons of ore a day was treated, and throughout the rest of the year the daily tonnage was gradually increased as changes were made to increase operating efficiency, until in December 940 tons were being handled daily. During 1929 the amount smelted daily was gradually increased to 1,300 tons. Late in November of that year additions to the smelter were completed which enabled the daily intake to be increased to 2,000 tons, a quantity the management hopes to maintain during 1930.

During 1928 the smelter treated 271,926 tons of ore, flux, and concentrates, nearly all of which came from the Horne mine. The average grade of the Horne ores shipped to the smelter was 6·52 per cent copper, 0·64 ounce of silver, and $3.82 in gold a ton; this average grade includes the low-grade, siliceous ore used as flux. The yield was 33,307,937 pounds of blister copper, averaging 99·27 per cent copper, 11·2 ounces silver, and 3·18 ounces gold a ton. The revenue from metal recoveries was $6,160,098, of which the gold values would constitute approximately $1,100,000, the silver values about $100,000. The total costs of mining, treatment, and delivery were $2,495,324. In this figure are included all costs of shaft sinking and other exploration.

During 1929, 428,221 tons of ore, flux, and concentrates were smelted, of which 43,916 tons were custom ores and concentrates. The average grade of the Horne ores, exclusive of concentrates, was 6·13 per cent copper, 0·72 ounce of silver, and $3.38 in gold a ton. The smelter produced 51,625,478 pounds of blister copper, averaging 99·22 per cent copper, 12·95 ounces of silver, and 2·66 ounces of gold a ton. Revenue from metal recoveries was $10,947,289, of which the gold values would constitute approximately $1,422,570, and the silver values about $160,000. Costs of mining, treatment, and delivery were $4,592,296.

ORE RESERVES

Ore blocked out by drilling, drifting, crosscutting, and raising, up to December 31, 1929, is estimated in the annual report of the company as 6,664,000 tons. Of this amount, 3,426,000 tons are direct smelting ore, estimated to average 7·53 per cent copper and $3.29 gold a ton; 3,000,000 tons are concentrating ore, averaging about 2 per cent copper and $3 gold a ton; and 238,000 tons are siliceous flux averaging 1 per cent copper and $2.43 gold. Since that report was published, the determined tonnage of siliceous flux has been largely increased, and much of the new ore, according to official statements, carries gold values of $12 to $15 a ton.

GEOLOGY

The rocks in the immediate vicinity of the mine are Keewatin lavas, breccias, and tuffs that have suffered extensive alteration, forming a wide variety of rock types that grade into one another in a most puzzling manner, and thus make it almost impossible to map individual rock units. These rocks are cut by a great number of irregular dykes and masses of quartz diorite, that split and come together again, and change their strike and dip so as to make it impossible to project any one of them with certainty for any distance beyond where it is actually visible. In addition, one or two small dykes of syenite porphyry, and two large dykes of later gabbro, are present.

Keewatin. The principal Keewatin rocks are termed rhyolites and dacites, for easy reference. The rhyolites are the usual light-coloured, massive or brecciated, highly siliceous rocks familiar to everyone. The dacites are like them, but contain more chlorite and less quartz, so that they are commonly darker in colour. The rhyolites weather white or light grey, the dacites to a darker, greenish tint, nearly the same as that of weathered andesite, and because of their colour were referred to as andesites in an earlier account. Both rhyolites and dacites pass gradually from massive into brecciated varieties.

The least altered rhyolite obtained is made up of some 20 to 25 per cent quartz and 75 to 80 per cent of what was, apparently, feldspar, but is now a mat of colourless mica, epidote, and chlorite. Rock of this sort is massive, fine grained, and usually fairly thickly sprinkled with little rounded blebs of quartz. In many places it passes gradually into a rock of much lighter colour, with an intermediate phase consisting of rounded spots of dark material in a lighter ground. The change from the darker to the lighter material is due to the replacement of chlorite, and of epidote if present, by colourless mica and some quartz. In one thin section a little fresh albite was seen to have formed along with the colourless mica.

The light grey, cream-coloured, or white rock thus formed by alteration of rhyolite lava is indistinguishable in hand specimen from a rock that is mined as flux for smelting operations, and is considered to be an altered, fine-grained tuff (*See* page 187). The similarity of the two is one of the features that make underground separation of rock units difficult.

In many places in the mine coarse rhyolite breccias are found, consisting of siliceous fragments in a light-coloured matrix. The siliceous fragments are identical in appearance and composition with the massive silicified rhyolite just described. The matrix is commonly rhyolite, so

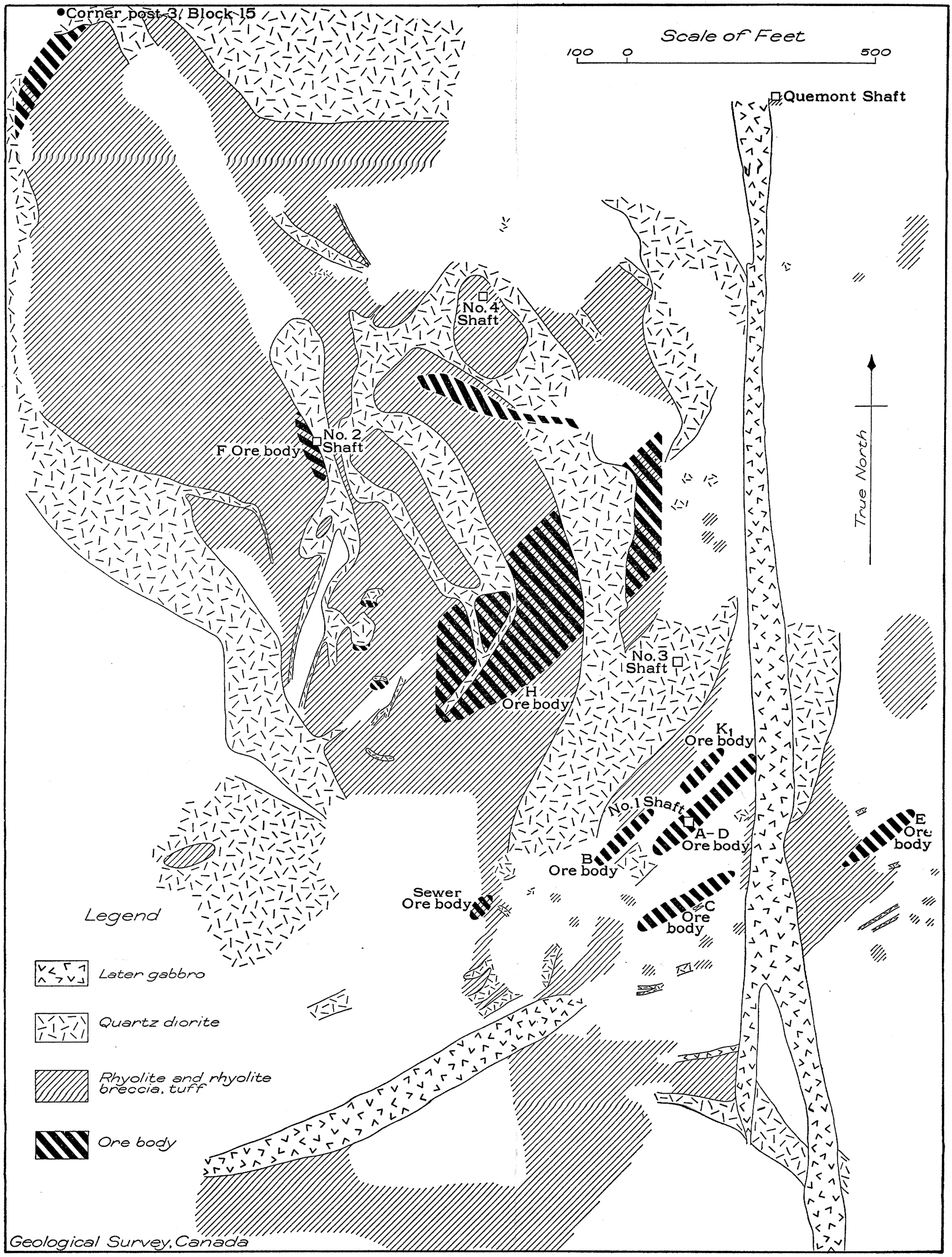

Figure 14. Surface geology, Horne mine.

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that the breccias are usually flow breccias rather than ash beds. True beds of mixed coarse and fine fragmental material may be seen on the surface in several places, however; and some of those observed underground may be of this type, but the distinction between ash beds and flow breccias is difficult to make underground on account of the general alteration and mineralization.

The rocks classed as dacite vary a great deal in appearance and composition, but are grouped together because the different varieties pass gradually into one another. The most basic is a dark, chloritic, massive rock containing a few phenocrysts of quartz. Some specimens are composed of quartz and chlorite entirely, the quartz in varying proportions up to 35 per cent. Others contain, in addition, considerable white mica. The mica and the chlorite, and perhaps some of the quartz, appear to be of secondary origin, formed perhaps partly from the original rock minerals, and partly from introduced material. The relations observed in the thin sections studied suggest two successive stages of alteration; in the first, the original rock was altered to a fine-grained mixture of quartz and colourless mica; in the second, the quartz-mica aggregate was replaced by chlorite, perhaps with addition of more quartz.

The very chloritic varieties of dacite, containing only a few phenocrysts of quartz, are closely similar to some highly chloritized rocks found in a few places in the mine, which carry no visible quartz.

Almost all the chloritic varieties of dacite may be traced laterally into breccias composed of light-coloured, rhyolitic fragments in a dark chloritic matrix. The change may be observed, for example, in drift No. 1125, first level. At first the fragments are few, and the proportion of matrix large. Farther from the massive chloritic dacite the number and size of the fragments increase, and the amount of matrix decreases, until finally, in places, the fragments are crowded together. The rock then closely resembles the rhyolite breccia as already described, except for the darker, more chloritic matrix.

The thin sections have, therefore, shown that most of the chlorite in the "dacite" has been introduced into the rock, replacing rock of more siliceous composition; and the megascopic examination shows that where the amount of chlorite, i.e., of alteration, becomes a minimum, the non-chloritized parts are identical with the rhyolites found elsewhere on the property. The conclusion, therefore, seems inevitable that the rocks conveniently classified as "dacite" and "dacite breccia" are in reality chloritized rhyolites.

In addition to these two main rock types, there are others that merit description. East of the north-trending dyke of later gabbro (*See* Figure 14), there is a large body of fine-grained, light-coloured rock of very uniform composition and grain. It is usually white or light grey, with a slight brownish or pinkish tinge. The average grain is 0·05 to 0·1 mm., and the composition quartz 70 to 75 per cent, the remainder colourless mica or sericite. The high percentage of quartz, the uniformity of its composition, and the fact that at no place does it grade into massive lava, identify the rock as a fine-grained, silicified ash. In hand specimen it cannot be distinguished from some varieties of silicified and sericitized rhyolite, but none of the latter contains anything like as much quartz as the ash rock.

This siliceous tuff is cut, near the "E" ore-body, by numerous stringers which at a distance from the ore-body consist only of pyrite and chalcopyrite, but closer to the ore-body are edged with a black alteration product which under the microscope is seen to consist of chlorite, pistacite (epidote), and sericite or talc. The siliceous tuff is mined for use as acid flux for the smelting operations, and the larger part of it contains so many sulphide veinlets that the rock is an ore of sufficiently high grade to repay the costs of mining and crushing. It averages between 1 and 2 per cent copper, and about $2 a ton in gold. A large mass of this rock outcrops about 500 feet east-northeast of shaft No. 3, and another large mass about 400 feet southeast of the shaft of the Quemont mine, or 700 to 800 feet due north of the first. If these are parts of a single band, the mass of possible flux is very large.

In drift 1323, third level, and also at the extreme southeast end of drift 1116, first level, there appears a black, glassy, hard rock. It is very uniform in grain and composition throughout its whole width of 75 or more feet. Under the microscope it is seen to consist of quartz and colourless mica, the quartz forming about 40 per cent; and having an average grain of 0·02 to 0·03 mm. Ramifying through the rock is a branching network of quartz and chlorite in vague, vein-like forms, the quartz forming 40 to 75 per cent of the "veins." Some pyrite accompanies the chlorite. There is little to indicate what the original nature of this rock may have been. Its fine grain, uniformity of composition, and entire lack of amygdules or other characteristic textures of lavas, relate it most closely to some of the rhyolite dykes so numerous in this region. The lack of feldspar, however, is not like them; and if the rock was originally a rhyolite dyke, it must have been quite completely altered.

A small mass of most unusual rock lies just east of No. 1 shaft on the first level, and another at the east end of "K" ore-body on the third level. The rock is light coloured, fine grained, massive, and very like soapstone, so soft that it may almost be scratched with the finger nail. It is practically all talc. It passes laterally by insensible gradations into rhyolite or dacite breccia, so that it is evidently an alteration product of the breccia. This peculiar alteration product does not appear to be directly connected with ore formation, because if it were, it would presumably be found near more of the ore-bodies.

Quartz Diorite. Numerous dykes of quartz diorite occur on the Horne property and in the mine itself. They vary in width from a few inches to 300 feet. The strike varies a good deal from place to place along the length, and the dykes likewise split and come together in a most complex manner. Underground work has proved that the dips exhibit equal variation, changing from nearly vertical to nearly flat, and then back, quickly or gradually, to very steep. The average dip of the dykes in the underground workings appears, however, to be about 45 to 50 degrees northeast; and the average strike is between north and northwest.

Syenite Porphyry. Small dykes of syenite porphyry occur in a few places. Only two have been found in the mine workings. The main one passes about 15 feet north of No. 1 shaft on the first level, strikes practically east, and dips about 60 degrees north. The porphyry has a reddish tinge, on account of its numerous dark red phenocrysts of feldspar. The fine-grained matrix is dark grey. The phenocrysts, so far as they are determinable, are albite; the matrix, also, is mainly albite, with some chlorite and much fine-grained blackish dust, part of which is magnetite, the remainder indeterminable. The dust-like material is arranged in needles or strings lacing through the mat of feldspar crystals, suggesting that it may have originated by alteration of needles of actinolite.

In places, as in drift 1233, second level, the dyke breaks up into a network of little stringers in the older rocks, forming a complex of very puzzling appearance. On the third level, in drift 1311, the dip suddenly flattens to about 20 degrees, carrying the dyke rapidly northward.

In a short drift run west from drift 1338, third level, the porphyry is cut by veinlets of chalcopyrite, and its colour is darker close to the contact of the chalcopyrite than farther away. Studied under the microscope, the blackened type is found to be cut by veinlets of quartz with wide borders of chlorite and a little colourless mica; and its feldspar, both phenocrysts and groundmass, is replaced to a large extent by colourless mica with some epidote.

In the same locality the porphyry contains a number of rounded nodules very like granite, of light grey colour and containing a good deal of quartz. The nodules, which are quite conspicuous on the roof of the drift, are 3 to 6 inches in diameter. A thin section of one of them showed about 5 per cent quartz, 5 to 10 per cent of some chloritized ferromagnesian mineral, 2 or 3 per cent of magnetite, and about 80 to 85 per cent of greatly sericitized feldspar. The texture is granitic, the average grain $1\frac{1}{2}$ to 2 mm. There is no evidence that the nodules have been formed by replacement of the porphyry, or by later introduction of acid material; they pass into porphyry at their edges by a rapid gradation; hence it appears that they must have been formed by differentiation of the porphyry magma itself.

Later Gabbro, or Diabase. The later gabbro or diabase forms three or possibly only two large dykes. One of these, about 80 feet wide, runs slightly west of north and passes about 125 feet east of No. 1 shaft. It has been traced north as far as the shore of Osisko lake, passing about 15 feet west of the Quemont shaft. In the opposite direction it has been followed south across two small islands in Osisko lake and on through Rouyn townsite to a point about a mile south of the lake. It could undoubtedly be traced a greater distance. This dyke has been cut on all three levels in the mine workings, and is thus known to have an almost vertical dip.

A second dyke lies south of the main workings, on claim Block 25 close to the north boundary. It is much the same size as the first, and strikes about north 65 degrees east. It has been traced for 850 feet on this claim, by scattered outcrops across the Chadbourne claim, Block 1, and across Noranda lake. The strike swings to north 50 degrees east on the Chadbourne claim. The dyke appears to end at a point about 325 feet west of the north-south dyke already described. If it does not end there, it undergoes a sudden change in width and direction, or does not come to the surface. In the underground workings it was identified with certainty only in drifts 1312 and 1323 on the third level. The other levels were not carried far enough south to cut it at the time the examination was made.

A third dyke, or what, possibly, is a continuation of the second, outcrops 450 feet east of the north-south dyke, forms a low ridge 200 feet long and 40 feet wide, trending east. Near the eastern end of the outcrop the strike changes abruptly, from north 85 degrees east to north 60 degrees east. The strike of the western end, if projected, meets the eastern end of the outcrop of the second dyke described, so that both outcrops may be parts of a single dyke. The strike of the eastern end, projected, runs across the island in Osisko lake on which the Horne powder house was formerly built, and on the shores of this island the dyke, or one like it, outcrops in exactly the projected position and with the same width and strike.

The later gabbro or diabase is a fairly fresh rock with pronounced ophitic texture, composed of labradorite ($Ab_{50}An_{50}$) and augite in about equal proportions, with 3 to 5 per cent of magnetite or ilmenite. The edges of the dykes are strongly chilled for widths of 1 to 2 feet, and the highly chilled parts next the country rock are very black and glassy, with a sort of resinous lustre when viewed in the light of the miner's lamp. The general appearance is entirely different from the grey or greenish grey colour of the chilled edges of the quartz diorite dykes, rendering separation of the two easy. The dyke has been jointed horizontally and vertically, giving the wall of a drift an appearance of having been built of rectangular blocks, a characteristic exhibited by no other rock in the mine.

Folding. The structure of the area is of great interest. A small outcrop on claim M.L. 1763 between the railway and Makamik road, or about 1,450 feet north of Horne creek, exhibits a well-defined contact between rhyolite flows, which strikes north 85 degrees east, dips vertically, and faces southwards. In a railway cut near the south boundary of M.L. 2012 the strike is north 80 degrees east, the dip is vertical, and the flows face south. On Block 58, the strike is north 80 degrees east, and dip is vertical; on Block 60, the strike is north 55 degrees east, the dip is vertical, and the flows face south; in the northeast corner of T 1785, thin-bedded cherts strike north 60 degrees east and dip vertically. Thus, in the area directly north of Horne creek, structure determinations were made in five places. In each place the strike was found to be a little north of east, and the dip vertical. At three of these places the flows were determined to face south, at the other two the face could not be determined.

South of Horne creek, on Block 15, the strike changes abruptly. Two hundred feet east of the northwest corner of the claim, thin-bedded tuffs and breccias are in contact with flows. The strike is north 30 degrees west, and the flows face northeast. At 1,270 feet east and 820 feet south of the northwest corner, or about 250 feet north of the hoist-house for shaft No. 3, thin-bedded tuffs strike north 45 degrees west, and dip 65 degrees southwest. A contact between two flows was traced southeasterly for about 200 feet from a point 700 feet east and 900 feet south of the same corner; the strike swings somewhat, but averages about north 20 degrees west. On the 100-foot level north and northeast of shaft No. 2, at three places, the first 175 feet due north of the shaft, the second, 160 feet northeast of it, and the third between the two, the strike is closely north 20 degrees west. In drift 1125, about 200 feet west of shaft No. 3, a contact strikes north 10 degrees west. Thus, in the area between Horne creek and an east-west line 100 to 150 feet north of shaft No. 3, seven determinations all indicate an average strike of about north 20 degrees west.

South of No. 1 shaft the strike again changes. At a point on the surface 2,490 feet south and 400 feet east of the northwest corner the strike is east, the dip vertical, and the flow faces south. Another flow contact, about 375 feet south of No. 1 shaft, strikes north 80 degrees east. On the first level, near the south end of drift 1111, or about 215 feet south of shaft No. 1, a flow contact strikes north 75 degrees west. On the second level several good contacts between breccias or between flows and breccias were found in drifts 1212 and 1215, at respectively 185 feet south and 200 feet south-southeast of shaft No. 1. The strikes vary between north 40 degrees and 70 degrees east, but most of them are about north 55 degrees east. On the third level, bedded tuffs occur between stations 283 and 339, drift 1312, or about 900 feet south-southeast of shaft No. 1. They strike due east. Two excellently displayed contacts in drift 1315, roughly 185 feet south-southeast of shaft No. 1, strike north 40 degrees east and dip vertically. A contact between two flows in drift 1319, roughly 300 feet east-southeast of shaft No. 1, strikes north 55 degrees east; about 100 feet northeast of this point, in drift 1313, the contact between the same flows strikes almost due north, suggesting that the strike is swinging to the north-northwest direction found north of shaft No. 1. In drift 1325, roughly 550 feet east-southeast of shaft No. 1, several contacts exhibit strikes varying from north 60 degrees east to north 80 degrees east.

The general attitude indicated by the observed dips and strikes is as follows. The flows and tuffs north of Horne creek have a general east-west strike. South from Horne creek across an area about 1,900 feet wide the strike is nearly at right angles to this; more precisely stated, the general strike is north-northwest in the area between Horne creek and an east-west line 100 to 150 feet north of shaft No. 3; and is northeast between this line and another roughly 200 to 300 feet south of shaft No. 1. South of the last-mentioned line the normal east-west strike is resumed.

These changes of strike can have been caused only by drag-folding of the 1,900 foot belt. In the drag-fold the flows and tuff beds are bent through somewhat more than a right angle. The fold must have been formed by a tendency, under great stress, of the beds on the north to move westward, and for those on the south to move eastward. Such a tendency would be present when the flows were folded into the great anticline of which they are now a part, as its crest lies to the north, and it plunges eastward. An alternative possibility is that the drag accompanied the formation of the Horne Creek fault, at a time later than the folding.

The inter-relations of the drag-fold, the faults, and the quartz diorite dykes indicate which of these alternatives is most probable. The quartz diorite dykes are very numerous within the drag-fold, and comparatively scarce immediately outside of it. This distribution is believed to mean that the dykes were injected after the formation of the drag-fold, and found the rocks of the drag-fold more fractured, and consequently more susceptible of intrusion, than those to the north or south. Again, although the quartz diorite dykes tend to parallel the bedding of the lavas, many dykes cut across this bedding at larger or smaller angles. During the drag-folding there must have been a good deal of slipping between the different flows (*See* Figure 5) and if the quartz diorites were injected prior to folding, those dykes that cut the flows would be faulted and fractured at flow contacts. This is not found to be the case; even small dykes cut across the folded rocks without displacement. This, accordingly, is a second reason for inferring that the dykes were injected after the drag-folding. The faults, however, cut the quartz diorites. Large masses of quartz diorite are crushed within the zone of the Horne Creek fault, and many dykes in the Horne mine are crushed or displaced by the smaller faults. If it is correct, therefore, that the quartz diorite dykes followed the drag-folding, the faulting must be still later, and, therefore, the drag-fold could not have been formed by the stresses of faulting.

Further evidence to the same effect is afforded by faults in the Horne mine, which displace dykes of syenite porphyry and crush the edges of the dyke of later gabbro. Both the syenite porphyry and later gabbro cut the drag-folded lavas in straight lines, and, therefore, must have been injected after folding was complete. The faults cutting the dykes are, accordingly, obviously later than the drag-folding.

Faulting. In the Horne mine a considerable number of faults are found, most of which seem subsidiary to the larger Horne Creek fault. Their usual strike is northeastward and the dip steeply east, but some strike east, and others north or a few degrees west of north. In a number of cases, the direction and amount of displacement have been determined by the displacement of dykes of quartz diorite or of syenite porphyry, and in all such cases the northwest side has moved toward the southwest. In other words, they are all left-hand faults, meaning that to an observer standing on one side of a fault and looking across it the other side moved to his left. Nearly all the fault striæ dip southwest at varying angles, usually about 45 degrees, indicating that the east sides moved up as well as north. As the dips of the fault planes are usually eastward, the faults are, therefore, thrusts.

An example of a fault on which the movement was thus determined is a fault that passes 100 feet west of shaft No. 1 on the first level, and was found also on the second and third levels. It strikes northeasterly, swinging a good deal, has an average southeast dip of 70 degrees, and striæ dip 60 degrees toward the southwest end. On the first level it cuts and displaces a dyke of syenite porphyry. The porphyry on the west is 45 feet, measured along the fault, distant from the point where it encounters the fault on the east, corresponding to a displacement of 25 feet due south.

Other faults involving displacements of 1 to 10 feet were found in drift 1114, first level, about 10 feet east of the later diabase dyke; in drift 1131, 14 feet south of mine station 328; in the same drift, near mine station 316; at the junction of drifts 1313 and 1338, third level; and in other places.

The largest fault in the mine workings runs along drift 1318, third level, about 500 feet east of shaft No. 3. It strikes about north 10 degrees west, and dips 40 to 50 degrees east. It cuts lavas and quartz diorite indiscriminately, and has crushed and rendered schistose a zone 4 to 10 feet wide. The striæ run straight down the dip, at right angles to the strike. The fault has been traced for more than 600 feet, but the direction of movement has not been determined. The fault, however, is probably a thrust.

A very flat fault occurs on the first level about 140 feet north of shaft No. 2. It strikes north 75 degrees east, and dips 20 to 35 degrees south. On the side of the drift north of mine station 182 where the fault is visible in cross-section, wedge-shaped fragments indicate that the upper side was thrust over the lower. The fault striæ run straight down the dip, indicating that there was no lateral movement; and the corrugation of the striæ confirms the conclusion that the movement was a thrust.

Most of the faults are evidently later than the quartz diorite, and at least some of them are later than the syenite porphyry. Their relationship to the later gabbro is not known in its entirety. In the mine, no large fault has yet been found to cut and displace the later gabbro, although such faults probably exist elsewhere (page 101). Small faults run through the country rock in many places to meet the later gabbro dyke visible in the mine workings. These small faults are clearly later than the dyke, as they are deflected where they meet it and run along its edge, crushing the edge slightly in places.

Nevertheless, although the faulting in general appears to be almost the last event of which there is record in this neighbourhood, there is a little evidence of the existence of older faults. In two places in the Horne mine, close to "H" and "J" ore-bodies (*See* descriptions), unfractured stringers of pyrite are found in the shatter zones of faults, implying that the faulting took place before the introduction of the pyrite. As the pyrite-pyrrhotite masses were formed between the injection of the quartz diorites and the syenite porphyries, these faults would seem to be older than the other faults in the mine. The existence of such older faults is to be expected, however, because some faulting would most probably have been caused by the intense strains of drag-folding.

ORE-BODIES

The ore-bodies of the Horne mine are large lenses of somewhat irregular outline. The complete delineation of the shapes will have to await the end of mining, but enough has already been done to indicate considerable irregularity. The general strike of the ore-bodies is northeast; and the dip steeply southeast; the "F" ore-body, however, strikes nearly due north. Some of the bodies have been named from the letters of the alphabet, but there are many as yet unnamed.

"H" Ore-body. The largest known body of sulphides is the "H" ore-body. On the first level it is approximately 150 feet wide, strikes north 60 degrees east, and dips about 80 degrees southeast. On the surface its southeast border passes about 150 feet northwest of shaft No. 3, and its continuity is broken by several large dykes of quartz diorite. On the surface and the first level this body is composed almost wholly of pyrite and pyrrhotite, but carries a little chalcopyrite. Average assays on the first level, as stated to the 1928 annual meeting of Noranda stockholders, are 0·46 per cent copper and $1.54 in gold a ton. On the third level, some parts of the body are sufficiently enriched in copper and gold to be ore.

Since the property was geologically examined in 1927, the No. 3 shaft has been deepened and was found to pass into the "H" ore-body a little above the 975-foot level. At this depth it proved to be a high-grade copper-gold ore. Development during 1928, according to the president's statement at the annual meeting on March 30, 1929, indicates that the high-grade part of the body extends from the 600-foot level to a depth of at least 1,300 feet.

The south boundary of "H" ore-body on the first level is a fairly strong fault marked by fractured and sheared material about a foot thick. The fault strikes north 55 degrees east, and dips 70 to 85 degrees northwest. From various evidences this fault appears to be older than the sulphide mass; for a distance of about 60 feet it is visibly the wall of the ore-body, and the shattered and schistose fault material contains lenses of unfractured sulphides, indicating that the latter were introduced after movement was completed; and in the drift northwest of mine station 68, a triangular tongue of sulphides 3½ inches long and 1 inch thick at the base projects at right angles from the main sulphide mass into the shattered zone, thus presenting a feature that could not have persisted if the sulphide mass had formed prior to faulting.

"F" Ore-body. The "F" ore-body is a large mass of sulphides striking north and dipping steeply east. No. 2 shaft has been sunk on it, to a depth of 100 feet, and drifting at that level has proved its length to be about 175 feet, its maximum width 50 feet. The ore consists mainly of pyrite and pyrrhotite, with a little chalcopyrite, carrying gold values averaging about $8 a ton.

The "F" ore-body is in contact, at the north end, with massive rhyolite, but just at the contact there are a few inches of rhyolite breccia, whose presence suggests that the sulphides have replaced a breccia almost to its contact with massive rhyolite. At the south end, the boundary of the ore on the first level is a dyke of quartz diorite, 5 to 6 feet thick, that near the roof of the drift dips northward at about 10 degrees, then bends sharply downward to a dip of 45 degrees and disappears into the floor of the drift. The sulphides lie directly on the dyke, as on a floor, and the dyke is cut by a multitude of fissures filled with pyrite, some of them several inches wide.

The walls of the pyrite veinlets have been slightly altered. Between closely spaced veinlets and on the sides of single veinlets the quartz diorite is converted into a greenish rock which, under the microscope, is found to consist of quartz and epidote in almost equal amounts, with some long needles of hornblende. The same alteration is found in various places in the mine near quartz diorite-sulphide contacts.

On the east side the ore-body is likewise bounded on the first level by a dyke of diorite, this time, however, only a few inches wide. It strikes north 27 degrees west and dips 55 degrees east. The massive sulphides stop sharply at this narrow dyke, on the other side of which is normal dacite.

The facts outlined in the preceding paragraphs make it evident that the iron sulphides are later than the dykes of quartz diorite, because stringers of the sulphides cut and alter them. It is also evident that the dyke material strongly resisted replacement, because little actual replacement took place even where massive sulphide is in contact with the diorite and pierces it with numerous stringers.

Two veins, each 3 or 4 inches wide, cut the massive iron sulphides of "F" ore-body about 75 feet south of shaft No. 2. They consist mainly of quartz and a carbonate, probably an iron carbonate, with some chalcopyrite, zinc blende, and an unidentified blackish material. Specimens assayed for gold gave no values.

"J" Ore-body. On the first level, about 75 feet northwest of the north end of "F" ore-body, drift 2,115 cuts a mass of zinc ore known as "J" ore-body. Very little work has been done on it, beyond drifting across it and exploring it with a few drill holes. The mass, which has a width of about 25 feet along the drift, is composed principally of pyrite and zinc blende; the zinc blende is later than the pyrite and replaces it. The ore-body is not solid sulphide like many of the others, but includes an appreciable amount of the country rock, and passes into country rock on each side by gradual diminution of the amount of sulphides. Inspection makes it evident that the ore has replaced the country rock, a dacite breccia.

The "J" ore-body lies beneath a flat fault (page 193) which strikes north 75 degrees east and dips 20 degrees to 35 degrees south. The evidence at this point indicates that the faulting at least commenced before the formation of the sulphides. In one place about 30 feet north of mine station 182, small veinlets of pyrite, one of them little thicker than a hair, run through the fault gouge. In three places west of station 182 the fault is paralleled in strike and dip by bands of heavily pyritized rocks running through less mineralized rock. Both lines of evidence indicate that fracturing took place before the introduction of the sulphides. If the pyrite of the veinlets in the gouge is of the same age as the pyrite in the rock, it is clear that mineralization took place after the fault movement ended, as otherwise the veinlets would have been crushed. However, the veinlets were found in only one place, and pyrite is a mineral that might easily be taken into solution and reprecipitated to form veinlets, so that it is only safe to conclude that the fault was initiated before the deposition of the sulphides.

" Crusher " and Other Ore-Bodies. Four impregnations varying from rhyolite thickly spotted with pyrite and chalcopyrite to masses of solid sulphides occur between 300 and 600 feet south of shaft No. 2. Three of these are directly on the projected strike of " H " ore-body. Each lies at the lower contact of a dyke of quartz diorite. The northernmost, about 325 feet south and 100 feet east of shaft No. 2, is massive pyrrhotite and pyrite with very little chalcopyrite. It is several feet thick, and lies below a small mass of quartz diorite that dips north at a small angle. The second lies about 100 feet south of the first, and is of similar character and relations, but the impregnation is less complete. The third is about 75 feet farther south, and consists of rhyolite breccia thickly splashed with pyrite and chalcopyrite. The bulk of the impregnation is beneath a dyke of quartz diorite about 5 feet thick, striking north 70 degrees west and dipping north at a low angle; but there is also some impregnation above the dyke. The amount of chalcopyrite in this mass is sufficient to make it fairly good ore. This body was found when the surface was being levelled for erection of a water tank. Drilling to determine the downward continuation of this mass resulted in the discovery of what appears to be a quite distinct body about 200 feet to the west. This, known as the Crusher ore-body because it is just north of the primary crusher, does not come to the surface, so far as known, but lies beneath a large dyke of quartz diorite striking due north at this point, and dipping about 35 degrees east. The body has been sufficiently outlined by drilling to indicate that it is large and of good grade, but no other development work has yet been done on it.

The fact that three of these sulphide masses are on the strike of " H " ore-body suggests that they and " H " ore-body may be localized on a single zone of fracturing, through which sulphide-bearing solutions rose. The fact that all four lie beneath quartz diorite dykes suggests that the dykes may have acted like dams, and controlled to some extent the movement of the ore-bearing solutions.

" A-D " Ore-body. The " A " ore-body was the first mass of high-grade ore found on the property. An exploratory shaft (No. 1) was sunk on this body, and continued in ore from surface almost to the first level, where it passed through the bottom of the lens. Exploration on the first level resulted in the discovery, some 200 feet northeast of the shaft, of what was termed " D " ore-body, but later it was found that the " A " and " D " bodies are merely parts of a single continuous mass, the bottom

of which, near the shaft, is only about 8 feet above the roof of the level. Both northeast and southwest of the shaft the mass dips below the first level; its depth on the northeast had not been determined when the geological examination was made, but on the southwest it had been proved to extend almost to the second level. The shape of the mass is thus that of an inverted " U ". The rock under the ore-body, beneath the legs of the inverted U, is a very soft talcose alteration product of rhyolite breccia (page 188). It is not known if the talcose rock was formed at the same time as the ore, or whether it was formed first and resisted replacement, thus forcing the ore-body to assume its present form; but the second alternative seems the more likely, as similar talcose material is found in only one other place.

The " A-D " ore-body on the first level lies between two dykes of quartz diorite which are about 40 feet apart, on the average, but variations in the strike and dip of the dykes cause corresponding variations in the distances separating them. They strike north 40 degrees east, and dip southeast at angles varying from 50 degrees to vertical. The dip of the ore-body is presumably the same as that of the dykes. In many places the ore lies directly against the quartz diorite, in others some of the unreplaced country rock intervenes, and consists of rather chloritic dacite breccia.

On the northeast, the " D " body and the dykes between which it lies are cut by the north-south dyke of later gabbro. On the east side of the later gabbro dyke a small mass of ore some 25 feet long and 10 feet wide lies directly in line with, and presumably represents the end of, the " D " ore-body sliced off by the intrusion. The small eastern mass of ore is completely surrounded by quartz diorite; apparently the two quartz diorite dykes here come together.

For the most part the ore ends sharply against the chilled edge of the later gabbro dyke and there is no visible replacement of the dyke material by ore. The chilled edge is slightly shattered by a small fault, and at one place in the roof of the drift a triangular tongue of chalcopyrite about 6 inches long and 1 inch thick at the base projects at right angles from the sulphide mass into the gabbro. Either the chalcopyrite formed after the intrusion of the dyke, or there must have been some redistribution of the chalcopyrite after the dyke was formed.

The southwestern end of the " A " ore-body is hidden as yet, but the general arrangement of the rocks suggests strongly that the two quartz diorite dykes between which the ore-body lies, come together and cut it off.

Copper values are very high in the " A-D " ore-body, and gold averages about $5 a ton. In places, particularly at the northeastern end, near the later gabbro, the ore is almost pure chalcopyrite. The main impurity consists of the unreplaced remnants of the original pyrite and pyrrhotite, which are found as numerous, irregular nodules and small masses. The amount of pyrite is small, and most of the older sulphide is pyrrhotite.

" B " Ore-body. The " B " ore-body lies just to the west of the " A " ore-body, and so close to it that there cannot be, at most, more than 25 feet of rock between them on the first level. The relations visible in the

drifts suggest that the two bodies are separated by a dyke of quartz diorite; but it is possible that the ore may have broken across the dyke and established a connexion between the two bodies. The "B" ore-body is a thick lens, about 110 feet long and at least 50 feet wide on the first level. It strikes about north 35 degrees east, or practically parallel to the "A-D" ore-body, and dips steeply southeast. On the second level a lens of ore in drift 1213 was formerly considered the downward extension of "B." This lens is some 50 feet long and 18 feet wide, and its centre lies nearly 40 feet southeast of the centre of "B" on the first level. Information lately received from Mr. H. L. Roscoe, assistant manager, and H. M. Butterfield, mine geologist, renders it possible that there is no connexion between the two. The ore-bodies in this vicinity are so irregular, however, that probably their connexions will not be definitely known until stoping is well under way.

The "B" ore-body, like the "A-D" mass, is completely walled in by quartz diorite. Almost the only places where any remnants of the replaced lavas were found, are on the first level at the extreme northeast and southwest ends of the sulphide mass. These, as elsewhere, consist of dacite breccia. The ore is massive sulphide, in all respects like that of the "A-D" mass except that it contains a somewhat larger proportion of pyrrhotite which reduces the copper content accordingly; it is nevertheless a very rich ore of copper, and the gold values, averaging about $8 a ton, are much higher than in the neighbouring body.

"*K-K_1*" *Ore-body.* On the second level, about 175 feet northeast of "B" ore-body and on its line of strike, there is a mass of ore to which no name has yet been given. It is a lens about 75 feet long and 25 feet wide. On the third level the probable continuation of this mass is nearly 100 feet east-northeast of its position on the second level, and is in contact with the north-south dyke of later gabbro. On the other side of the dyke, directly opposite, there is a mass of similar ore which has been named the "K" ore-body. There seems to be no reason to doubt that the "K" ore-body and the sulphide mass on the west side of the dyke were formerly one, and have been separated by the intrusion of the dyke. In this report, therefore, the part west of the dyke will be termed the "K_1" ore-body.

The space relationships of the "K_1" mass on the second and third levels suggest that the body strikes about north 40 degrees east, dips 64 degrees southeast, and rakes to the northeast at about 56 degrees. The dip as thus calculated corresponds fairly closely with the observed dip of the contacts on the second and third levels. If this dip be projected upward to the first level, the position thus located is occupied by a mass of pyrite and pyrrhotite some 30 feet wide. This mass was cut by a drill hole running northwest from drift 1110, and what is presumably the southwest end of the same mass is cut by drift 1112.

These data strongly suggest the following conclusions: that the "K_1" ore-body is a mass striking northeast dipping approximately 64 degrees southeast, and raking strongly to the northeast; and that the upper parts contain little copper, but that replacement of the older sulphides by chalcopyrite increases with depth, so as to form a rich ore.

The "K_1" ore-body on the second level passes into dacite breccia at the northeast end, and exhibits the usual evidences of having been formed by replacement of it. Like the "A-D" body, it is otherwise walled in between dykes of diorite.

On the second level there is a fault striking northeast and dipping steeply southeast, which in places forms the northwest wall of the ore-body. At the northeast extremity of the ore-body the ore tails off into the fault, forming long, narrow stringers in the fault fissure. The ore itself is not cracked nor crushed, indicating that in all probability it is later than the fault.

Better evidence to the same effect was obtained near mine station 349. In the roof of the drift at this point there is a fragment of schist about 2 feet long and 3 to 4 inches wide, which is completely surrounded by chalcopyrite. The sulphide is not sheared nor fractured. At the end of the ore-body, a few feet to the northeast, the country rocks are not schistose except along the fault fissures, where schist has been formed by the fault movements. The presence of the schist fragment within the massive chalcopyrite indicates, beyond a doubt, that the faulting occurred before the sulphide was introduced, and that the chalcopyrite filled the faulted zone and replaced most of the rock there.

On the third level a dyke of syenite porphyry (page 189) runs through the extreme western end of the "K_1" mass, and is cut by veins of chalcopyrite. One vein about 2 feet thick cuts completely across the dyke at 45 degrees to the strike, and another about 8 inches thick runs into it and continues in it parallel to the strike. The porphyry near the sulphide veins is much darker than the normal porphyry. A thin section of the darker material showed the presence of a number of quartz stringers edged by wide borders of chlorite and some colourless mica, whereas away from these stringers the feldspar of the rock is replaced to a large extent by colourless mica or talc and a little epidote. The relations between the ore and the syenite porphyry, therefore, are identical with those found at the Aldermac mine.

Where the ore is in contact with the dyke of later gabbro the relations are the same as those described for the "D" ore-body on the first level. In several places stringers, always composed of pure chalcopyrite, run for short distances into the chilled edge of the dyke. The largest observed is between 1 and 2 feet long and 3 to 4 inches thick at the base. It projects into the dyke at right angles to the contact for some 4 or 5 inches, then turns and parallels the contact.

Unnamed Ore-body. In drifts 1314 and 1317 on the third level there is a mass of sulphides some 90 feet long and 20 feet wide. A raise driven up in this, following the sulphide mass, entered the second level in drift 1219, where a mass of rather lean sulphides about 50 feet long and 25 feet wide occurs. The centre of this mass is about 75 feet northwest of the centre of the body in drifts 1213 and 1214, already described (page 198). The dip of this body, between the second and third levels, is about 85 degrees southeast. On the second level the sulphides are mainly pyrite and pyrrhotite, with a little chalcopyrite; on the third level the copper content is much higher. This body, therefore, repeats the conditions already noted in " H " and "K_1 " ore-bodies, in that, lean at the top, it passes into better grade at depth.

Like the other ore-bodies described, this mass, on both second and third levels, is walled in between dykes of diorite, which undoubtedly control the dip and extent.

" C " Ore-body. On the first level the " C " ore-body is a sulphide mass about 210 feet long, with a maximum width of about 50 feet. It lies about 100 feet southeast of " A " ore-body, strikes north 55 degrees to 60 degrees east, dips about 60 degrees southeast, and rakes strongly northeast. On the second level the ore-body is cut by the north-south dyke of later gabbro. On the west side of the dyke the sulphide mass is about 175 feet long, and has a width of more than 40 feet where the dyke cuts it. On the east side of the dyke there is only a small body of ore extending about 40 feet along the dyke, and 10 or 12 feet to the northeast. On the third level the body is much larger, and is again cut by the dyke. On the west side of the dyke the total width of sulphides is about 110 feet, and a drift has been run about 100 feet west in sulphides without reaching the edge of the body. On the east side of the dyke the width along the contact is likewise about 110 feet, and the body extends about 125 feet to the northeast.

At its ends, the " C " mass passes gradually into mineralized dacite or rhyolite breccia, evidencing that the sulphides have replaced that rock. On the northwest side, first level, the sulphides are also bounded by breccia, and the contact is not sharp. The southeast side, however, is a sharp boundary against hard, glassy rhyolite. On the second and third levels the northwest side is sharply bounded by glassy rhyolite, and the southeast boundary is a dyke of later gabbro striking north 65 degrees east. These relations indicate that the massive lavas, like the quartz diorite dykes, were not readily replaced, and hence tended to wall in the ore-bodies.

In drift 1336, third level, east of the north-south dyke of later gabbro, two dykes, each 4 to 6 feet thick, cut through the " C " ore-body. One, of quartz diorite, runs northeast; the other, of later gabbro, runs east; and the two intersect about 40 feet east of the big dyke of later gabbro, so that a triangular area of sulphides is enclosed between the three dykes. The sulphide within the triangle consists of lean pyrite and pyrrhotite, whereas that outside is of good grade, carrying 6 to 10 per cent of copper.

The sequence of events producing this peculiar arrangement is clear. Evidence obtained elsewhere and already given shows the pyrite and pyrrhotite to be later than the quartz diorite and earlier than the later gabbro, and the chalcopyrite to be later than the later gabbro. In the beginning, therefore, there was here a mass of breccia intruded by the dyke of quartz diorite which strikes northeast. The breccia on both sides of the dyke was then replaced by pyrite and pyrrhotite to form the original " C " mass of sulphides, but the dyke itself resisted replacement. Then came the intrusion of the later gabbro, dividing the sulphide mass into two parts, and cutting off the triangle of sulphides. This intrusion, in turn, was followed by the injection of the copper-bearing solutions, which attacked the mass of pyrite and pyrrhotite and replaced it to form copper ore. The triangle of sulphides, however, was protected by the dykes surrounding it, so that the copper-bearing solutions were unable to reach and replace it.

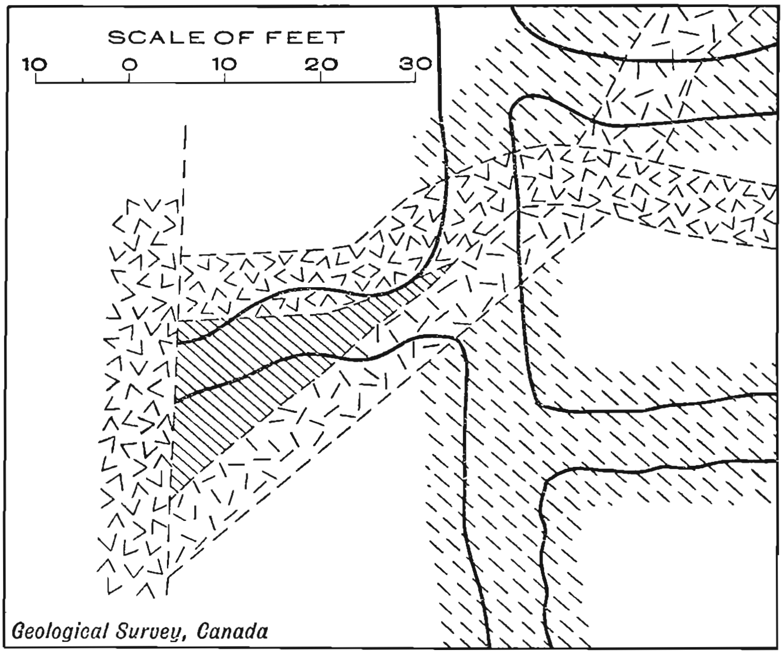

Figure 15. Sketch of relations in drift "1336," Horne mine, showing trianguar arc of iron sulphides (oblique lines) enclosed by dykes of later gabbro (angle pattern) and of older gabbro (irregular pecked pattern) outside of which replacement by copper and iron sulphides (broken oblique lines) has taken place.

" E " Ore-body. The " E " ore-body is about 250 feet east-northeast of " C " ore-body, and between them, on the surface and first level, lies the north-south dyke of later gabbro. There is no evidence that the intrusion of this dyke was accompanied by much north or south movement of either wall. The " C " and " E " ore-bodies are so very nearly on the same line of strike that they may be supposed to lie on a single line of fracturing or weakness which was later displaced by the opening of the wide dyke fissure.

On the first level the " E " ore-body is about 200 feet long and 50 feet wide, and strikes north 60 degrees east. It appears to maintain much the same size between the surface and the first level. In that distance it dips very steeply southeast, almost vertically, and has no determinable rake. On the second level its length is reduced to 175 feet, and its width to about 15 feet; this body lies almost directly beneath, but somewhat southwest of, the mass on the first level. About 25 feet southeast of the northeast end there is a small mass of ore about 25 feet long and 10 feet wide, separated from " E " by a wedge-shaped body of massive rhyolite. Most probably the rhyolite body is wedge-shaped upward as well as laterally, so that the small ore-body is a " root " extending downward from the main " E " body above. On the third level " E " ore-body is represented by a small spot of ore 6 or 8 feet in diameter. It lies about 25 feet southeast of the position of the small mass on the second level, and if the two are connected, the mass has a dip of 77 degrees southeast, corresponding roughly to the very steep southeast dip of the " E " body and to observed dips on the second level.

Unlike most of the other ore-bodies, the " E " mass is not bounded by quartz diorite on any of the levels, but is surrounded by a light grey siliceous rock supposed to be a silicified tuff (page 187). The ore-body has formed by replacing this rock, as indicated by the presence within it of numerous fragments of the rock in all stages of replacement.

For 100 feet or more west of the ore-body, on the first level, this rock is traversed by a network of veinlets of pyrite and chalcopyrite, enough mineral being present to convert the rock into a lean ore carrying 1 to 2 per cent of copper and $1 to $2 in gold a ton. This material is used as smelter flux. Near the ore-body the veinlets are edged by irregular, blackish rims, that consist of chlorite, epidote, and talc replacing the original rock constituents. Farther away the rims are absent, and the pyrite and chalcopyrite form clean-cut fissure veinlets.

An interesting feature of the " E " ore-body is the almost complete absence of pyrrhotite, whereas in all the other ore-bodies pyrrhotite is present in large amount. The original sulphide of the mass was pyrite, which has been replaced by chalcopyrite to form the ore.

Other Ore-bodies. In addition to the already mentioned ore-bodies there are a number of masses of ore or of barren sulphides on which little or no work has yet been done. One of these, the so-called sewer ore-body, lies about 500 feet southwest of shaft No. 1. It is a mass of high-grade copper ore about 70 feet long and 40 feet wide on the surface, and was discovered in September, 1927, when a trench was being dug for water and sewerpipes. A second body of ore about 200 feet long and 40 to 50 feet wide was found in the spring of 1927 about 225 feet east-northeast of shaft No. 2, when the surface gravel was being removed for concrete-making. This body averages about $22 a ton in gold, and 2 per cent copper. Unlike most of the masses so far discovered, it strikes about north 75 degrees west; this strike is nearly parallel to the strike of the lavas and quartz diorite dykes in this part of the area. The ore-body forms the northwestern extremity of a large mass of otherwise barren pyrrhotite.

To the north at least two large bodies of massive pyrite have been found by trenching, but no further work has been done on them. One lies near the northwest corner of Block 15; it is 35 or 40 feet wide, and has been traced more than 200 feet on a strike of north 30 degrees east. Another of large size has been exposed in a trench 400 feet south and 500 feet east of the northwest corner.

Sequence of Ore Minerals. Study of thin sections and of polished sections of ore from the different sulphide masses shows that the sequence of the ore minerals is the same as that already described for the Aldermac mine. The first mineral to form was pyrite, and a little magnetite either accompanied the pyrite or closely followed it. Pyrrhotite then formed, tending to replace the pyrite and magnetite. Sphalerite, where present, replaces pyrite and pyrrhotite, and the last mineral of all to form was chalcopyrite, replacing all the earlier minerals.

SUMMARY

The facts set forth in detail in the preceding pages may be briefly summarized as follows.

The rocks on the Horne property consist of rhyolite and dacite lavas, breccias, and tuffs, intruded by dykes of quartz diorite, syenite porphyry, and later gabbro.

The lavas have been drag-folded over a width of about 1,900 feet, so that whereas outside the limits of the drag-fold the prevailing strike is roughly east and west, within it the strike is north-northwest between Horne creek and an east-west line drawn 100 to 150 feet north of shaft No. 3, and northeast between this line and another drawn roughly 200 to 300 feet south of shaft No. 1.

The northern edge of the drag-fold is a large fault striking north 77 degrees east. Smaller faults, presumably subsidiary to the main fault, occur throughout the mine, with strikes varying mostly between north and northeast. They appear to be all of the same type, left-hand faults, the west or northwest sides having moved south or southwest. The direction of displacement of the main fault has not been directly determined, but if all the faults are related, as seems likely, then it probably is also a left-hand fault, i.e., a fault whose north side moved westward.

The faults in the mine are either of different ages, or else movements have taken place along them at more than one time. Some cut the dykes of syenite porphyry and later gabbro, and hence must be later than the pyrite-pyrrhotite deposition, which occurred before these dykes were formed. Other faults must be earlier than the pyrite-pyrrhotite deposition, because veinlets and projections of these minerals, not crushed or broken, are found in the fracture zones.

The numerous quartz diorite dykes split and re-unite in a most complex fashion, both along the strike and down the dip. In a general way the strike of the dykes parallels the bedding of the lavas, being north-northwest north of shaft No. 3, and northeast south of it. Their dip is eastward, averaging 40 degrees to 50 degrees, but is not uniform, changing from nearly vertical in one place to nearly flat in another. This rolling dip appears to be characteristic of the quartz diorite dykes.

The sulphide bodies replace beds of breccia or tuff, commonly the more chloritic dacite breccias. Evidences of replacement may be seen at the margins of the bodies, where grains of sulphide, usually pyrite, appear in the country rock and become more and more numerous until the whole becomes a solid mass of sulphide enclosing a few unreplaced fragments of the original rock. The massive lavas and the various dyke rocks were not readily replaced, and are apt to form walls to the ore-bodies. This is particularly true of the quartz diorite dykes, which in many places are either the roof or the floor, or both, of the ore-bodies. Presumably they acted as dams, stopping or directing the movement of the metalliferous solutions.

The dominant strike of the sulphide bodies is northeasterly, and is entirely independent of the bedding. This is best seen toward the northeast end of the " H " ore-body, the northeast strike of which is almost at right angles to the bedding, and in the body of barren pyrite at the northwest corner of Block 15, the northeast strike of which is again almost at right angles to the bedding. The lack of correspondence between the bedding and the strike indicates that deposition was primarily controlled by some factor other than bedding; and as the northeasterly direction is the general direction of faulting and stress, it seems logical to conclude that deposition was probably localized by the faulting and fracturing. The inference is supported to some extent by the fact that the sulphide masses are later than some faults, and that some of them have formed in faulted zones.

A secondary or minor influence controlling the strike of the ore-bodies is the direction of bedding. As the sulphides replace breccias and tuffs readily, and other rocks with difficulty or not at all, sulphide masses forming along northeasterly fracture zones might be expected to follow the bedding wherever easily replaceable beds cross the fracture zones, and perhaps to extend for considerable distances laterally. At present there is but little evidence of any such lateral extensions, as most of the development has been around shafts Nos. 1 and 3, where bedding and faults both strike northeast. The sulphide body, described on page 202 as east of shaft No. 2, strikes north 75 degrees west, and hence appears to be an example, as it nearly parallels the bedding. Probably also the "Crusher" ore-body will prove to be another example. Some other ore-bodies, such as " C " and " E," do not exhibit fracturing at their ends, so far as could be seen at the time of examination, and thus appear to have formed by replacement along bedding planes.

The sulphide bodies are composed of pyrite, pyrrhotite, and chalcopyrite in varying proportions, with a little magnetite and sphalerite in places. Pyrite was the first to be deposited, followed in order by pyrrhotite, sphalerite where present, and chalcopyrite; and each, as it formed, replaced the earlier minerals to a greater or less extent. The iron sulphides formed after the intrusion of the quartz diorite dykes, as indicated by the small veinlets of the sulphides which run into and alter the quartz diorite. No evidence was obtained at the Horne as to the age relationship between the iron sulphides and the syenite porphyry, but it is presumed, from the data obtained at the Aldermac mine, that the syenite porphyry is later than the iron sulphides. Veins of chalcopyrite, on the other hand, cut and alter the syenite porphyry, as was also observed at the Aldermac. Chalcopyrite veinlets likewise cut into the chilled edge of the later gabbro dyke, and fill fault fissures that have crushed the chilled edge. The chalcopyrite is, therefore, younger than both syenite porphyry and later gabbro. No data have been obtained to indicate when the zinc blende was introduced. It is only known that it was formed at some time between the deposition of pyrrhotite and that of chalcopyrite.

The introduction of the sulphide-bearing solutions has been accompanied by alteration of the country rocks. Veins of pyrite have altered narrow widths of wall-rock to quartz, epidote, and hornblende. Veinlets of chalcopyrite are edged with alteration rims of chlorite and colourless mica or talc, with some epidote and quartz. In addition to these smaller alterations, the causes of which are evident, practically all the lavas and tuff on the Horne property are highly altered, and the changes have proceeded in two stages. The earlier was the addition of much quartz to the original rock, and the replacement of the original feldspar by this quartz and by sericite with a little albite. The second stage was the replacement of the silicified rock by chlorite. Evidence suggests that all or nearly all of the chlorite-bearing rocks in the mine, and particularly the rocks termed dacite and dacite breccia for convenience, have really been formed by the chloritization of rhyolites and rhyolite breccias.

The distribution of chalcopyrite relative to the other sulphides is suggestive. Leaving out of consideration bodies such as "E," "A," "B," and "D," the whole mass of which, in each case, is well impregnated with chalcopyrite, and dealing only with those bodies in which chalcopyrite is not uniformly distributed, there are: (*a*) three sulphide masses in which chalcopyrite enrichment occurs only at one end; and (*b*) three masses that are lean at the top and carry good copper values at depth. The three sulphide masses in which enrichment occurs at one end are: the "C" ore-body, the northeastern half of which contains the bulk of the copper values; the sulphide band east of shaft No. 2, striking north 75 degrees west, which is enriched with copper for 200 feet at the western end; and the Crusher ore-body, which, as previously stated, appears to be the eastern end of the lean "H" ore zone. The "A-D" ore-body, too, is very much richer at the northeastern end than elsewhere, running nearly pure chalcopyrite. The three sulphide masses which are lean at the top and pass into ore lower down are: the "K_1" ore-body; the body about 75 feet northwest of "B" ore-body; and the "H" ore-body. Probably other examples of these relationships will appear as development proceeds.

From these facts the conclusion is obvious that no body of sulphides on this property should be neglected, but that each should be thoroughly explored both along the strike and down the dip, for barren sulphides may pass into ore at depth or at the ends, or both.

As the quartz diorite dykes wall in the ore-bodies, and dip to the east, and as the ores are of the deep-seated type and, therefore, may be expected to continue to occur at depth, it seems reasonable to conclude that with further exploration a series of lenses will be found, dipping beneath one another. Instances of this are already known, even though the depth to which exploration has been carried is limited. Thus the "K_1" ore-body dips beneath the "D" ore-body. The same type of relationship is found also on the Aldermac where No. 3 ore-body is underlain by No. 4, and is overlain at the surface by a body that bottoms at a depth of 20 or 30 feet. Thus there may be assumed to be an ore " zone " extending steeply downward, in which quartz diorite dykes and ore lenses occur at various horizons, with east or southeast dips.

The distribution of the gold values in the Horne ores is most erratic. The Horne and Robb-Montbray mines are the only properties in the district on which the sulphide bodies carry important gold values. It would seem, therefore, that the gold is not an element of the general sulphide mineralization, but that it was introduced from purely local sources. A careful study of the Horne assay sheets shows that the gold is not in any way related to the amount of chalcopyrite present, but varies independently. This condition is illustrated, in a general way, by the average copper-gold content of the different bodies: " F " ore-body carries about $8 a ton in gold, and very little copper; " B " ore-body averages about the same gold content as " F," but carries 8 to 10 per cent of copper. The " A-D " ore-body averages 10 to 15 per cent of copper, but only $4 to $5 in gold, whereas the " K_1 " ore-body beneath it is equally rich in copper, but carries only about $2 in gold. The gold content also appears to be equally independent of the other sulphides. Thus while " F " ore-body, as stated, averages $7 to $8 a ton in gold, the " H " ore-body, which on the first level is practically identical with " F " in its proportions of pyrite, pyrrhotite, and chalcopyrite, carries only $1 to $2 a ton in gold. On the other hand, the Mines Branch, Department of Mines, tested the sulphides of " F " ore-body by separating the different sulphides and assaying each, and showed that the pyrrhotite carries no gold, but that all the gold is associated in some way with the pyrite and chalcopyrite. The data already given, however, indicate that neither the pyrite nor the chalcopyrite, as originally deposited, carried the gold, for, if they did, some proportionality would surely exist between the gold content and the amounts of one or other, or both, of these minerals present in the ores. The known, pertinent facts thus seem to indicate that the gold was introduced, in a local and erratic fashion, into the sulphide bodies at some time after their formation. Its association with pyrite and chalcopyrite rather than with pyrrhotite may have been caused by selective precipitation.

Amulet Mines

LOCATION AND HISTORY

Amulet Mines, Limited (132 St. James street, Montreal), owns a group of seventeen claims, comprising about 1,500 acres, astride the Duprat-Dufresnoy boundary, and between 1 and 2½ miles from the south boundary of these townships. All the discoveries, to date, are in Dufresnoy township.

The first discovery, known as the north showing, was made in 1924 near the north end of claim M.L. 1897. The amount of ore at this spot is small. A much larger ore-body, called the south showing, was found later near the east side of claim M.L. 1891, and was thoroughly outlined by drilling and trenching. During the winter of 1925-6 small masses of ore were located in the southwest corner of claim M.L. 1890, and an exploratory shaft 150 feet deep was sunk. As the underground work was not attended with great success, a program of drilling was instituted, with the result that several lenses of sulphides were found in the vicinity of the shaft. During the summer of 1929 another large ore-body was found by drilling about 1,200 feet east of the initial discovery. A 300-ton mill was built during the winter of 1929-30, and a railway spur run into the mill-site. Geological examinations were made by Survey officers in 1925 and 1929.

GEOLOGY

The rocks on the Amulet claims are chiefly Keewatin lavas, and they lie on the broad summit of the Dufault anticline. The area of flat-lying flows extends north and south of the Amulet property.

The great bulk of the lavas on the claims consists of rhyolite, though some dacite and a small amount of andesite are also present. The rhyolites, of which there are several flows of differing acidity, are all hard, fine-grained rocks, commonly amygdaloidal and in some cases noticeably porphyritic. They are fresh enough, as a rule, to be extremely hard and brittle, so that thin slabs ring when struck.

The rhyolite in the neighbourhood of the south end of the south showing (No. 2, Figure 16) was determined in 1925 to contain 5 to 10 per cent of quartz, 2 or 3 per cent of fine-grained magnetite, about 35 per cent of a very pale-coloured actinolite, and the remainder a feldspar, apparently oligoclase. The feldspar forms long, narrow laths, pierced by numerous needles of the actinolite, and more or less altered otherwise. Amygdules, which are numerous, are filled with biotite and quartz, with an occasional grain of pyrite or magnetite. A considerable area of this rhyolite is exposed.

About 400 feet west of the north end of the north showing (No. 1, Figure 16), there are excellent exposures of rhyolites. These particular flows are stratigraphically the lowest on the property, as they outcrop over the crest of an anticlinal dome. There are several flows closely alike in composition. At the base of a flow the lava is massive, very fine grained, dark grey in colour, weathering to a light grey. It contains few amygdules, but those that occur are usually half an inch or more in length, and filled or partly filled with hornblende. In the upper parts of the flows ropy and stringy textures become very prominent. Amygdules are numerous, and in places, notably a locality about 800 feet west of the south end of the north showing (No. 1, Figure 16) and another locality 2,850 feet a little west of south from the first-mentioned locality, large numbers of true spherulites, rounded nodules composed of radiating needles of quartz and feldspar, also occur.

In a number of places, the rhyolite contains irregularly shaped lumps of lighter colour than itself. These vary in size from a few inches to 20 feet or more in diameter; they are not sharp-angled, but usually are rounded, though irregular. Similar lumps have been found in rhyolitic and trachytic lavas of the region in a number of places, but their origin has previously been in doubt. At the outcrop 400 feet west of the north end of the north showing (No. 1, Figure 16), the lumps consist of very fine-grained rock of very siliceous composition, filled with small amyg-

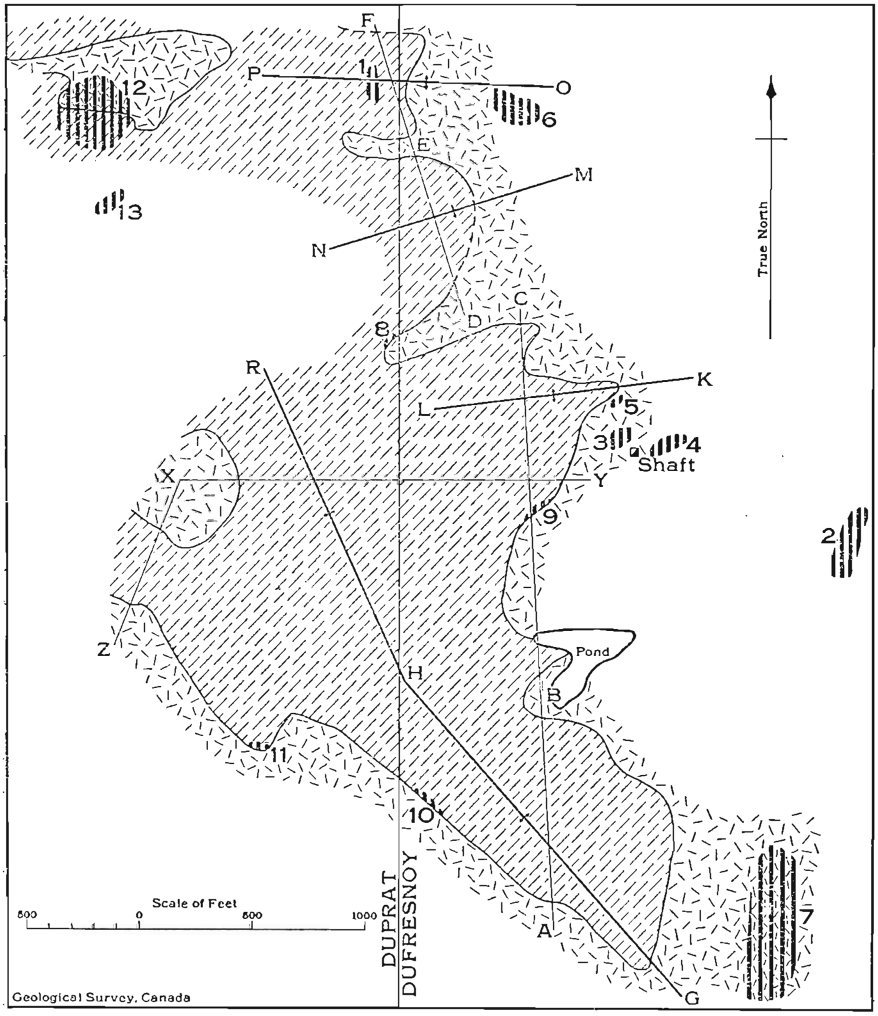

Figure 16. Surface geology, Amulet mine, Quebec. Dacite, some andesite shown by irregular pecked pattern; rhyolite shown by broken diagonal ruling; ore-bodies and areas of heavy mineralization shown by heavy vertical ruling.

dules. Each lump is completely surrounded by a band half an inch to an inch in width, of stringy-textured matrix. The stringy texture, at all points, parallels the edge of the lump, and the band follows faithfully all the irregular outlines of the lump. Farther away from the edge of the lump, the lava is less stringy, or else massive. Lumps tend to be more numerous in the upper horizons of the flow than in the lower. The stringy band around the lumps indicates that they were solid while the matrix was still fluid or semi-fluid, so that the rock is a flow breccia. The general similarity between the composition of lumps and matrix, and the amygdules in the lumps, suggest that the lumps are fragments of the lava itself, either blown out from a vent, or pieces of a primary crust broken up and engulfed in the flowing lava. The rounded outlines, in that case, must be due to partial re-melting.

Microscopic examination shows the matrix to be pretty thoroughly altered, so that the composition of this rhyolite must be judged from that of the fragments. These are made up, it was estimated, of about 35 per cent of quartz, perhaps 5 per cent of chloritized hornblende in sheaves of needles, and the remainder fine-grained oligoclase, $Ab_{80}An_{20}$. Grain size averages about 0·05 mm.

To the east of the rhyolites just described, running south completely across the property (*See* Figure 16), is a flow of dacite. At the base this flow is medium grained, dark grey or greenish grey in colour, and easily distinguishable from the lighter-coloured, stringy-textured rhyolites. The finer-grained upper horizons of the flow are lighter in colour and less easily distinguishable from the rhyolites. The rock is of importance because its lower contact can be traced, and thus yields valuable information as to the structure. A specimen of it, as fresh as possible, taken in the vicinity of the shaft, consists of about 35 per cent partly chloritized hornblende, 3 or 4 per cent of biotite, 2 or 3 per cent of quartz, and the remainder slightly kaolinized oligoclase, $Ab_{75}An_{25}$. Average grain about 0·2 mm.

A few patches of true andesite are scattered here and there over the south showing. The rock is amygdaloidal and, like the dacite, exhibits well-developed pillow structures in places. It is dark grey, weathering to a brownish grey, and the weathered surface is marked by numerous rounded protuberances, one-twentieth to one-eighth inch in diameter, which consist of small aggregates of hornblende. The rock is composed of 50 to 60 per cent of actinolite, 2 or 3 per cent of magnetite, and the remainder a feldspar that appears to be andesine, although definite determination could not be made in the one thin section available.

In addition to the lavas, a large dyke of later gabbro runs through the northeast corner of the property, and several dykes of older gabbro cut across it in a direction about northeast to north 60 degrees east.

Dalmatianite. In 1925 the senior author described an unusual rock characterized, in certain phases, by numerous rounded, whitish nodules up to ¾-inch diameter embedded in a dark brownish matrix. The striking, spotted appearance of the weathered surface (Plate III B), resembling somewhat the coat of the Dalmatian, or coach dog, caused the rock to be christened dalmatianite, or spotted dog; and by these names it has become known throughout the district.

The examination of that year was confined largely to the north and south showings (Nos. 1 and 2, Figure 16). At the south showing the dalmatianite is highly amygdaloidal in places, is characterized locally by well-developed pillow structures, and is sandwiched, with well-defined contacts, between a hard rhyolite below and an andesite above. At the north showing parts of the dalmatianite have ropy or cordy textures, and certain dykes of rather similar lava have, also, the spotted texture developed in them. On these facts the opinion was based that the dalmatianite was a primary lava of unusual composition and texture; in spite of the facts that the composition varied from place to place within the flow in a most extraordinary manner, and that the " spots " are filled with inclusions like crystals of secondary development.

In 1927 J. G. MacGregor, then manager of the property, stated that some drill cores near the shaft showed a progressive intensity of " spotting " as ore-bodies were approached, and concluded that the spotted texture was really a secondary alteration induced by the ore-bearing solutions. His data were examined by the senior author in that year, and it was observed that although some drill cores were undoubtedly as he described them, in other places, in surface exposures, ore-bodies are in direct contact with rock that has no spotted texture. The question, therefore, remained in doubt.

In 1929 a second examination was made, in which attention was specially directed to the large areas of dalmatianite west of the north showing (No. 1, Figure 16). The small areas of dalmatianite near the shaft were also studied. Definite proof was obtained that the spotted texture is a secondary development, and, in fact, is only one of the later steps in a progressive alteration. In many places, but particularly in a locality within the area of mineralization (No. 12, Figure 16), 2,400 feet west of the north showing, ordinary lava without spots was observed to pass gradually into normal dalmatianite. In some places the change occurred, first by the appearance in the non-spotted lava of a few spots of ordinary size; the spots then gradually became more and more numerous until dalmatianite of the ordinary type resulted. In some other places, very numerous, but very small, spots first appeared; and the size of these gradually increased until the rock became normal dalmatianite.

Dalmatianite forms as an alteration product of both rhyolite and dacite. It seems to have been produced by the action of the ore-bearing solutions on the rocks, but only in certain places under special conditions. The description of the whole process of alteration will be given in a later paragraph.

STRUCTURE OF THE AREA

To determine the structure in this area of well-exposed lavas, the lower edge of the dacite flow was selected as an easily recognizable horizon, and traced as far as time would permit. Mapping was done by ordinary pace and compass methods, but the traverse was tied at frequent intervals to points fixed by transit survey, such as the Duprat-Dufresnoy line, claim corners, and intersections of co-ordinate lines which were run at 400-foot intervals in 1925. Half, or more than half, of the pickets marking these co-ordinate intersections may still be found by careful search. The boundary as shown in Figure 16 is, therefore, believed to be accurately located within 10 or 15 feet, except where broken lines indicate less accuracy.

The general dip along the northwest-striking south contact is 55 to 65 degrees southwest. The dip of the east contact running northerly across the property is eastwards at angles varying from 5 to 30 degrees. The east contact follows an irregular course because the flow has been wrinkled during the folding in a complex manner. Figure 17 shows, by cross-sections, the details of the folding as far as they have been worked out.

Figures 16 and 17 make it evident that a main anticlinal axis occupies approximately the position of the line GH, and swings northwest along HR. Beyond R it has not been determined, but perhaps continues through the dacite mass on the projection of HR. A second important anticlinal axis occupies the position LK, approximately, and still others are indicated by MN and OP. A minor axis runs through the small lake, and a second lies about 600 feet north of LK. Points B, D, and E lie approximately on the axes of synclines between the mentioned anticlines.

RELATIONS OF ORE-BODIES TO STRUCTURE

It is obvious from a glance at Figure 16 that ore deposition is in some way related to the rhyolite-dacite contact. The north showing (No. 1, Figure 16) is only the root of an ore-body from which the upper part has been eroded; it lies only about 500 feet west of the contact, which has a gentle eastward dip. The ore-body must, therefore, have lain just below the contact, prior to erosion. The new "F" ore-body (No. 6, Figure 16) must similarly be close to the contact, either above or below it, as its upper surface lies at a depth of about 200 feet. The ore-bodies marked Nos. 3, 4, and 5, on Figure 16, around the shaft, have been proved by development to lie either just above or just below the contact. An area of heavy mineralization, No. 7, Figure 16, lies just east of the contact in the southeast corner of the area. Spots of heavy mineralization have been found in several places along the contact, near points Nos. 8, 9, 10, and 11, Figure 16.

The figure shows, likewise, that all the larger ore-bodies yet discovered have a very definite position with regard to the axes of folding. Those numbered 1 and 6 occur along the crest of the anticline whose axis is OP. Nos. 3, 4, and 5 are on the crest of the anticline whose axis is KL. The south showing, No. 2, lies on the crest of an anticline, which may be the faulted extension of LK, or may be the eastward extension of the subordinate anticline beneath the small lake. The area of heavily mineralized lavas, No. 7, occurs on the crest of the anticline whose axis is HG.

The rather numerous occurrences of mineralized spots and ore-bodies along the contact of the two flows suggest that the highly flow-textured, amygdaloidal top of the rhyolite flow afforded a comparatively easy channel for the movement of ore-bearing solutions, and that these were confined to that channel by the overlying massive and impenetrable base of the dacite flow. The grouping of ore-bodies along the crests of the anticlines, and their non-occurrence elsewhere, suggest that the movement of the solutions was checked in these situations, and that this ponding permitted, or caused, replacement of the country rock to occur.

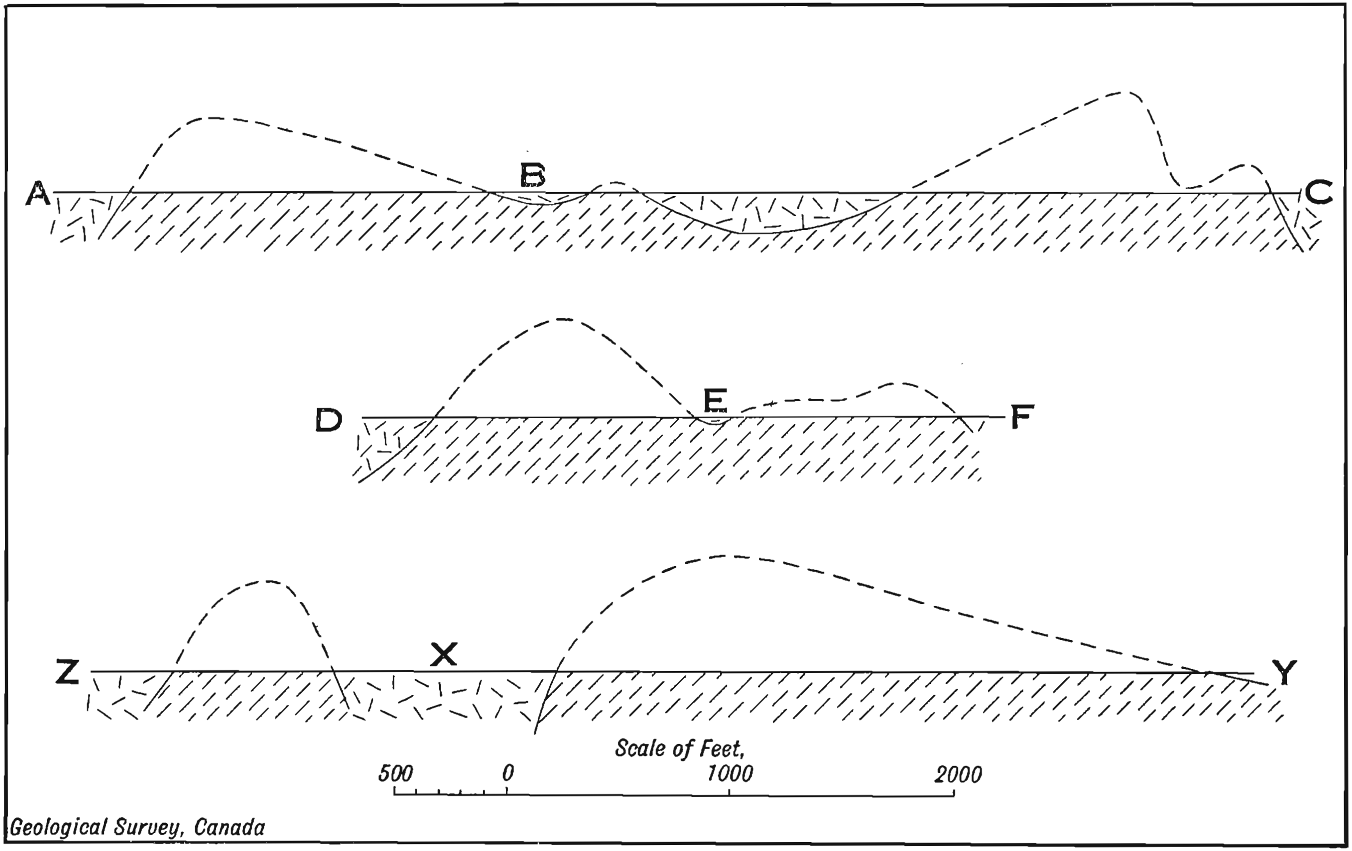

Figure 17. Cross-sections (*See* Figure 16) showing structure, Amulet mine, Quebec. Dacite shown by pattern of irregular pecks; rhyolite shown by broken diagonal during.

RELATION OF DALMATIANITE TO STRUCTURE

Dalmatianite is very localized in its occurrence. A considerable area of it is found around the north showing (No. 1, Figure 16). It is well developed over the south showing (No. 2, Figure 16). Patches of it occur here and there over ore-bodies Nos. 3, 4, and 5, near the shaft, and the upper parts of the rhyolite flow directly west of these ore-bodies are likewise converted into it. The largest area on the property, approximately 2,000 feet from east to west and 1,000 feet from north to south, is in the northwest corner of the area represented by Figure 16, where OP and HR, if projected, would meet. Outside of the areas mentioned, dalmatianite does not occur, except possibly along the westward extension of the axis MN, which was not examined. It will be noted, therefore, that the only occurrences of this interesting alteration product are along the crests of anticlines. Further, the largest area of it is found in an area that is probably a dome, where anticlinal axes, if projected, intersect; the next largest areas, over ore-bodies Nos. 1 and 2, are where the eastward dip appears to have been quite low; and the smallest areas, around the shaft, are where the eastward dip was somewhat higher. It would appear, therefore, that the formation of dalmatianite was likewise dependent on the ponding of the solutions causing rock alteration, and that where such ponding could not occur, alteration did not go as far as the formation of the spotted texture.

ORE-BODIES

Six bodies of ore have been found to date. Of these, the north showing (No. 1, Figure 16) contains only a small tonnage; it appears to be merely the root of a larger ore-body cut away by erosion.

All the ore-bodies are rather flat, pancake-shaped bodies, conforming roughly in strike and dip to the surrounding lavas. The shapes are most irregular, rendering it difficult to estimate tonnages accurately. Like other bodies in the region, they are replacements of the altered lavas. They consist of masses of solid sulphides, with very little silica or other earthy impurity. The sulphides present are pyrite and pyrrhotite, zinc blende, and chalcopyrite. Pyrite and pyrrhotite were the first to be deposited, then the zinc blende, and finally the chalcopyrite.

At the annual meeting of the company held in August, 1929, Mr. J. Tuttle, manager, presented estimates of the tonnage and metal content of each of the different ore-bodies then known. The " F " ore-body (No. 6, Figure 16) was not then fully known, and no estimate of it was given. Mr. Tuttle estimated the known ore-bodies to contain slightly more than 400,000 tons of ore, grading 2·78 per cent copper, 12·48 per cent zinc, $1.04 gold, and 2·91 ounces silver a ton. Since this estimate was made, " F " ore-body has been thoroughly explored by drilling. No official statement of its tonnage or value has been made, but it will probably add some 200,000 tons to the previously known reserve.

ALTERATION OF COUNTRY ROCK

The rocks in the vicinity of ore-bodies are highly altered, but certain differences are found between the alteration of the dacite above the ore-bodies, and the rhyolite beneath and to one side. The two may, therefore, be separately described.

The dacite above an ore-body is first sliced by a series of narrow cracks, in places only 1 or 2 inches apart, in others farther. In many places only one set of these parallel cracks is developed, but in other places there are two sets which cross at angles of 45 degrees or more. In the latter case one set is nearly always more perfectly developed than the other. The cracks, which are about one-fifth of a millimetre in width, are filled with epidote, chlorite, sericite, and a little of some colourless mineral not identified. Although the rock on each side, viewed under the microscope, does not seem to have been altered, it has in some way been rendered more resistant to weathering, for the veinlets, and the rock for perhaps one-eighth inch on each side, stand up on the weathered surface as ridges about one-quarter inch in height, thus giving it a characteristic ribbed or cross-ribbed appearance sometimes termed "grid structure." Mr. J. G. MacGregor has considered any large area thus ribbed as a reasonably sure indication of ore beneath, and directed exploratory drilling accordingly. Several ore-bodies have been discovered in this way.

In the second stage of alteration, the dacite is converted into a rock that is dark brownish grey on the fresh surface, and weathers to a light brownish grey with characteristic smooth, rounded contours. Prior to this alteration the dacite is made up of 3 to 4 per cent biotite, 2 to 3 per cent quartz, about 40 per cent green hornblende, and the remaining 50 to 55 per cent oligoclase with accessory magnetite. The altered material is about 40 per cent biotite, 15 per cent or more quartz, 5 to 10 per cent recrystallized actinolite, and the remainder, 35 to 40 per cent, oligoclase. Thus alteration caused great increase in the amounts of biotite and quartz, with corresponding decrease in the original hornblende and feldspar.

In the third stage of alteration, spots begin to form in the matrix, which continues to change in composition. Under the microscope it is seen that the original feldspar has completely disappeared, and the amount of quartz has increased to 35 or 40 per cent. The biotite of the second stage has likewise disappeared in part, and is replaced by chlorite or hornblende. The hornblende is almost colourless, with a very small extinction angle. It appears in needles and rods, with a tendency to aggregate into sheaves; and these rods cut indiscriminately across both biotite and quartz crystals. The spots are sericitic aggregates, including within themselves numerous quartz inclusions. Apparently the sericitic aggregate, or the mineral from which it was derived, replaced the hornblende and biotite of the matrix, leaving the quartz comparatively unaffected. It is thought that the sericitic aggregate may be pinite, the result of alteration of cordierite, but this has not yet been proved.

The final stage of alteration is reached in some specimens obtained from the mine. In these the matrix is wholly chlorite, with some hornblende, and the spots are clear mineral crystals, without inclusions. These crystals, according to determinations made by Dr. T. L. Walker,[1] of the University of Toronto, are cordierite, and this determination was confirmed by X-ray studies made by Dr. A. N. Winchell[2] of the University of Wisconsin. Many of the crystals exhibit the beginning of the alteration to micaceous aggregates such as those mentioned in the previous paragraph.

The alteration of the rhyolite, which does not directly overlie the ore-bodies, follows a somewhat different course. The first change above described, namely the slicing and veining of the rock with production of a ribbed surface, was nowhere observed.

About 400 feet west of the north showing (No. 1, Figure 16) the least altered rhyolite obtained was that in the fragments of flow breccia. It consists of about 35 per cent quartz, 5 per cent chloritized hornblende in sheaves of needles, and 60 per cent oligoclase, $Ab_{80}An_{20}$. The matrix, which presumably was originally of much the same composition, has a perfectly developed cordy flow texture. It can be seen with the unaided eye to be partly altered, as strings, dots, and irregular patches of biotite have formed in it. The microscope shows this rock to consist of a few phenocrysts of oligoclase, $Ab_{80}An_{20}$, more or less cracked and replaced by the matrix; small masses of introduced quartz grains; small patches of biotite partly replacing the matrix; and a matrix made up of quartz, oligoclase, 6 or 7 per cent actinolite, and a few crystals of biotite. The relative proportions of the oligoclase and quartz in the matrix are impossible to estimate, as the grain is very fine, 0·03 mm., and the feldspar is fresh and has about the same index of refraction as the quartz. Even without being able to do so, however, it is evident that the first stage of alteration consists, in addition, of some quartz and biotite.

For about a hundred feet eastward the rock undergoes little change in composition, then becomes rusted, owing to impregnation with a good deal of pyrite. Thin sections of this rock show a large increase in the amount of introduced quartz, which forms blebs, while the groundmass is altered to a mat of fine-grained white mica with a few grains of epidote. The quartz blebs constitute about 25 per cent of section.

About 70 feet to the east of the last locality, small patches of " spots " begin to appear in the rusty rhyolite. They weather out as raised greyish nodules about $\frac{1}{4}$ inch in diameter. They lie in a matrix consisting of about 60 per cent biotite, the remainder largely quartz, with some sericitized remnants of feldspar, and a little magnetite and pyrite. The " spots " are single crystals of a clear colourless mineral, filled with inclusions of quartz and mica. The index of refraction of the mineral is slightly lower than that of Canada balsam; its birefringence is about that of quartz; it is biaxial and optically positive; and it exhibits neither twinning nor cleavage. These characters were thought at first to indicate that the mineral is not

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[1] Walker, T. L.: "Dalmatianite, the Spotted Greenstone from the Amulet Mine, Noranda, Quebec"; University of Toronto Studies, Geol. Ser. No. 29, p. 9 (1930).

[2] Dr. Winchell's letter is as follows: "We have X-ray patterns from this mineral, a cordierite from Scotland, and another cordierite from our collections. The three patterns are essentially identical. I think this establishes the nature of your mineral beyond reasonable doubt. You may be interested further to know, by the accurate methods now in use here, the optical properties of your mineral were found to be as follows: $2V=84°-85°$; $N_g=1·5582$ (in sodium light); $N_m=1·5524$; $N_p=1·5458$."

cordierite, but albite-oligoclase. However, I. C. Chacko has described a cordierite[1] occurring in a diorite at Teruwalla, Travancore, India, as optically positive. This cordierite, according to his analysis, is unusually high in ferric iron. It is, therefore, possible that the Amulet "spots," although optically positive, may still be cordierite. Unfortunately, the inclusions with which the crystals are filled make it difficult to apply precise methods of determination.

As the ore-body is approached further, the principal change that takes place is the gradually more perfect development of the spotted texture. Spots become scattered through the whole body of the rock, instead of being confined to patches; they also become larger. Some of the spots are optically negative; in some of the thin sections both optically negative and optically positive spots were found. The matrix continues to be made up almost wholly of biotite and quartz, with a little colourless mica.

A foot or two from the ore-body the very dark brown matrix becomes lighter in colour. Its tint and general appearance are such as to suggest that the rock has been impregnated with very fine-grained sphalerite. A thin section shows, however, that no sphalerite is present, but that the proportion of biotite has decreased suddenly to about 20 or 30 per cent, and its place taken by a colourless mica. The spots, closely observed, are enclosed by narrow, dark-coloured rims, which, under the microscope, seem to consist mainly of muscovite.

In 1925, the "spots" in material from this locality were determined as andesine, $Ab_{70}An_{30}$ to $Ab_{60}An_{40}$. Unfortunately, the best of the thin sections obtained at that time have been forwarded by request to the British Museum, so that they could not be compared with those of 1929.

Half a mile west of the north showing, the body of dacite shown in Figure 16 is largely altered to dalmatianite. The alteration is of the same general character as that observed around the shaft, and the "spots," like those formed near the shaft, are wholly aggregates of mica, which may be secondary after cordierite. In this locality many of the spots are not merely rounded lumps, but rather exhibit imperfectly developed, though distinct, hexagonal outlines, which suggest cordierite, as that mineral forms pseudo-hexagonal forms by twinning.

In this vicinity a rather extraordinary peculiarity in the distribution of the dalmatianite was observed. Three dykes, each 15 to 20 feet wide, and spaced 100 to 150 feet apart, strike east, cutting through the dalmatianite. In each case the dyke material has weathered so much faster than the surrounding rock that the outcrop is marked by a steep-walled depression 5 to 15 feet in depth. Here and there a small outcrop of the dyke rock projects through the soil at the bottom of the depressions. All the dykes dip south, the two northernmost at 40 degrees, the southern at 60 degrees. The northernmost dyke is a rather siliceous quartz diorite, the middle one an ordinary altered gabbro; no good specimen of the southern was obtained. Each of these dykes has affected the dalmatianite in the same manner. On both sides of each dyke, for a distance of $1\frac{1}{2}$ to 2 feet at right angles to the dip, the lava contains no spots whatever. Then follows a band, parallel to the dyke and 6 or 8 inches wide, of rock that is whitish

[1] Chacko, I. C.: Geol. Mag., 1916, pp. 462-4.

on the weathered surface. This in turn is followed by a band of about the same width that is crowded with small " spots "; these rapidly increase in size, away from the dyke, until within a few inches the " spots " are of normal size and appearance.

The reasons for this peculiar behaviour can only be surmised. The fact that the phenomena are the same on both sides of the dyke prohibits the conclusion that they are due in any way to the dykes damming or checking the movement of solutions. It will be noted, however, that the phenomena here differ in one way from those where spots normally appear for the first time in a rock previously without them. The normal manner of appearance is for a few spots to form first, and those few of considerable size; then more and more are formed, as the source of alteration is approached. The first occurrence of spots near one of the dykes, on the other hand, is marked by the sudden appearance of swarms of minute spots; and, so far as the eye can determine, the total volume of the small spots is about the same as that of the larger spots in the rock a few feet farther away. Evidently, therefore, the spot-forming tendency was the same close to the dykes as farther away; but the dykes, in some way, hindered their formation. There is no evidence that the dykes caused any chemical alteration of the rock on each side; in fact, as they are comparatively small and are strongly chilled, any such action would be unusual; hence the only possible alternative would seem to be, that the heat of the injected dykes caused sufficient cementation or recrystallization to inhibit subsequent alteration and the formation of the spots.

In the south showing (No. 2, Figure 16) the original lava is most thoroughly altered to biotite. This mineral forms about 75 per cent of the rock body, and the remainder is largely quartz, with a little feldspar and magnetite. The " spots", in the thin sections studied, are now mainly micaceous aggregates. Careful search was made, in 1929, to find less altered material, so as to determine what rock had given rise to the dalmatianite in this locality. In one place only, the dalmatianite graded into a small patch of less altered material, which was a highly amygdaloidal rhyolite very like that found about 500 feet west of the present shaft. At the south showing, therefore, it would seem that a whole thin flow of amygdaloidal rhyolite had been converted into dalmatianite.

Summary of Rock Alterations. To generalize the observations described, together with many of which lack of space forbids description, the course of alteration appears to have been about as follows. The first step was the replacement of the original feldspar and chlorite of the rock by silica and biotite. The introduction of the silica took place rather in advance of that of biotite, so that silicified rocks, with comparatively little biotite, are found farther from the source of alteration than those with much biotite. The next step was the development of spots in the quartz-biotite rock. This took place by the replacement of part of the quartz, biotite, and other minerals by the material forming the spot. Consequently, the spots, except where the replacing action has been extreme, are filled with inclusions of quartz, mica, and other minerals not completely replaced. The spots are single crystals, and exhibit this fact by simultaneous extinction, under crossed nicols, of all the mineral in the spot other than the inclusions. The spots are either two minerals, cordierite and oligoclase-albite, or else cordierite both optically positive and negative in character. Spots consisting of micaceous aggregates are also common, but it is assumed, until otherwise proved, that these are altered cordierite. The conditions that determine whether the optically negative or optically positive mineral shall form are not yet understood; about all that can be said is, that the optically negative cordierite seems always to have formed in the alteration of dacites, the optically positive mineral in that of acid rhyolites.

The final step in the alteration appears to have been the elimination of inclusions from the spots, and the replacement of the biotite-quartz matrix by hornblende and chlorite. This result, partly completed, can be observed in many places; but has been seen wholly complete only in specimens from the workings at the shaft.

The reaction required quite favourable conditions in order to proceed even as far as the formation of "spots." The first condition was, apparently, that the solutions causing alteration had to be checked or dammed in their movement, to give time for the reactions to proceed. This occurred only at the summits of the low anticlines, and the occurrence of dalmatianite is, so far as known, entirely confined to such summit areas. A second condition, though not one absolutely necessary, was the presence of flow and amygdaloidal textures. Where "spots" are few, they are commonly confined to strongly flow textured material; and they exhibit their largest developments in such rock. Where the altered rocks are massive, as in the case of the dacites near the shaft, the areas of spotted material are comparatively insignificant, and alteration is mainly confined to the first stages of silicification and biotitization.

The idea has been put forward at times, that the "spots" are really cavity fillings rather than replacements. The evidence detailed in the preceding pages emphatically forbids such a conclusion. The regular hexagonal forms of many of the spots are not those of cavity fillings; the numerous inclusions, the lack of any sharp boundary, and the manner in which most spots grade at the edges into the matrix by increase of the proportion of inclusions, all point to their origin as replacements. The gradual appearance of swarms of small spots in massive rock and their graduated increase in size to large spots, in the mineralized area No. 12, Figure 16, also indicates them to be replacements, not cavity fillings. Finally, the only true cavities of any size in the rock, namely the amygdules filled with quartz, biotite, etc., are everyhere entirely unaffected by the processes of replacement; so that the observer can walk from unaltered, highly amygdaloidal lava across the same lava in various stages of replacement to lava in which spots are thickly developed, and note that the amygdaloidal character is entirely unaffected. It is quite common to find well-developed spots entirely enclosing one or more amygdules, proving that the mineral of the spot must have replaced the rock that primarily surrounded them.

Waite-Ackerman-Montgomery Mines

This property was staked in March, 1925, by J. H. C. Waite, C. H. Ackerman, and T. Montgomery. It includes twenty-eight claims, with a total area of 2,379 acres. Of these claims, fifteen are in Duprat township, the remaining thirteen in Dufresnoy township. Later in the same year an 85 per cent interest in the property was sold to N. A. Timmins, who transferred it early in 1927 to Noranda Mines, Limited. A subsidiary company known as Waite-Ackerman-Montgomery Mines, Limited, and controlled by Noranda Mines, was then formed to operate the mine.

The original discovery is in the northwest corner of claim A 2864, Duprat township. It lies $3\frac{3}{4}$ miles from the south boundary of the township, and $\frac{1}{4}$ mile from the east boundary. The ore-body is in a clay-filled valley running east and west between rock ridges. Its discovery was accidental. Mr. Montgomery was crossing the valley, which at that time was muskeg, and, passing a fallen tree, saw an exposure of ore beneath the upturned roots. It proved later that this was almost the only spot where ore approaches the surface closely enough to be thus exposed.

Development work during 1925 consisted mainly of trenching, and by this means the presence of ore was proved over an area roughly 100 feet from north to south, and 200 feet from east to west. Diamond drilling was carried on throughout the following winter, and the ore-body thereby outlined. In 1926 a small force made a geological and magnetometric survey of the property, but found no further ore. Accordingly, work was discontinued until late in 1927, when preparations for mining were commenced under the direction of R. V. Porritt. Since that time a two-compartment shaft has been sunk, levels run at 187 and 300 feet, and much underground drilling done, in addition to the extraction of ore.

The known ore-body has been proved by the diamond drilling to be a roughly lenticular mass of sulphides with a dip of about 25 degrees to the southeast. The sulphides, as in the other bodies, are pyrite, chalcopyrite, sphalerite, and some pyrrhotite; and their order of deposition is the same as in the Horne and Aldermac mines. The ore-body is made up of a core of sulphides rich in chalcopyrite, surrounded by a leaner shell of iron sulphides and sphalerite. According to the published annual report of the company, this ore-body is estimated, from the drilling, to contain 140,160 tons of ore averaging 7·46 per cent copper and 2·47 per cent zinc; 27,460 tons averaging 2·64 per cent copper and 10·34 per cent zinc; and 288,150 tons averaging 11·52 per cent zinc. These figures total 455,770 tons of ore averaging 2·46 per cent copper and 8·67 per cent zinc.

In addition, three other bodies of yet unknown size have been discovered by drilling to lie vertically beneath the first. The uppermost occurs at a depth of about 500 feet from the surface, the second at 650 feet, and the third at about 700 feet. They appear to be lenses parallel to the No. 1 ore-body, but as yet little is known as to their position, size, or tenor, because when the examination was made they had been tapped by only five drill holes. The shaft is now being deepened to 700 feet, to explore them in more detail. According to existing drill records, the lower bodies contain no zinc, but are composed wholly of chalcopyrite, pyrite, and pyrrhotite.

Production began in September, 1928. All the ore is shipped direct to Noranda for treatment. The first shipments carried much zinc, and had to be concentrated before smelting. Afterward it was found possible, by careful mining, to ship direct-smelting ore, and practically all ore shipped during 1929 was of this type. The average grade of the shipments varied from 8 to 10 per cent in copper, and 4 to 6 per cent in zinc, though occasionally the zinc content was slightly greater. Four thousand tons have been shipped monthly. The ore has been mined by open-cut methods.

The geology in the immediate vicinity of the mine is extremely complex. The oldest rocks are Keewatin lavas of andesitic composition, but these are present in comparatively small quantity. The bulk of the rocks are intrusives, mostly diabasic or dioritic in composition. The oldest of these, known as D1, is a dark grey rock that weathers to a light greenish grey; it is equigranular and of fine to medium grain. The next, D2, is dark grey, but weathers to a very dark green. It is commonly characterized on the weathered surface by numerous small projecting knots of hornblende. Next in age is a rhyolite porphyry, a very fine-grained grey rock, weathering to a light grey, containing small phenocrysts of quartz. It forms narrow dykes and sills, cuts D1 and D2, and is cut by D3 and D4. D3 is also a dark grey rock that weathers to a very dark green, like D2. Unlike D2, it lacks the knotted surface, but is otherwise very similar. D4 seems to be more acid in composition than D2 or D3, and weathers to a lighter grey. It is equigranular.

All these diorites or diabases, it is believed, are to be classed with the older gabbro or quartz diorite. None has the characteristics of the later gabbro. Excellent exposures on which the contact relations between the four types are beautifully exhibited, occur around picket N 89, E 133, of the co-ordinate survey of the property. D1 seems to occur in fairly large, irregular masses; D2 forms dykes running north, and also in other directions; D3 and D4 form dykes running north 60 degrees east, parallel to the strike of some small faults by which D1 and D2 are displaced.

A single thin section of each of these dyke rocks was examined. All are rather badly altered. The feldspars have gone over in large part to kaolin, epidote, and other secondary minerals, and are badly cut up by needles of secondary hornblende, which pierce them in every direction. In addition to this secondary hornblende, D1, D2, and D3 contain an older hornblende as a prominent constituent, which may possibly, in part at least, be secondary after augite, although no remnants of original augite were found in the sections examined. Leaving out of consideration the secondary hornblende, and the kaolin, epidote, etc., the composition of each of these rocks was roughly estimated as follows:

D1: grain, 0·4 to 0·5 mm.; quartz, about 5 per cent; hornblende, about 25 per cent; feldspar, doubtfully identified as oligoclase, about 70 per cent; accessory magnetite or ilmenite.

D2: grain, 0·5 to 0·7 mm.; no quartz; hornblende, about 30 per cent; feldspar, probably andesine, about 70 per cent; accessory magnetite and pyrite or pyrrhotite.

D3: grain 0·3 to 0·4 mm.; quartz 2 or 3 per cent; hornblende, about 50 per cent; feldspar, close to andesine in composition, about 45 per cent; magnetite, about 2 per cent.

D4: a mat of feldspar laths up to 0·5 mm. long by 0·05 mm. wide; feldspar about andesine in composition; a few grains of quartz, and about 1 per cent magnetite; a good deal of the secondary hornblende in needles lacing through the feldspars.

Rhyolite porphyry. A few phenocrysts of quartz and feldspar, embedded in a matrix consisting mainly of fine-grained oligoclase, $Ab_{85}An_{15}$, with 15 or 20 per cent of actinolite in fine needles and laths. A few grains of magnetite.

Structure. The structure around the Waite has not been as thoroughly worked out as at the Amulet, partly because of poorer exposures, partly because of the great number of intrusives. However, there is sufficient evidence to indicate that in all probability the structural conditions in the two places are similar. At a point about 2,200 feet from the shaft, bearing south 6 degrees west from it, an excellent contact between flows was observed, from which the strike was determined as north 60 degrees east, the dip 33 degrees north, and the top as facing northwards. Near the shaft itself, and for some distance southwards, the strike, as inferred from the attitude of the ore-bodies and from sill-like intrusive masses, is about the same, but the dip is about 25 degrees south. On Beaver hill, a high, rocky knob about a mile northeast of the mine, and north of the line of strike drawn from the shaft, the strike is northwesterly, the dip 17 degrees northeast. Although the data, therefore, are meagre, they indicate that strata are folded into small folds with gentle dips on the flanks, and that the ore-body is located on a low anticline.

Alterations around the ore-body are of much the same character as at the Amulet mine, though less well developed. The same "grid structure" and spotted alteration that appears above all the Amulet ore-bodies is also seen above that at the Waite, although, singularly, it is rather poorly developed immediately above the ore-body, and much better developed a little to the south. A second area, about 1,000 feet in diameter, in which the grid structure is very perfectly developed, appears a quarter mile or more southeast of the shaft, suggesting the possible existence of another ore-body beneath.

A number of small faults were observed on the property, one of which underlies the valley in which the ore-body was discovered. They strike north 50 to 60 degrees east, have steep, almost vertical dips, and the north sides moved west relative to the south sides. They certainly cut the two oldest diabases or diorites, and perhaps later rocks. There is no evidence as yet that they were connected in any way with mineralization.

The ore-bodies were formed by the replacement of the andesitic lavas. They do not appear to have replaced any of the intrusives to any notable extent.

Chance Claims

The Chance group of claims is in Beauchastel township about a mile northeast of the Arntfield claims. The principal discovery lies near the northeast corner of the Howard claim, No. M.L. 1860 or block 18, some 50 feet north of the centre line of the township and 2½ miles east of its western boundary.

The country rocks at this point are light coloured, hard, rhyolite lavas interbanded with beds of breccia. Two of the flows cut by the vein-like band of ore are respectively 60 and 80 feet thick; the three beds of breccia with which these flows are interbanded are 15, 32, and 18 feet thick, respectively. The beds strike north 62 degrees east and dip steeply north; and an excellent determination was obtained, indicating the south sides of the flows to be the original tops. The rhyolite is made up of some phenocrysts of quartz embedded in a fine-grained matrix of fresh feldspar with a little actinolite. The feldspar has a low index of refraction, about that of albite or oligoclase-albite; but the exact determination is not possible in thin section, as the minerals are full of strain shadows.

Sulphides have replaced the rhyolites along a well-defined band or zone striking north 75 degrees west, and, therefore, cutting across the bedding at an angle of about 45 degrees (*See* Figure 18). It would seem, therefore, that the replacement has taken place along some original straight-line fracture. Where the sulphide band cuts through a rhyolite flow it is 3 to 6 feet wide. Where it crosses a bed of breccia it swells into a great mass of solid sulphide 30 feet or more in width, and partial replacement of the breccia has occurred for 100 to 200 feet farther.

The sulphide mass is composed almost wholly of pyrite, with some magnetite toward the edges. It has been stated that some zinc blende was found, but none was visible when the property was examined in 1923. The pyrite is said to carry low gold values, but no definite information on this point was obtained.

The sulphide band where it lies in massive rhyolite may be divided into two parts, a central zone of complete replacement, and two outer zones of partial replacement. The central zone, 3 to 6 feet wide, is a solid mass of fine-grained pyrite. The outer zones exhibit the rhyolite cut by numerous veinlets of solid pyrite, and a good deal of fine-grained magnetite and pyrite scattered sparsely through the rhyolite between veinlets. Beyond the zone of pyrite veinlets there is another zone of magnetite veinlets, the larger of which contain a central string of pyrite grains.

A thin section of one of the veinlets showed, in addition to pyrite and a little magnetite, an assortment of minerals characteristic of deposits from very hot solutions. These are quartz, a hornblende close to actinolite in composition, pistacite (epidote) in clean-cut primary crystals, and a good deal of a mineral, now altered beyond recognition, with the outlines of a feldspar.

The rhyolite breccias are some of them ash beds and some of them probably flow breccias. The one of which a thin section was made appears to be of the latter class. It consists of pebbles of light-coloured rhyolite up to a foot in length in a matrix of fine-grained, dark greenish, chloritic

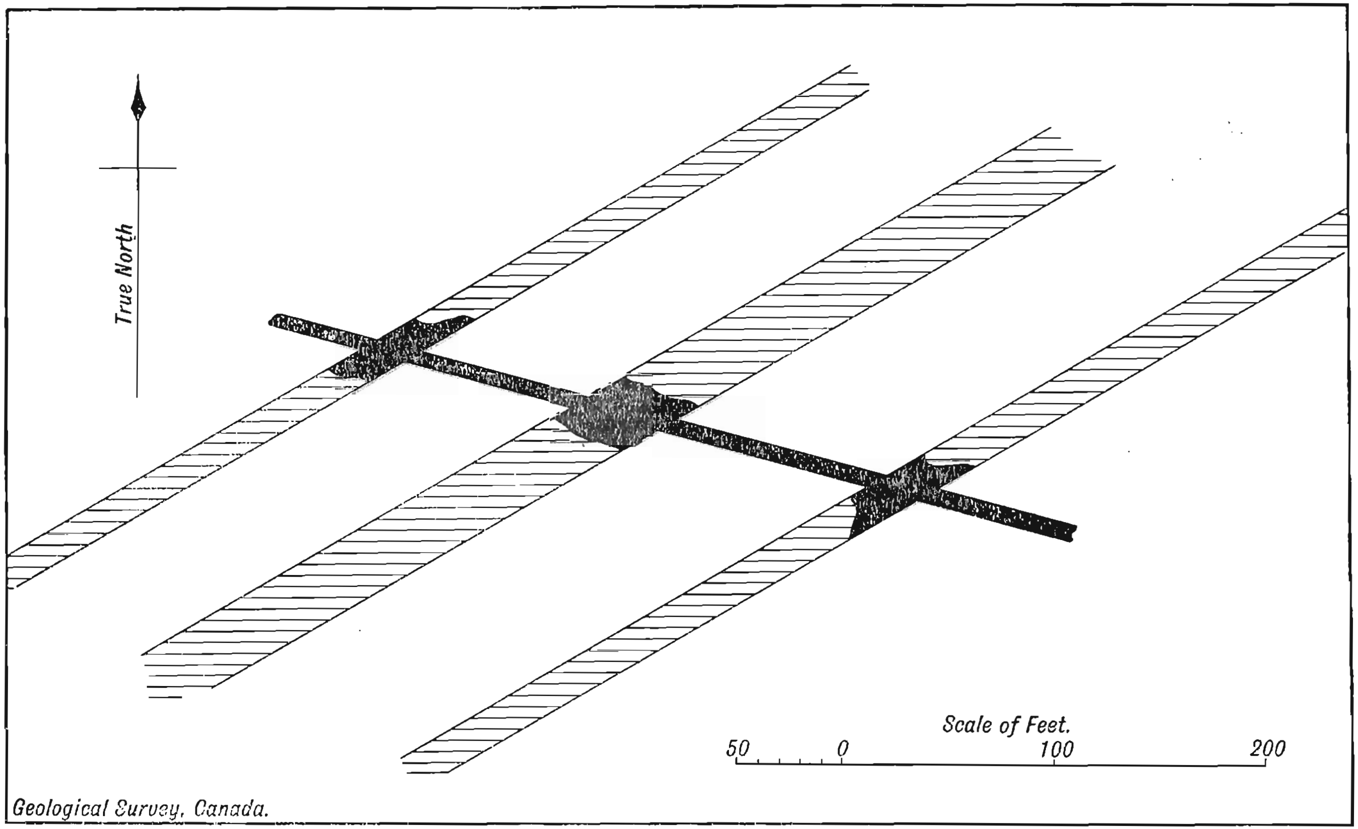

Figure 18. Chance pyrite deposit. Rhyolite flows are represented by blank areas; rhyolite breccia shown by horizontal ruling; solid sulphide shown by solid black.

material. Under the microscope the matrix is seen to consist of needles of actinolite largely altered to chlorite, and a fine-grained feldspar near albite in composition, in about equal proportions. A few grains of quartz were also identified. The pebbles are a very quartzose rhyolite, like that already described.

Where the vein crosses the breccia it swells into great masses of massive pyrite 30 feet or more in width, through the complete replacement of both pebbles and matrix. Beyond the edges of this body of solid sulphide a selective replacement has occurred, the matrix of the breccia being completely or partly altered to pyrite, the pebbles left comparatively untouched, although a little sulphide may have been introduced into them also, particularly near the borders of the mass of solid sulphide. The microscope also shows that the introduction of pyrite into the matrix has been accompanied by that of a good deal of magnetite.

The principal items of interest resulting from the study of the Chance deposit are as follows: (1) The deposit beautifully exemplifies the influence of the physical character of the rock upon replacement. In the massive rhyolite the sulphide band is narrow, but in the rhyolite breccia it swells to large size; (2) The mineral assemblage is characteristic of deposits from hot concentrated solutions; (3) The rhyolite around the edges of the pyrite mass is of the same composition as farther away; i.e., there is none of the alteration to chlorite, biotite, or cordierite found where chalcopyrite is a part of the sulphide bodies.

Robb-Montbray Mines

Robb-Montbray Mines, Limited, owns a group of ten claims, comprising about 400 acres, in the southeastern corner of Montbray township. Most of the work has been concentrated on claims 4847, 4848, 4849, and 4850. The property was staked in 1924 or early in 1925 by Quebec Prospectors, Limited; and in October, 1925, was optioned by them to the Nipissing Mines Company, Limited. For three years the latter carried on development work. A shaft was sunk to a depth of 560 feet, from which levels were run at depths of 63, 125, 225, 325, 425, and 525 feet, and about 5,000 feet of drifting and crosscutting were done. In addition, the property was electrically surveyed, and more than 21,000 feet of diamond drilling was done. In January, 1929, it was decided that the ore-bodies were too small and scattered to repay mining, and work ceased.

The rocks on the claims are rhyolites of Keewatin age cut by dykes and irregular masses of quartz diorite. Most of the latter are rather fine-grained rocks, but in the extreme southeast corner of the property a 70-foot dyke of similar composition but coarser texture, striking northeast, cuts across the finer diorite and is chilled against it. This coarse dyke is itself cut by a small basic dyke a few inches wide. The area thus appears to indicate that there are two, and perhaps three, different rocks which, at present, must all be classed as quartz diorite.

Prospecting operations have shown the existence of two parallel gossan-covered zones, striking northwest, and 400 to 600 feet apart. The southern, in which all the ore-bodies have been found, is about 2,000 feet long and up to 500 or 600 feet wide. It proved to be a zone of brecciation, the boundaries of which are very hard to map, as the intensely crushed material of the central parts passes, without any sudden change, into less and less fractured material, and finally into rhyolite only slightly fractured. The intensely crushed material is made up of angular to rounded fragments varying in size from small particles to lumps 2 feet in diameter, embedded in a fine-grained fragmental matrix. The fragments, where unaltered, are rhyolite identical in composition with the massive rhyolite outside the brecciated zone. Some of them are massive, others exhibit flow textures. The breccia is clearly a dynamic breccia, formed by the crushing of the massive rhyolites by differential movements.

The quartz diorite dykes that cross the brecciated areas are not themselves brecciated, but on the contrary have highly irregular contacts, as if they had intruded brecciated material. The brecciation, therefore, occurred before the intrusion of the quartz diorite dykes.

The rhyolite in the neighbourhood of the ore-bodies is a very dark grey rock, superficially basic in appearance, but containing much visible quartz. Under the microscope quartz is seen to compose about 75 per cent of it; the remainder is a mixture of chlorite and sericite, with a little epidote. The quartz is clouded by numerous minute inclusions. The chlorite-sericite mixture fills interspaces between the quartz grains, and forms vaguely outlined, irregular vein-like masses. It appears to be replacing the quartz. The highly siliceous composition, the lack of feldspar and other original minerals, and the numerous inclusions in the quartz, all point to the conclusion that the original rock, which was probably a rhyolite, has suffered large addition of, and replacement by, silica. The relations visible between the silica and the chlorite-sericite mixture indicate that a second, partial replacement of silica by chlorite and sericite has taken place.

Replacement of the silicified rhyolite by chlorite may be seen with the naked eye in the brecciated zone. Throughout that zone the finer particles of the breccia are for the most part replaced by chlorite, which thus forms a matrix enclosing the larger fragments of silicified rhyolite. In places, however, the action goes much farther, and chlorite can be observed to replace, first the smaller, then the larger, and finally the largest, fragments in the breccia, so that the whole rock is converted into a featureless mass of chlorite. A thin section of the chloritized rock, under the microscope, shows nothing but very pale green, almost colourless chlorite.

The chalcopyrite bodies have been formed by the replacement of the chlorite rock. The evidence of this replacement is as follows:

(1) Chalcopyrite masses are confined within the areas of chlorite rock, and, so far as known, do not occur outside them.

(2) Near the edges of chalcopyrite bodies the chlorite schist is cut by numerous minute veinlets of chalcopyrite, many of them little thicker than a hair. In many places, particularly at intersections, the veinlets enlarge suddenly into irregularly shaped small masses up to the size of large peas. The surrounding schist shows no sign of distortion, as it would do if the

material of the little bodies had been forced in, so as to push aside the schist without replacing it. The bodies have no sharp outlines, but the solid chalcopyrite at the centre passes into a mixture of chalcopyrite grains mixed with rock in which the proportion of sulphide lessens outward until it passes into pure rock. A condition of this sort can be produced only by replacement.

(3) In the case of at least one large mass of chalcopyrite, the slightly weathered surface shows the schistose texture of the chlorite rock retained in the chalcopyrite. A polished specimen from this locality exhibits the schistose pattern very beautifully.

The sequence of events in the area, therefore, appears to have been: (1) shearing and brecciation of the country rock; (2) intrusion of the quartz diorite; (3) silicification of the country rock; (4) chloritization of the silicified material; (5) replacement of chlorite by chalcopyrite.

Surface showings of some promise were found in three places. That designated by the company as deposit No. 1 lies in the southeast quarter of claim 4847, about 750 feet southeast of the shaft. It consists of disseminated chalcopyrite, with some small lenses of massive chalcopyrite. The largest of the mineralized areas at this locality is about 100 feet long and 20 feet wide; its average tenor at the surface was about $1.50 in gold a ton and 2 per cent copper. Four diamond drill holes cut these showings at a depth of 75 feet, at which depth the average grade proved somewhat lower than at the surface. Six further holes intersected the deposit at depths of 200 to 500 feet, with similar results.

Deposit No. 2 is about 400 feet from the shaft, in a direction slightly north of west. It was discovered by dip needle and trenching. Drilling appears to indicate that it is a somewhat pear-shaped mass, about 80 feet deep, and 50 feet wide near the bottom. Its average tenor was $0.80 in gold a ton, and 2·5 per cent copper.

Deposit No. 3 is about 200 feet west of the shaft. Much the highest values were obtained on this deposit, and consequently most of the underground exploration and drilling were concentrated on it. At the surface it appeared to be a mineralized zone at least 500 feet long and 50 feet wide, carrying disseminated chalcopyrite below commercial grade. Greater concentration was found in two places. The first, a body of massive chalcopyrite at the bottom of a 12-foot pit in drift, was 3 feet wide and assayed $15 in gold a ton and 11 per cent of copper. At the second place, 125 feet from the first, there was heavy chalcopyrite over a length of 30 feet and a width of 9·5 feet, with an average tenor of $21 gold and 12 per cent copper.

The underground work in this zone, according to the company's annual reports, demonstrated the existence of a number of high-grade ore-shoots, some of which assayed as high as $30 gold and 16 per cent copper, and much higher individual assays were obtained in many places. The shoots were all small, however, seldom exceeding 15 feet in length; in addition, they became fewer and smaller with depth, and at 425 feet it was found that chlorite, whose association with the gold and copper was known, was almost entirely absent.

The mineralogy of the deposits is somewhat unusual. Pyrite and pyrrhotite, which occur in large volume in other deposits in Quebec, are found in the main ore zone in very small amount, and almost the only sulphide is chalcopyrite. In other deposits chalcopyrite replaces pyrite and pyrrhotite; here it replaces chlorite directly. The Robb-Montbray is the only property, with the exception of the Horne, on which important gold values accompany the sulphides. The gold seems to occur mainly in the native state, although possibly some of it is present as telluride. Tellurides of various kinds are rather common, and their presence commonly indicates high gold values in the upper levels, but not in the lower levels.

Ellis Thomson, to whom were submitted specimens of the heavy tellurides found here and there in pockets, has identified quite a variety both of tellurides and of other mineral species.[1] Among the tellurides, altaite (PbTe), tetradymite ($Bi_2(Te, S)_3$), krennerite $(Au, Ag)Te_2$, petzite $(Au, Ag)_2Te$, and coloradorite, HgTe, are present, and associated with them are chalcopyrite and small amounts of sphalerite, pyrrhotite, gold, pyrite, and chalcocite.

Coniagas Claims

Coniagas Mines, Limited, prospected a large group of claims near the junction of Montbray, Duprat, Beauchastel, and Dasserat townships. The principal discovery was made on claim A 5365, in the extreme southeast corner of Montbray. The rocks in the neighbourhood are rhyolites and rhyolite breccias, cut by a north-trending dyke of later gabbro. A shear zone, striking about north 25 degrees west, cuts the rhyolites, which have been altered and mineralized. The rhyolite near and within the shear zone has been highly silicified, so that under the microscope it closely resembles a very pure quartzite. This silicified material has been replaced by chlorite, as on the Robb-Montbray property; and the chlorite-rock has been replaced in turn by pyrite and chalcopyrite, some of which is massive. Mineralization was exposed over an area about 150 feet long by 10 feet wide; but the bodies discovered were not large enough or rich enough to repay mining.

Eplett-Metcalfe Claims

Eplett-Metcalfe Mining Company, Limited, own thirteen claims, aggregating about 520 acres, lying astride the Montbray-Duprat boundary line and just south of the centre line of these townships. Ten of the claims are in Montbray, and three in Duprat township. The principal discovery is in claim 6617, Montbray township.

The country rock consists of acid volcanics intruded by a sill of quartz diorite dipping gently eastward. Both are intruded by a 75-foot dyke of later gabbro that strikes almost due north and dips steeply west.

[1] Thomson, Ellis: "A New Telluride Occurrence in Quebec"; University of Toronto Studies, No. 27 (1928).

The ore-bodies occur within the dyke of later gabbro. The principal occurrence is an included mass of volcanics about 40 feet long and 10 feet wide, which has been partly or completely replaced by sulphides. The sulphides are massive over a width of about 5 feet, and disseminated over the remaining width. They consist chiefly of pyrrhotite, with some chalcopyrite. Drilling has shown that this " horse " of mineralized volcanics dips eastward so as to pass out of the dyke of later gabbro a short distance below the present surface, so that its connexion with the volcanics is not broken. Mineralized material is also found at one or two other places in the dyke.

Mineralization of the lava is supposed to have taken place prior to the intrusion of the later diabase, so that the smaller occurrences are really inclusions, broken from the mass of mineralized lava and engulfed in the liquid lava. The larger mass is almost an inclusion, but is still connected with the parent rock by a neck.

Don Rouyn Gold Mines

Don Rouyn Gold Mines, Limited, owns or controls a group of eight claims near the western boundary of Rouyn township. These are numbered M.L. 1799, M.L. 1800, M.L. 2028, T. 1785, T. 1786, T. 1787, T. 1788, and T. 1789. The mine buildings are in the northwest corner of M.L. 1799, facing the Rouyn-Cheminis road 2½ miles from the town of Rouyn. The road runs through claims M.L. 2028 and M.L. 1799, the southern end of the property, and the railway between Swastika and Rouyn also runs through M.L. 1799, a few hundred feet west of the buildings.

South of the Rouyn-Cheminis road the rocks consist of Keewatin lavas cut by a few dykes of quartz diorite. Lavas are also found at the extreme north end of the property. The intervening belt, not quite half a mile wide, is underlain by the Powell granite, which here and there contains inclusions of greenstone, some of fairly large size. The band of granite is bounded on the south by a well-defined valley which the road follows. This valley is an extension of the valley of Horne creek, and is probably occupied by the fault that has already been described. On M.L. 2028 the south side of the valley is a very steep-sided ridge, which in places exhibits almost vertical cliff faces.

Up to the end of August, 1927, the attention of the operators was centred mainly on the granite area. A belt or zone in the granite, striking about north 70 degrees east, approximately parallel to its southern contact, is rather heavily mineralized with chalcopyrite and a little pyrite. This zone was opened up by a rather extensive system of trenches, and a shaft said to be 60 feet deep was put down in one place. The chalcopyrite is in grains scattered through the granite, and also forms irregular veinlets along with a good deal of quartz. The shaft is sunk on a shattered zone filled with the quartz-chalcopyrite mixture. According to the manager, this shatter zone or vein was 7 inches wide at the surface, and widened to 3 or 4 feet at the bottom of the shaft.

It is interesting to note the parellelism of the mineralized zone to the fault valley a short distance south. It suggests that the granite may have been shattered by the same forces that caused the faulting. If so, the chalcopyrite is later than the faulting, as on the Horne property.

Much trenching and stripping have also been done over other parts of the granite area. Mineralization has been found in a number of places, particularly in the greenstone inclusions in the granite, and along planes of shearing. No body of payable ore, however, has as yet been found.

Archean Mines

The Archean Mines Development Company, Limited, with which was associated the Harvie Mining Exploration Company, Limited, owned or had under option some seventy-four claims in Dufresnoy and Clericy townships. One group of thirteen claims lies north of Kinojevis river, in Dufresnoy township close to the east boundary and just north of the centre line. The Rouyn Mines railway runs through the southern part of this group, and Clericy station is about a quarter of a mile to the east. The remainder of the claims lie southeast of the river and station, and are mostly in Clericy township.

The main camp was on the east shore of Savard lake, about 2 miles south of Clericy station. A road runs north from the camp to the river opposite the station, but in summer freight and supplies were brought from the station by boat about 5 miles down Kinojevis river, and thence across a half-mile portage into lake Savard. Operations ceased in 1928, the property was closed, and the equipment sold.

Lavas, mostly of acid types, underlie the greater part of the area. They are intruded by the Clericy granodiorite, a body several miles long and about $\frac{3}{4}$ mile wide, striking north 30 degrees west. One-half to three-quarters of a mile southeast of Savard lake there is a large dyke of later gabbro, striking northeast and cutting granodiorite and lavas alike.

The bulk of the work was concentrated on the claims south of the river. Of these, somewhat more than one-third, or roughly twenty-three claims, are underlain by granodiorite. All the discoveries of mineral were made in the area to the east of the granodiorite boundary.

On claim A 2509, a little more than a mile due east of the camp on Savard lake, a shaft was put down to explore a mineralized zone. The shaft was sunk 125 feet, with levels run at 45 and 125 feet; and about 800 feet of lateral work is said to have been done on these levels. No examination of the underground work was made, but the dump showed some good-grade zinc ore. Careful examination of specimens indicated that the order of formation of the ore minerals is the same as elsewhere in the Rouyn camp. In a number of veinlets the minerals are clearly segregated, pyrite lining one or both walls; the centre is filled with zinc blende.

The rocks around the shaft are light grey, fine-grained lavas, presumably approaching dacite in composition. Like the lavas on all these claims, they are fairly well mineralized with scattered grains of pyrite, the rusty weathering of which conceals the surface textures and structures so effectually that the strike and dip of the flows could not be ascertained. Pillow structure is excellently developed in places near the shaft; and in one place just west of it there has been much replacement of the pillowed lavas by sulphides, chiefly pyrite. This replacement is a beautiful example of the influence of composition and texture. The fine-grained, somewhat fractured, and highly chloritic material that lies between the pillows has been largely or completely replaced by the sulphides, and the fine-grained edges of the pillows are also attacked to a certain degree; but the massive, rather acid, central parts of the pillows are not replaced. Here, also, was seen an alteration already mentioned in the description of the Horne, of the rock on each side of a veinlet to black, highly chloritic material.

In addition, there are near the shaft a number of well-defined shear zones each a few inches wide, and one or more rather vaguely defined fracture zones of varying width. They strike about 5 degrees west of north, and appear to dip almost vertically. The fracture zones are well mineralized with pyrite and a little chalcopyrite; in places quite large splashes of chalcopyrite occur.

About half a mile north of shaft No. 1, in the southwest corner of claim A2505, a vein of quartz and chalcopyrite was opened up, known as showing No. 3. The vein is exposed in a trench some 30 feet long, which was filled with water at the time of examination. The vein has a northwesterly strike, and is said to dip southwest, and to be 10 to 15 feet wide. Fragments on the dump consist mainly of quartz and chalcopyrite, with a little pyrite. In some of them the chalcopyrite content is fairly large, but the average vein material might run between 3 and 5 per cent copper. The chalcopyrite fills small fractures in the quartz.

Toward the north side of the same claim there is another vein, or rather lode, of much the same character. It consists of a number of quartz stringers up to 6 inches wide filling a zone about 6 feet wide. The lode strikes north 20 degrees west, and probably dips steeply west. The quartz carries some chalcopyrite and a good deal of pyrite.

On claim A2515, about half a mile slightly north of west from the last-described vein, there is a light grey trachyte heavily mineralized with pyrites, which fills small cracks in the rock. Here was discovered a vein of quartz and zinc blende about 2 feet wide, striking east and west. The outcrop is now completely hidden by the dump. A shaft was sunk on this vein. It is stated that for about 50 feet from the surface, the shaft followed the vein; the vein then dipped off to the south. At the 100-foot level a crosscut toward the vein was started. The crosscut entered either the same vein or another, said to be 8 feet wide, and dipping toward the north. Drifting on this vein was in progress at the time of examination. The vein materials as seen on the dump consist of rock pierced by numerous stringers of quartz with a little chalcopyrite. Some of the specimens contain a good deal of chalcopyrite, but for the most part the mineralization is very light.

In general, the fairly widespread mineralization of these claims suggests that bodies of payable ore are likely to exist on them; but up to the present time such bodies have not been discovered.

Quemont Mining Corporation, Limited

Quemont Mining Corporation, a subsidiary of the Mining Corporation of Canada, Limited, owns seven claims in Rouyn township adjoining the property of Noranda Mines on the northeast. The claims are numbered M.L. 1733, 1734a, 1734b, 1743, 1745, and 1796, and T361, and include about 600 acres. The shaft is in the southeastern corner of M.L. 1734a, between the Noranda boundary and the south shore of the northwest bay of Osisko lake. It is 905 feet deep, with levels at 215, 500, and 900 feet. In September, 1929, about 2,800 feet of lateral work had been done on the 215-foot level, and 1,600 feet on the other two levels, in addition to much underground drilling.

This development was undertaken in the hope that at depth some of the Horne ore-bodies might be encountered. Up to the end of 1929, however, these expectations had not been crowned with success. The work is of particular interest from a geological viewpoint, in that it established the existence and size of the Horne Creek fault, which has already been described (*See* Folds and Faults).

Newbec Mines, Limited

Newbec Mines, Limited, was incorporated in February, 1927, as an amalgamation of the Rouyn Gold Pan Syndicate, Norbec Mines, Limited, and the McLeod claims. The property consists of some thirty-two claims in Dufresnoy township, aggregating about 2,000 acres. A shaft has been sunk to a depth of 250 feet near the middle of claim Block 8, $\frac{5}{8}$ mile northwest of Dufault lake, with levels at 75, 125, and 250 feet. Some 700 feet of lateral work was done on the 125-foot level up to September, 1929, and about 600 feet on the 250-foot level. In addition, a good deal of trenching has been done on Claim A 1415, which adjoins Block 8 on the north.

The rocks on the claims include lavas, minor intrusives, and the Dufault granodiorite. About 850 feet south of the shaft is the northern border of the granite of the western half of the Dufault intrusive. The border here runs east and west. About the same distance east of the shaft is the western margin of the diorite-anorthosite sill which occupies the centre of the Dufault intrusive. It strikes north 20 degrees west, and dips about 50 degrees east. The mine thus lies in the acute angle between these contacts.

The lavas are of medium acidity, approaching dacite in composition. The minor intrusives include older gabbros or diorites of at least two ages, and a very siliceous quartz porphyry which is older than both gabbros, but intrudes the lavas. The lavas, in the vicinity of the mine, strike north 20 degrees west, dip 35 degrees east, and face toward the east. The quartz porphyry forms sill-like masses that parallel the general strike and dip of the lavas, but crosscut it in places. Most of the observed dykes of diorite likewise parallel fairly closely the strike and dip of the lavas; these are the older set of dykes. Of the later dykes only one was seen, in the mine workings. It is about 20 feet wide, strikes north 70 degrees east, at right angles to the others, and dips vertically or very steeply north.

A small fault is a prominent feature in the workings. It strikes north 70 degrees east, dips 82 degrees north, and cuts all the rocks present, namely the lavas, porphyry, and both diorites. Its relations to the main diorite-anorthosite body on the east are as yet unknown. Movement along the fault does not appear to have been more than a few feet. Its direction has not yet been determined with certainty, but probably it is similar to that of other faults in the district, i.e., the north side to the west.

The ore-body at the surface filled the fault fracture, appearing as a vein of chalcopyrite and other sulphides, about a foot in width. When the shaft was sunk on this vein, the vein was found to rake strongly eastward, so that the shaft passed out of it at a depth of 35 feet. Accordingly, the different levels were run eastward to pick up the ore anew and explore it at different depths. The exploration appears to show that the position of the ore-body is related, partly to the fault fissure, partly to the top of the andesite lava flow in which it occurs and which it replaces. Between the surface and the 250-foot level the ore-body forms an irregular pipe, striking north 70 degrees east and dipping 82 degrees north, like the fissure, but raking 35 degrees east, parallel to the top of the andesite flow and a few feet below it. The mass is not large; its cross-section on the levels is some 30 feet in length and 5 to 10 in width. These figures are not exact, as the ore is quite irregular; they afford merely a general idea of the approximate size of the pipe.

As already stated, the ore at the surface occupied the fault fissure, but this is not the case at the lower levels. At the 125-foot level the ore lies about 15 feet north of the fault fissure, in much fractured andesite. On the 250-foot level the ore surrounds the fault fissure, but the latter, filled with quartz, carbonates, and some pyrite and chalcopyrite, cuts through the mass of ore. These relations suggest that there must have been a preliminary fracturing along the lines of the present fault, and that the ore-bearing solutions entered along the openings thus formed. After the ore deposition, the main fault movement occurred, and the fault fracture was filled with quartz, calcite, and other carbonates, and minor amounts of pyrite and chalcopyrite. Somewhat similar relations, it will be recalled, occur at the Horne mine, where some small faults are filled with ore, others cut the ore-bodies.

The ore is of good grade, averaging 5 or 6 per cent copper. It is made up of chalcopyrite, pyrite, and pyrrhotite; practically no zinc is present. On the 125-foot level the ore is a sort of breccia, in which blocks of pyrrhotite and magnetite lie in a matrix of chalcopyrite and pyrite. Numerous stringers of chalcopyrite run out from this mass into the country rock. Some of them were found to pass, within distances of a few feet, into veinlets of quartz and carbonate containing scattered grains of sulphide.

The ore is later than all the rocks present. On the 125-foot level it replaces the andesite, and extends eastward for some distance into the quartz porphyry. On the 250-foot level it occurs in both these rocks, and also replacing a short length of the latest dyke of diorite. Neither the porphyry nor the diorite appear to be favourable hosts for the ore, however; its occurrence is mainly confined to the lava.

Rock Alteration. Pronounced alteration of the country rock, both andesite and quartz porphyry, has taken place near the ore-bodies. The quartz porphyry, where not affected by this alteration, is made up of quartz and oligoclase ($Ab_{85}An_{15}$) phenocrysts in a groundmass of the same minerals. The proportion of quartz is estimated, roughly, at about 20 per cent. Some original ferromagnesian mineral may have been present, but if so it is now masked by the presence of more or less secondary chlorite that fills cracks, with irregular replacement edges, that cut across groundmass and phenocrysts indifferently. At some distance from the ore-bodies this rock has been more or less strongly silicified. In one specimen the proportion of quartz had increased to 40 or 50 per cent; in another, almost all the original feldspar had been replaced by quartz. Vaguely defined, vein-like masses of sericite are also present. Closer to the ore-bodies, where the rock becomes mineralized, the rock becomes dark coloured through development of chlorite. Thin sections show that the fine-grained quartz or quartz-sericite mixture of the silicified rock has been replaced by chlorite in some places, and by a mixture of chlorite and epidote (pistacite) in others. The grains of pyrite or chalcopyrite practically always occur along with the masses of chlorite.

The andesite exhibits much the same series of alterations, namely, a preliminary silicification, and a final alteration to chlorite with addition of pyrite and chalcopyrite. One specimen, however, exhibited an intermediate stage in which biotite is developed after the preliminary silicification, and is later replaced by chlorite. This resembles the alteration near the Amulet ore-bodies.

18555—16½

CHAPTER XI

GOLD DEPOSITS

Russian Kid Claims

In October, 1924, A. W. Balzimer and Mike Mitto staked a group of thirty-three 40-acre claims on the northeast side of Labyrinth lake, Dasserat township. Balzimer later made a discovery of gold on claim T2108 that created much interest. Since that time the partners have done much work both in opening up this discovery and in prospecting the remaining claims. The property was examined during the summer of 1925. At that time the vein had been exposed by cross-trenching for a length of about 350 feet, and a number of shallow pits were sunk on it, one about 12 feet deep. At the west end the vein pinches out, but a quarter of a mile beyond this point and on the projected strike of the vein, a pit was sunk in the drift, and ore was found at bedrock; so that there is evidently another expansion of the vein in this direction, but little is yet known of it.

The vein follows closely the contact between a body of granite and one of quartz diorite, cutting here into the one, there into the other, rock. It strikes north 70 degrees east, and dips 75 degrees south. At the easternmost exposure, where it disappears beneath swamp, it is 7 feet wide. About 200 feet west the width lessens to 2 feet, then increases again to 5 feet 70 feet farther on, finally decreasing to zero about 350 feet from the eastern exposure.

The vein matter consists of white quartz and a little iron carbonate very heavily mineralized with coarse-grained pyrite. The wall-rock is also rather heavily mineralized with pyrite for distances of 1 to 3 feet from the vein. The pyrite apparently carries the gold. A sample consisting of about 80 per cent pure pyrite assayed $9.60 in gold a ton. The average tenor of the vein matter, excluding free gold, is $6 to $7 a ton according to the owners, and that of the heavily mineralized wall-rock $3 to $4 a ton.

Much free gold was found in the vein when it was first opened up, giving the discovery a highly spectacular character. The free gold has been found, up to the present, only in the limonitic material formed by weathering of the pyrite; it seems probable, therefore, that the free gold is merely residual, and will not be found in unweathered vein material. Accordingly, it seems unlikely that the average tenor of the vein materials will exceed the values quoted.

The rock on the north side of the vein is a large sill of quartz diorite, differentiated in place so that the southern or upper side is much more feldspathic than the northern or lower. On the south side of the vein there is a body of granite so similar in its general texture and appearance to the more acid phases of the diorite as to suggest that it is a differentiate of the diorite magma. It is made up of about 30 per cent or more of quartz, 5 per cent of hornblende in long needles, now largely altered to chlorite, 2 or 3 per cent of magnetite in coarse crystals, and the remainder mainly oligoclase ($Ab_{80}An_{20}$).

The rock along the granite-diorite contact is rather highly sheared, either by faulting or by slip between the two formations during folding.

Granada-Rouyn Mining Company, Limited

The Granada-Rouyn Mining Company now owns or controls a block of forty-five claims in the southwestern quarter of Rouyn township. The original holding consisted of a block of seventeen claims staked in 1924 and then known as the Bathurst claims. Soon after staking, the claims were optioned to McIntyre-Porcupine Mines, who made a geological survey of the property and did much trenching and stripping. Work was then discontinued until the property was taken over by the present owners, who have added largely to it.

Development work has been largely concentrated on the Edna Bathurst claim, T 371. A shaft has been sunk to 670 feet, and levels run at 125, 250, 375, 500, and 625 feet. Little work has been done at the 250-foot level, but on the other four about 2 miles of lateral work has been completed, about half of which is on the 125-foot level. It has been stated in the press that a mill is to be erected in the near future.

Lavas and tuffs of the Keewatin series underlie the northern part of the block of claims, and Timiskaming greywackes and conglomerates the southern part. Dykes and small irregular masses of red and grey feldspar porphyry intrude the conglomerates throughout a belt 8,000 to 9,000 feet long and some 2,000 feet wide. The porphyries contain large feldspar crystals, up to an inch in length in some varieties; the red varieties look much like some of the Aldermac porphyries. Numerous quartz veins carrying gold values are found in the conglomerates within the belt of dyke intrusion. The general strike of this zone is north 60 degrees west.

Exploration up to the end of 1929 was largely confined to a large vein known as No. 2, which strikes north 60 degrees west and dips about 50 degrees north. The vein has been followed for about 1,000 feet from the shaft on the four working levels. For the most part it consists of numerous parallel stringers of quartz cutting the conglomerate; along the hanging-wall there is commonly a larger vein of quartz. Values are rather low, and it is doubtful whether the vein material, diluted by the country rock that must be mined with it, will repay mining. On the two lower levels, however, near the east ends, the vein widens to 8 to 10 feet of white quartz without any admixture of country rock, and these sections are very rich. Coarse gold is visible in the quartz in many places, and average assays of the vein material run, it is stated, about $100 a ton. The lengths of the wider sections, unfortunately, are short as yet; and the efforts of the operators are being directed toward finding greater lengths.

The vein material in the richer sections is white quartz, containing in places a little tourmaline or hornblende. The quartz is greatly checked and fractured, with numerous little planes of slip filled with films of chlorite, or, more rarely, of sericite. The fractures tend to parallel the walls of the vein, but they also run in other directions. Free gold is deposited on the chlorite or sericite in the slip planes, and also in minute cracks in the quartz, away from the slip planes. Small quantities of very fine-grained galena and sphalerite are found here and there, usually marking spots where the vein is very rich. Practically no carbonate accompanies the quartz, though some is found in the faults that break the vein.

Faults are rather numerous, but most of them, fortunately, displace the vein only a few feet. The greater number strike between north 10 degrees east and north 60 degrees east. Both right and left-hand types are found. The largest displaces the vein throughout a horizontal distance of 150 feet.

The country rock, for a distance of 2 or 3 feet from the veins, is more or less bleached and mineralized with pyrite. Over a width of about 6 inches from the veins this effect is pronounced, so that the dark grey greywacke is converted into a light grey, almost cream-coloured rock speckled with pyrite. A thin section of the ordinary greywacke some distance from a vein consists of about 25 per cent quartz, 25 per cent biotite partly altered to chlorite, and 50 per cent feldspar partly altered to muscovite. Somewhat bleached greywacke about 3 feet from the vein contains neither chloritized biotite nor feldspar, but both these minerals have been replaced by a mat of small crystals of white mica. The light grey alteration product a few inches from the veins differs from the last only in that some 20 to 25 per cent of carbonate has been introduced. The alteration, therefore, consists in the replacement of the feldspar, chlorite, and biotite of the rock by white mica, and the addition, close to the vein, of a good deal of carbonate and some pyrite.

Powell Vein

The Powell vein is a large vein of gold-bearing quartz on the claims numbered Blocks 60, 61, and 62, lying southeast of Héré lake, Rouyn township. The discovery of this vein late in the autumn of 1922 was the event that started the rush of prospectors to Rouyn area, and initiated the great development that has since occurred. The property was optioned by Noranda Mines, Limited, in 1923, and a large amount of trenching, stripping, and drilling done under the direction of L. K. Fletcher. The property was then optioned to Nipissing Mines, under whom development was continued. Results showed that the tenor of the vein was too low, under the transportation conditions of the time, to repay further work, and the options were dropped. Block 62, however, is still held by Noranda Mines.

The rocks are Keewatin lavas intruded by the Powell granite and by diabase dykes. The lavas are predominantly acid, although basic flows also occur. They strike between east-northeast and east, and dip vertically or steeply south, with the flow tops facing southward.

The vein has an average strike of north 30 degrees west, and dips east at an average angle of 60 degrees to 65 degrees, but both dip and strike vary a good deal over short distances. The width averages from 3 to 6 feet. The vein has been traced for a distance of 3,600 feet, and as it is very narrow at both ends this distance is probably close to the total length. There is also a gap of about 250 feet, where the vein appears to pinch out temporarily, about 1,000 feet from the northern end. That part of the vein north of this gap will herein be termed the northern vein, the remainder the southern vein.

The vein materials are mainly white quartz with more or less pyrite; the wall-rocks are somewhat altered by addition of pyrite, carbonate, and in places some chrome mica or fuchsite. In a few places a crystal of chalcopyrite may be found.

The original vein fissure was evidently formed by faulting, as striæ occur in many places on the walls, dipping as a rule toward the south end at angles of 50 degrees to 60 degrees. In a pit about 400 feet from the north end of the northern vein striæ of asymmetrical shape were found on the west wall. The south sides of the striæ have a much steeper slope than the north sides, indicating that the east wall moved northward, and, therefore, also upward, since the striæ dip to the south. The fault was, therefore, an overthrust. A granite dyke that crosses the fault and is cut by it shows no determinable displacement, however, so that the movement must have been quite small.

Twenty-two hundred feet along a base-line run along the vein from the north boundary of the T. Powell claim, there is a steep cliff some 50 feet high, at the foot of which there is a fault striking north 80 degrees east and dipping vertically or steeply north. Striæ on the fault-plane dip about 45 degrees west. Where the fault cuts the vein, the vein north of the fault has been moved about 40 feet to the westward, and, as the striæ show, downward also.

It may be noted that this displacement of the north side toward the west corresponds with that observed for the Pelletier Lake faults. On the R. Cockeram claim north of the T. Powell claim, a number of faults were observed, also with the same direction of displacement. This is, therefore, a common type of fault in Rouyn area.

The vein north of the fault is small and narrows rapidly, so that the fault may be considered, roughly, as the northern limit of the vein. At this point the northern vein is about 6 inches thick, and consists chiefly of barren quartz, with little or no sulphide in either vein or wall-rock. Some 200 feet south the thickness increases rather rapidly to 3 feet, and the proportion of sulphide also increases considerably, particularly in inclusions of country rock. The increased thickness and sulphide content coincide with a change in the character of the country rock. On the north the vein lies in a grey lava of about the composition of trachyte, and where the thickness changes it passes into an intrusive body of porphyritic granite. The granite is composed mainly of albite and quartz, in proportions of about 3 to 1, together with a very few grains of chlorite, hematite, and pyrite. It is strongly porphyritic. Phenocrysts of both quartz and albite, up to 2 mm. in diameter, form roughly 15 per cent of the mass; the groundmass has an average grain of 0·1 to 0·2 mm.

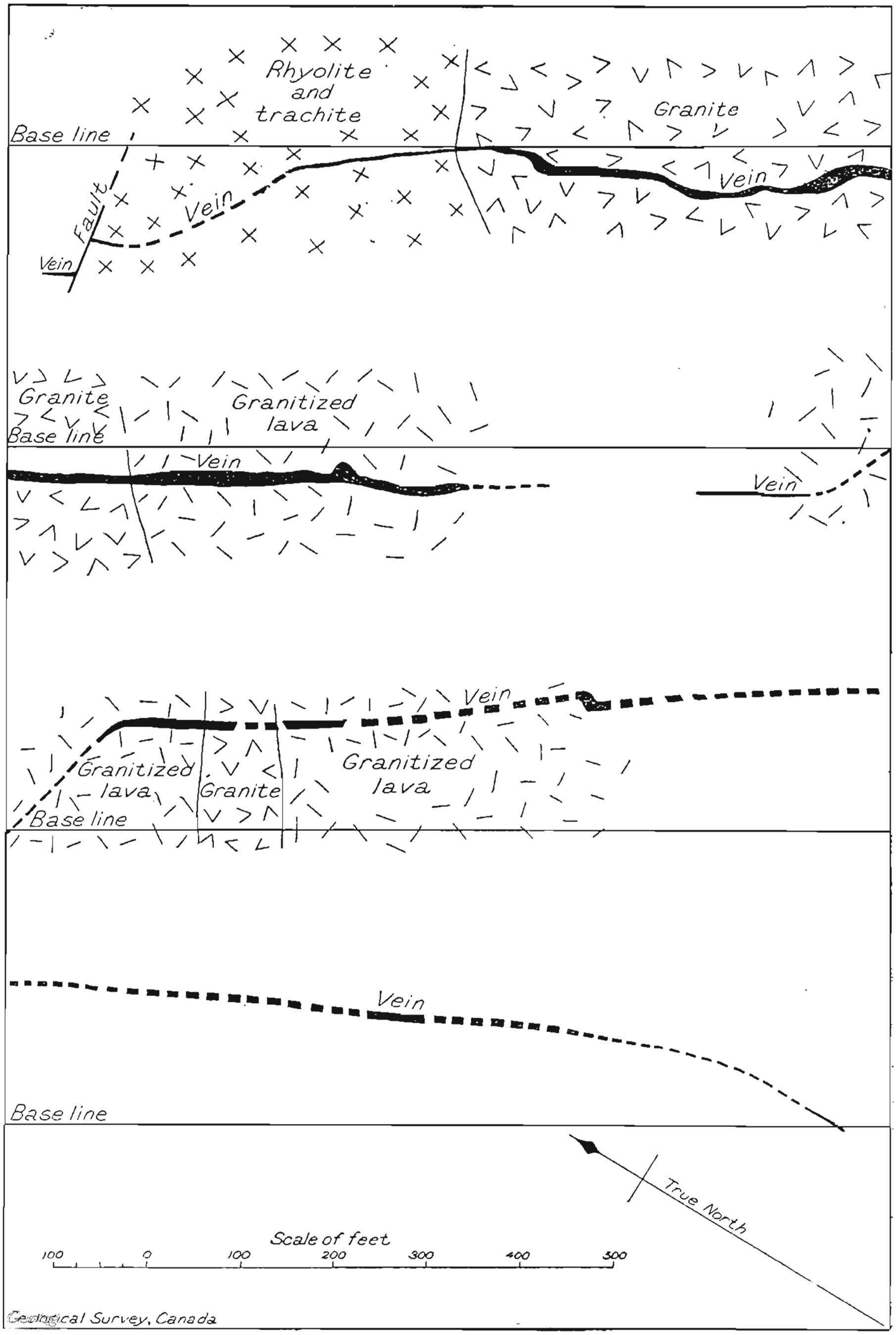

Figure 19. Plan of Powell vein, Rouyn township. Known parts of vein shown by solid black, drift-covered by broken line.

The vein lies in granite for a total length of about 600 feet and in this distance the width varies from 2 to 12 feet. The wider parts are found in the rather numerous bends; narrower parts form the straight lengths connecting the bends, so that the vein is a series of lenses connected by narrower parts. The wider parts of the lenses tend to be well mineralized, but the narrower parts are rather barren.

The vein has been traced for about 350 feet farther south, the country rock being a somewhat granitized[1] lava. In the last 200 feet of this distance the part of the vein that fills the fault fissure is about 2 feet wide, but there is also much quartz filling subsidiary fractures on the east side of the main fault, yielding a total width of 6 to 8 feet. This part of the vein is well mineralized and carries fair values. A short distance to the south it appears to pinch out. Some 250 feet farther, on the same strike, the north end of the southern vein appears, as a stringer 4 to 6 inches wide, gradually increasing to a maximum of 6 feet, 230 feet farther south. This width is maintained, so far as exposures in the rather widely spaced trenches show, for about 1,200 feet, beyond which the vein again gradually decreases to a stringer.

The southern vein cuts lavas for the most part, except at a part about 400 feet from the northern observed extremity, where it cuts the narrow end of a body of granite. The lava for a considerable distance on both sides is badly granitized. Not only does the vein attain its maximum width where it cuts the granite and granitized lava, but it is also most heavily mineralized, and contains its best values.

A peculiar rock is found here and there along the course of the southern vein. It is dark green and highly altered to carbonate, and lies between the vein and the country rock; so that at first sight it appears to be an alteration product formed by the action of the vein-forming solutions on the country rock. It does not occur uniformly along the vein, however, but is found, in places on one side, in places on the other, and in places is absent from both sides. It varies in width from a few inches to 20 feet. The contact of the carbonated material with the country rock is always a sharp line, never gradational; and a careful comparison of specimens from the contact with the country rock and a couple of feet farther away showed, in spite of the extreme alteration, that the part close to the contact has a much finer texture or grain. This material is, therefore, an ancient basic dyke filling the same fissure that was afterward re-opened prior to the formation of the vein. It is younger than the granite, since it cuts it.

The origin of the Powell veins is not clear. The descriptions show that the veins are intimately connected with the granite intrusives in some way, since they are widest, most heavily mineralized, and contain their highest gold values, in the granite or close to it, whereas the quartz, pyrite,

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[1] Granitization. A rock is said to be granitized when it contains quartz and feldspar that have filtered in from some nearby mass of granite during the process of intrusion. The added quartz and feldspar may be deposited in cavities between grains of the original minerals, or along planes of schistosity, or they may, and commonly do, almost completely replace some or all of the original minerals of the rock. A granitized rock is, therefore, a hybrid, produced by the interaction of the granite and the original country rock; and it is obvious that its composition may vary greatly, from that of a country rock to that of a granite, according to the extent of the addition and replacement. Thin-bedded sediments and schists are the rocks likely to be most altered in this way, because of the multitude of channels afforded to the granitizing solutions by the planes of bedding or schistosity.

and gold, individually and collectively, decrease in amount as the distance from the granite increases. This cannot be because the solutions forming the veins originated in the cooling granite, because the granite was cooled, faulted, and intruded by a basic dyke, before the formation of the veins. The peculiar arrangement is, therefore, more likely due to the greater brittleness or toughness of the granite and granitized lavas, leading to the formation of cleaner and more persistent fractures in them than in the unaltered lavas, that may have yielded to the comparatively small fault stresses by bending or shearing. Under such a conception the veins would be wider in the granite than in the lavas; and for some reason, mineralization is commonly a function of width. This may be seen readily within the granite areas themselves, where the wide parts of the lenses are comparatively well mineralized, many heavily so, whereas the narrow parts are lean and barren.

A number of assays were made by the Noranda assayer, Mr. Erickson, to determine whether the gold values accompany the pyrite in the Powell vein. Samples of pyrite as nearly pure as possible were selected from various places, and the proportion of sulphide to rock and gangue material estimated as closely as possible. Results indicate that the values do accompany the pyrite, and are inversely proportional to the grain of the pyrite; that is, the finer the grain of the pyrite, the higher the gold values. But the values vary between wide limits, even in cases of material of the same grain from the same locality, suggesting that the gold is, probably, present in the native condition and has by some means been precipitated on or in the pyrite. The gold assay values of the pure pyrite in the samples were as follows:

Coarse pyrite from hanging-wall of pit 7: (1) \$5; (2) \$7; a ton
Coarse pyrite from foot-wall: (1) \$10; (2) \$62; (3) \$50; (4) \$18; a ton
Medium-grained pyrite, pit 13: (1) \$60; (2) \$24; a ton
Very fine pyrite, in wall-rock, pit 13: \$130 a ton
Fine pyrite in silicified rock: (1) \$100; (2) \$450; a ton

Chadbourne Claim

The Chadbourne claim, Block 1, forms part of the holdings of Noranda Mines, Limited, in Rouyn township. It lies about half a mile west of the south end of Osisko lake, on the north side of Noranda lake.

The rocks consist of acid lavas, rhyolites or dacites, cut by a few dykes of red feldspar porphyry. There is also much of a fine-grained basic rock, that may be either an extrusive or an intrusive.

The dacites are fairly fresh, hard, fine-grained, and in many places very dark-coloured rocks. A thin section of one of the dark-coloured, almost black, varieties shows it to consist of 5 or 6 per cent of quartz, 40 to 45 per cent of chlorite secondary after hornblende, and the remainder oligoclase ($Ab_{70}An_{30}$) in long, thin laths, and rather badly sericitized. The lighter-coloured varieties were not examined, but presumably contain more feldspar and less ferromagnesian mineral. Both massive and fragmental types occur, in alternating bands. In addition there are fragmental varieties, formed by the crushing of both the massive lavas and the tuffs.

The porphyry is a bright red rock of striking appearance. In places the phenocrysts are crowded together, forming more than half of the rock, and individuals attain sizes of 3 mm. or more. All are albite to albite-oligoclase. The groundmass consists largely of the same feldspar, with a good deal of quartz, and a little titanite, magnetite, and chlorite.

The basic rock mentioned above is finegrained, dark greenish, badly chloritized, and with a massive appearance. It resembles closely the ordinary massive phases of basalt lava that form the lower parts of thick flows. It also appears identical with the fine-grained intrusive quartz diorite of the Horne claim, a mile to the northeast. Exposures, though reasonably numerous, are small and scattered so that no texture or structure was discovered during the examination that would render identification certain. In one place, close to the west side of the Chadbourne ore-body, undoubted flow textures were found, proving the presence of at least some basalt lava; but the bulk of the basic rock may be intrusive.

The general strike of the lavas is north 55 degrees west, dip vertical or almost so, upper side facing toward the south. A sharp drag-fold changes the stripe abruptly, over a length of about 600 feet, to north 40 degrees east. The strata have, therefore, been bent sharply through a right angle. The Chadbourne ore-body lies in the bend thus formed and outcrops as a low, triangular hill whose sides are about 500 feet long. It is covered by a hard, ferruginous gossan varying from a few inches to several feet in thickness, formed by the oxidation of the pyrite of the underlying rhyolite. The gossan is probably of pre-Glacial age, since pyrite is present in the rhyolite nearby in approximately equal amounts, but there is little or no gossan. Up to the time of examination of the property in 1923, exploration had been confined to trenching the gossan for the purpose of sampling the fresh rock beneath, and to sinking six shallow test pits. Later, a shaft was sunk and some underground exploration done, but of recent years the property has lain idle, as all the efforts of the company have been directed toward the development of the Horne mine.

The lavas of the drag-fold contain much pyrite that appears to be an original constituent, since it is also found in about the same quantity in the lavas outside the drag-fold. This pyrite carries no gold values.

The lavas of the drag-fold are crossed by one or more rather vaguely defined zones of shattering. These have a strike, apparently, nearly northwest, and a dip not yet determined with certainty, but which seems to be toward the northeast at 45 degrees or less. The zones of shattering are probably connected in origin with a fault that strikes northwest across the northwest edge of the hill. Quartz, calcite, and pyrite have been deposited in the shattered belts, forming a network of veinlets enclosing blocks of the country rock. Both veins and country rock are heavily mineralized with pyrite. Values obtained in the shattered zones are extremely promising, and exploration should be carried on to determine definitely the size, strike, dip, and continuity of these zones.

As in the Powell vein, the gold values accompany the pyrite and are inversely proportional to its grain. The following results were obtained by assaying samples of pure pyrite:

Original pyrite of rhyolite: no values
Coarse-grained pyrite, from veins: (1) $5; (2) $15; (3) $8; (4) $5.50; a ton
Medium-grained pyrite, from veins: (1) $13; (2) $40; a ton
Medium-grained pyrite, from wall-rock: $36 a ton
Fine-grained pyrite, from wall-rock: (1) $20; (2) $130; (3) $12; a ton
White quartz, without mineral: $0.40 a ton

As in the case of the Powell pyrite, the variation in the values found in the pyrite points probably to the presence of free gold associated closely with pyrite, probably deposited on or in it.

A second source of values may be a telluride of gold. A black mineral found in very small amount in the ore was shipped for test to New York by Noranda Mines, and is said to have reacted to the test for tellurium and to have assayed high values in gold. Tests conducted in the field on a sample of fine-grained black mineral did not give the tellurium reaction and the black mineral assayed only $4 a ton; the mineral by its other physical characteristics was identified as galena. It seems probable, therefore, that the black minerals in the veins include both galena and gold telluride. The amount of them is so exceedingly small that they can have but little influence on the values.

The country rock bordering the veins has been altered and mineralized. The alteration commonly extends for a distance of 2 or 3 inches from a veinlet, and converts the dark grey country rock into fine-grained, very light grey or white material. Study of the alteration under the microscope shows that the dark grey country rock was probably originally dacite like that described, but is altered very completely to a mixture of sericite and calcite in about equal proportions, with 2 or 3 per cent of disseminated magnetite. The light grey or whitish altered rock close to the vein has almost the same composition, except that the magnetite has been entirely removed, and some pyrite has been deposited. The vein-forming solutions were evidently, therefore, of simple composition, carrying only silica, sulphur, gold, and lime, CO_2, and perhaps iron.

Martin Mining Company

The property of the Martin Mining Company lies on the south shore of De Montigny lake and consists of a part of lots A and 37, ranges VIII and IX, Dubuisson township. The vein was discovered prior to 1917, and a small mill was erected in 1918, through which a certain amount of ore was run. A shaft was sunk 125 feet, and a small amount of drifting and crosscutting was done. The company went into liquidation in 1920, and the property was bought in at auction by John Dalton, and optioned by him to James J. Godfrey, representing American mining interests. The lessees did about 4,500 feet of diamond drilling, deepened the shaft from 125 to 300 feet, did about 700 feet of drifting and crosscutting on the different levels, and finally ceased operations toward the end of 1922.

The principal rock is a dark green, altered basalt, now composed of chlorite and rather thoroughly granulated andesine feldspar in about equal proportions. It is cut by a number of syenite porphyry dykes, very irregular both in shape and strike. The porphyry is a light grey rock, with phenocrysts of albite, and a few of orthoclase, up to 4 mm. in diameter. The phenocrysts compose 10 to 20 per cent of the rock, and are badly

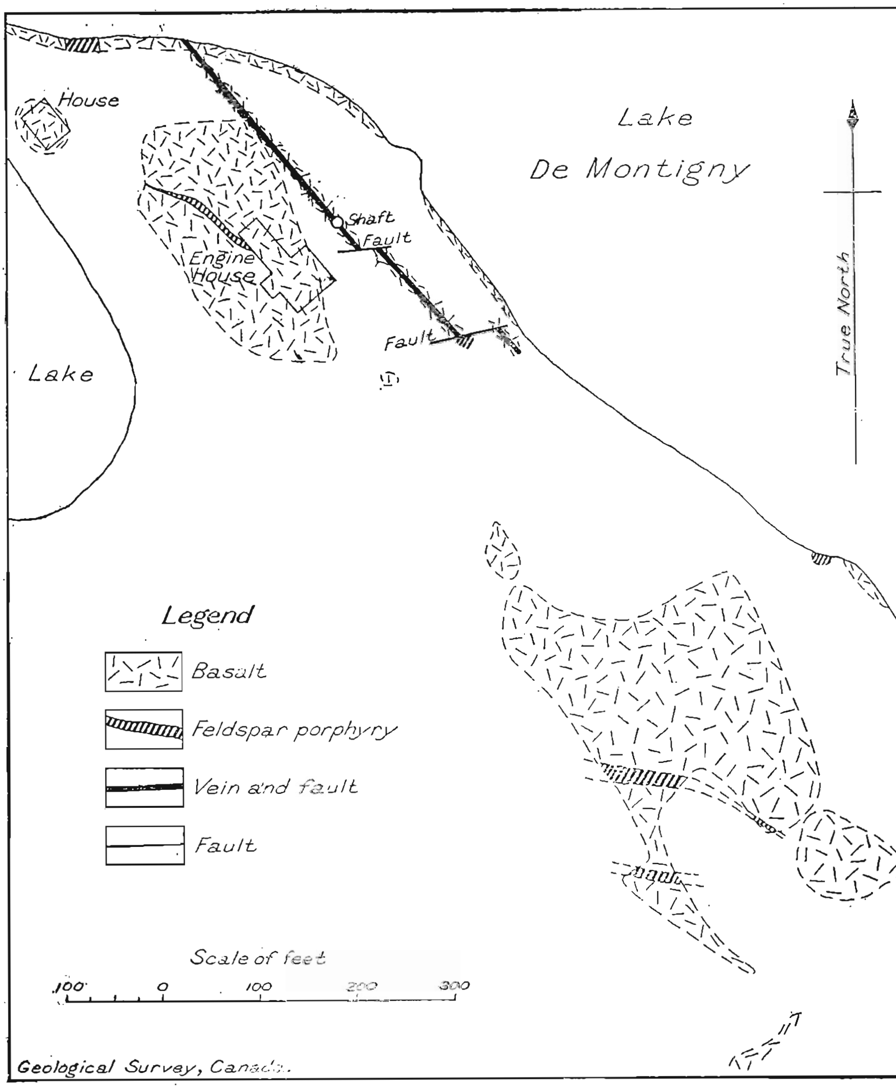


Figure 20. Plan of Martin claim, De Montigny lake, Dubuisson township.

altered to kaolin, sericite, and calcite. The groundmass is largely fine-grained albite, with 10 to 15 per cent of hornblende and a little biotite, both altered largely to chlorite. In some parts of the rock the chlorite has been recrystallized, forming long needles and laths of actinolite, which cut through the groundmass and phenocrysts in all directions. Pyrite and magnetite are accessory.

The vein strikes north 43 degrees west, dips about 80 degrees northeast, has an average width of 1 to 2 feet, and has been stripped for about 500 feet. At the northwestern end it continues under the lake. In the exposed length it is cut by two faults, the larger of which strikes north 77 degrees east, the smaller about the same, or slightly more easterly. In both, the south side has moved east relative to the north side, and striæ on the fault-plane indicate that the movement was horizontal or nearly so. The displacement is about 20 feet in one case, and 40 feet in the other. A porphyry dyke that roughly parallels the vein has also been cut and displaced by the faults.

Along the walls of the main vein vertical striations were found in two places, indicating that the vein fills a fault fissure, and that the last movement in this fissure was vertical. It could not be ascertained, however, which side had moved down relative to the other.

The vein filling is chiefly white, sugary quartz, with a little calcite and pyrite. The quartz forms lenses, widening and pinching, but growing wider on the whole from south to north. The vein is widest at the northern end, where it plunges beneath the lake, and a number of parallel veins and stringers together give a total width there of 11 feet. Values are rather low for the most part, rarely over $3 a ton.

The underground workings were filled with water and could not be examined. It was stated by one of the miners, however, that the vein is somewhat wider on the first level than on the surface, but that it was not picked up on the second or third levels.

The somewhat schistose basalt on each side of the vein is much altered and heavily charged with pyrite over widths of 1 to 3 inches, or more in places where the rock has been badly fractured by the preliminary faulting.

From a zone about 1½ inches wide, three thin sections were cut; one from dark greenish, unaltered rock farthest from the vein, one from the partly altered rock next to it, of a dark grey tint, and one from light grey material close to the vein. The dark greenish rock, unaltered by the vein-forming solutions, consists of chlorite and granulated andesine in about equal proportions. The intermediate specimen of dark grey rock, apparently only partly altered, is really very thoroughly metamorphosed. All the chlorite and andesine have disappeared and have been replaced by albite in branching, leaf-like forms. These are filled with minute inclusions of slightly higher refractive index, the nature of which could not be determined, but which may be remnants of the original colourless to slightly greenish chlorite. The albite exhibits undulatory extinction, indicating that some movement took place after it was formed.

In this section there is also seen the beginning of a second set of replacements. The albite is cut by a vein of pyrite, biotite, and pale green hornblende in long, narrow laths. The vein has irregular replacement edges, and the section also contains, at a distance from the vein, individual crystals of the above minerals replacing the albite. A slight movement has displaced the sides of the vein a distance of 0·3 mm. relative to each other, and deformed the vein minerals accordingly; but the corresponding minerals scattered through the section show no undulatory extinction.

The light grey rock nearest the vein is again quite unlike that just described. The albite, biotite, hornblende, and pyrite of the last section are very largely replaced by calcite with a little quartz. The calcite forms about 60 per cent of the section, in small, rounded grains averaging 0·02 mm. in diameter. Biotite and hornblende not replaced by calcite are largely altered to chlorite. The quartz is present mainly in narrow lenses, as if filling small, closed fissures, and also in small clusters of crystals around larger crystals of pyrite.

The alterations thus preserve a record of a considerable change in the nature of the solutions passing through the vein cavities. The solutions were at first high in soda, so that they readily dissolved the lime and magnesia of the original chlorite and andesine, and deposited albite. Thus they gradually lost their soda, and then began to deposit the ferromagnesian minerals, pyrite, hornblende, and biotite. With cooling, presumably, these constituents in turn disappeared, and then calcite only was deposited, mixed with some quartz toward the end.

There is no direct evidence as to the origin of the vein materials, except that the alterations of the country rock indicate hot juvenile solutions. The only fact of possible significance is the occurrence, beneath the widest part of the vein, of the largest mass of porphyry in the area. Drill hole No. 10, put in at right angles to the vein and about 210 feet to the southwest, on a dip of 35 degrees, cut porphyry from 76 to 250 feet, corresponding to a mass about 150 feet wide if the dip is vertical and the drill-hole cuts it at right angles to the strike.

Parker Island

Parker island is a small island lying near the west shore of De Montigny lake, in range IX, Dubuisson township. The discovery is a quartz vein with a maximum width of about 10 inches, although it breaks up in places into stockwork of reticulating veinlets, with correspondingly greater width. It strikes roughly north 65 degrees east, but is extremely crooked; and dips vertically. It is chiefly of interest on account of an assemblage of minerals that is rather unusual for the locality. It contains pyrite, chalcopyrite, galena, and sphalerite in a gangue of quartz, and the wall-rocks are impregnated for a few inches from the vein with pyrite and pyrrhotite. In the wider parts the ore minerals tend to be segregated along the walls, the middle of the vein being almost pure quartz. The vein exhibits a somewhat marked crustification, and open cavities or vugs are fairly common in the middle.

Gold values for the most part are low, although picked specimens from one of the most highly mineralized parts yield very high values. The vein has been stripped for about 150 feet, and some small test pits have been put down.

The property was optioned by A. W. Jenks, together with the Martin claims, and was explored by four diamond-drill holes. These failed to reveal the presence at depth either of a vein of any size or of an ore-body of commercial grade. Evidently the vein pinches rapidly with depth, and all the valuable ore is concentrated in the rich spot on the surface. Operations were accordingly abandoned.

The country rock is the ordinary altered basalt of the district. A little porphyry is reported by Mailhiot, but the mass must be very small, for it was not seen by the writer, on the ground or in the drill-cores.

Unison Gold Mines

This company, a subsidiary of the Union Gold Mines Trust, owns the property on the west side of De Montigny lake formerly known as the Foisie-Kengrow claims, and later as the Union mine.

The deposit was discovered in 1919. It lies about 100 feet west of the corner post marking the boundary between ranges VII and VIII, and lots 27 and 28, Dubuisson township. Here a small knoll of rock, perhaps 200 feet in diameter, rises from the surrounding swamp. The rock has been diagnosed as quartz diorite, a basic marginal phase of the large granodiorite mass to the east.

The vein, which has been uncovered for about 200 feet, is very tortuous, and throws off numerous branches and stringers. The general strike of the easternmost 130 feet is north 45 degrees west, of the remainder north 15 degrees west. The average dip is about 45 degrees southwest, the average width about 10 feet. The vein material is almost wholly white quartz, rather badly shattered, with a little tourmaline and native gold. Mailhiot states that pyrite, chalcopyrite, and stibnite are present, but the amount of these is so small as to be practically nil. After some search, a single crystal of chalcopyrite was found, but none of the other minerals was discovered. Of the native gold, an unusual number of specimens are obtainable. The wall-rock is impregnated here and there with iron carbonate.

Drill-cores from the quartz diorite near the veins exhibit an interesting set of alterations. The somewhat schistose diorite, composed largely of chlorite and granulated oligoclase feldspar, is filled in places with irregular veinlets of hard, greyish or brownish, very fine-grained material. They are introduced between the leaves of the schist, and commonly form a succession of small lenses, flat or stout, each of which is either entirely unconnected with adjoining lenses or connected with them by narrow necks. The veinlets, or rather strings of lenses, follow the schistosity very faithfully, and are rarely seen to cut across it. In places they become so numerous that the whole body of the rock is filled and replaced by the hard material, which was found to be albite, mostly in grains about 0·02 mm. in diameter and affording evidences of having been subjected to severe strain after formation.

A later set of veinlets and lenses, consisting of calcite and quartz, is also found, like the first, filling and replacing the rock in places. They cut the albite veinlets in places, and are cut in turn by veinlets of quartz with some tourmaline and pyrite.

Some diamond drilling was done in 1922, establishing the fact that the vein maintains its width to a depth of 400 to 500 feet, and that it is of about the same nature at that depth as at the surface. There is, therefore, a sufficient ore-body for mining purposes, if values be high enough. Since that time mining machinery has been installed, and a shaft said to be 100 feet deep has been sunk.

Siscoe Gold Mines, Limited

The claims of Siscoe Gold Mines comprise some 948 acres situated on De Montigny lake, in Dubuisson and Varsan townships.

The principal holding is Siscoe island, which is the largest island in De Montigny lake and lies mostly in range X, Dubuisson township, but extends into range I, Varsan township. Some of the nearby islands are also held by the company, as well as lot 39, range I, Varsan township.

Gold was discovered on the northernmost claim, lot 39, range I, Varsan township, during the initial prospecting in 1911 and 1912, but gold showings on Siscoe island were not reported until three or four years later. For the development of the property, the Siscoe Mining Syndicate was formed and later the Siscoe Gold Mines, Limited.

Work on Siscoe island consists of much surface stripping and trenching, most of which was done several years ago, a great deal of diamond drilling, the records of which were not available, shaft sinking, and underground work. Four shafts, called A, B, C, and D, have been sunk and are located as shown on the accompanying plan (Figure 21).

Siscoe island is flat and for the most part generally about 30 feet above the surface of the lake. It is formed chiefly of bedded lake clays, through which at intervals low, rounded knobs of rock protrude. At very low water narrow outcrops appear at the water-line, but most of these are covered during periods of high water. The outcroppings form three main areas in the central and northern parts of the island, but on the whole form only a small percentage of its area. The southern part of the island is underlain by flows and tuffs of medium to basic composition. Locally, small areas of the volcanics are intensely sheared. Pillow and other volcanic structures occur in many places. Some small, basic dykes, containing chlorite and serpentine, cut the lavas. The northern part of the island is underlain by a much altered intrusive mass presumably related to the granodiorite in the vicinity of De Montigny lake. The contact of the intrusive does not appear on the surface of Siscoe island, but is to be seen on a small island to the northwest.

Diamond drilling in 1926, at a point over the contact, disclosed a great depth of boulders beneath the upper clays, thus suggesting that a valley had been eroded in the rock surface along the line of contact. The reason for such erosion is seen underground where a considerable width of sheared and altered rocks occurs in the contact area.

The intrusive rock, as a whole, is much altered and replaced. Originally it must have been a granodiorite composed of albite-oligoclase, some amphibole and biotite, and large eyes of opalescent quartz. Local areas

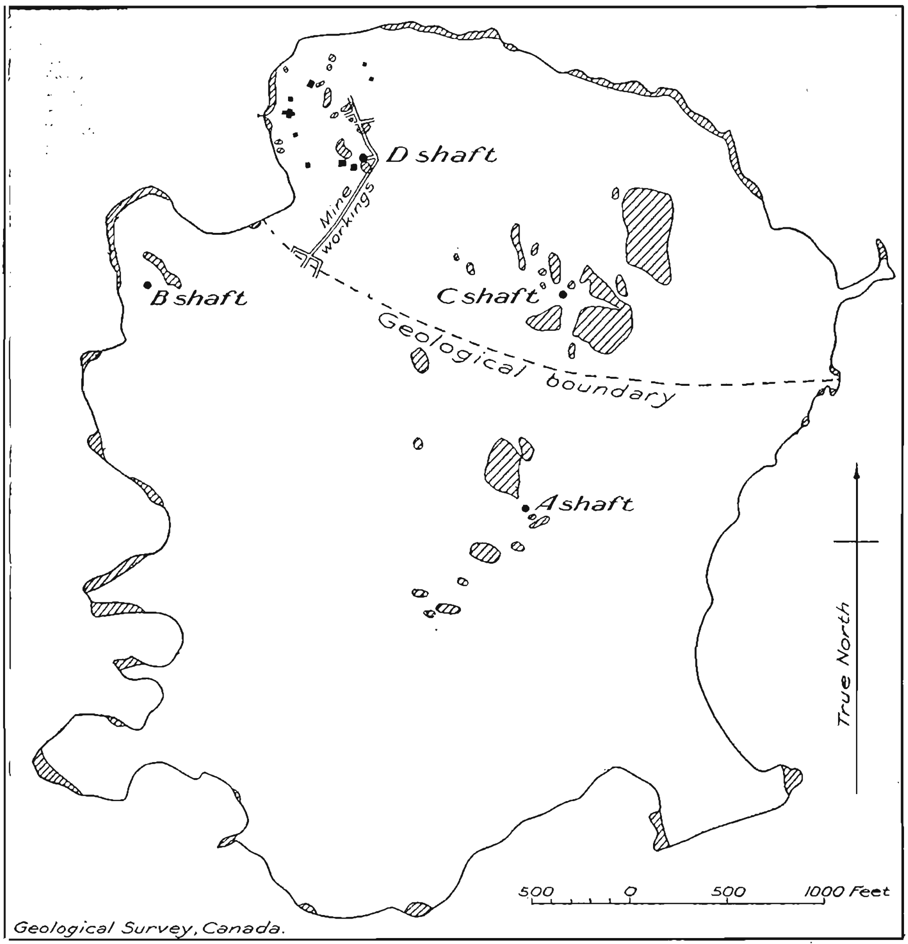


Figure 21. Siscoe island, De Montigny lake, showing outcrops (pattern of ruling); those north of the geological boundary are granodiorite; those south, volcanics.

within the mass still retain some of the original characters, but the bulk of the rock has been replaced by carbonate and epidote, and in part at least by albite due to the action of the vein solutions. The ferromagnesian minerals have been largely replaced by chlorite. The grain varies from fairly fine to extremely coarse. The distribution of the coarse, opalescent quartz eyes seems to be irregular. The connexion between the intrusive and the masses of granodiorite to the east of Bourlamaque township is inferred from the occurrence of the opalescent quartz and the similarity of the feldspars.

All the rocks so far mentioned are cut by some dykes of granodiorite porphyry, which attain a width of 15 feet locally. They are perhaps part of the same magma that produced the granodiorite, and only slightly later in age.

The bulk of the development work up to 1926 was concentrated around D shaft, where a network of veinlets cuts the basic granodiorite throughout a zone some 200 feet wide. A mill run of about 8 tons of selected ore from this zone yielded over $39 in gold a ton, according to assays published by the British Minerals Corporation. Mill runs of the rock body netted by the small veinlets yielded only small values, in the neighbourhood of $2 a ton.

The veins of the D zone fall into two distinct sets. Those of the older set trend approximately north and south, and dip from 45 degrees to 60 degrees toward the east. They are very irregular both in shape and strike; they widen and narrow again, and in some places pinch out entirely. They throw off numerous stringers which may unite farther on with the original vein so as to enclose a horse of country rock, or may cross a band of country rock and join an adjacent vein of the same set. The veins are only a few inches wide, with a maximum of 1 foot, and are composed principally of quartz. In a few places a small bunch of tourmaline needles is seen near the centre of a vein, but as a rule very little of this mineral is present. The edges of the veins are mostly characterized by a very narrow rim of calcite crystals, and in places calcite with some tourmaline may fill a vein entirely. Little or no sulphide is to be found within the veins themselves, but free gold occurs. The country rock is altered for a short distance, usually less than an eighth of an inch, with deposition of some quartz, carbonate, and pyrite. The veins of this type are roughly at right angles to the granodiorite-Keewatin contact.

The veins of the second set are commonly less than an inch in width, strike about east and west, and are flat or dip northward at angles up to 30 degrees. They cut and fault slightly the veins of the first set and are, therefore, somewhat younger. Their composition is quite different from that of the first set as regards the tourmaline content, which may vary from 25 per cent upward to almost pure tourmaline in places. The other principal constituent is quartz, but a good deal of albite, calcite, pyrite, and gold are also present. From a study of one thin section it appears as if the calcite crystallized after the tourmaline, but before the albite and quartz. In the field it was observed that the calcite tends to concentrate along the edges of the veins, as in the first set, but the tendency is less marked. The pyrite content is rather large, particularly in the larger veins that consist mainly of quartz.

The veins of this set have altered the country rock much more strongly than those of the first set. The alteration extends to a distance of several inches, and the country rock is thereby enriched with sulphide and, occasionally, with tourmaline. Thin sections show that the alteration has proceeded as follows:

The original rock, unaltered by the vein-forming solutions, is composed of perhaps 50 per cent of slightly greenish chlorite and 35 to 40 per cent of leafy, irregular albite, $Ab_{90}An_{10}$. The remainder consists of quartz, calcite, and skeletons of fairly large crystals of, presumably, some original ferromagnesian mineral, now completely altered to masses of epidote, albite, and magnetite or ilmenite. In a specimen labelled "partly altered rock" taken from a point somewhat nearer a vein, all but 1 per cent or 2 per cent of the chlorite, and all the epidote, have disappeared. About 80 per cent of the rock is now albite, and the remainder is mainly calcite, with 4 per cent or 5 per cent of quartz, the residual chlorite mentioned above, and the original magnetite. The "completely altered" rock nearest the vein exhibits a rather unexpected variation. About 95 per cent of it is pure albite ($Ab_{100}An_0$), in large crystals about 0·7 mm. in length. In both the previous sections the albite is in much smaller crystals. The remainder consists of quartz and calcite in about equal proportions. Chlorite has entirely disappeared.

The effect of the alteration, therefore, has been to remove chlorite and epidote from the rock, to recrystallize the albite into larger crystals of higher soda content, and to add more albite. In the absence of analyses it is impossible to say whether the appearance of additional calcite and quartz in the partly altered rock is due to addition of material, or simply to rearrangement. The disappearance of these minerals in the completely altered rock suggests, however, that it is due to rearrangement rather than to addition.

Chemically the alteration consists of a loss of lime, magnesia, and iron from the original rock, and addition of soda and probably of silica and alumina. The presence of tourmaline and pyrite in parts of the altered zones, though not in the thin sections examined, also indicates addition of boron and sulphur. The principal constituents of the vein-forming solutions must, therefore, have been soda, silica, and probably alumina, with lesser amounts of sulphur, boron, lime, and carbon dioxide.

The principal values in the veins appear to be due to the free gold which in various specimens was found to be closely associated with tourmaline, some in the interior of bunches of tourmaline crystals.

To the north of D shaft are some old pits now full of water, so that no adequate idea could be formed of the vein explored by these pits. At one place it seems to be about 4 feet wide, but is said to be 9 feet wide in a pit a short distance east. From the location of points designated by Mr. Siscoe, the vein has a strike of north 70 degrees east. The vein quartz is blue-grey and carries some pyrite, chalcopyrite, and free gold. A considerable fault with a strike almost parallel to that of the vein appears in the underground workings, but the connexion, if any, between vein and fault, is not known.

The underground workings, when examined in June, 1926, included a shaft inclined at 57 degrees and sunk to a vertical depth of 105 feet, together with about 1,500 feet of drifting and crosscutting (Figure 21).

Most of this work has been of an exploratory nature, directed to finding single veins large enough to mine. The tenor of the network of small veins and enclosed rock is too low to render mining of the whole mass possible.

Near the north end of the underground workings fair-sized veins have been found both east and west of the main drift. Those on the west side are a number of small, easterly-dipping quartz veins, and one vein about 2 feet thick. These veins belong to the class striking slightly east of north and dipping east. The country rock is fine-grained granodiorite, much altered and mineralized with pyrite cubes. The quartz is grey, glassy, and contains pyrite cubes. Tourmaline veins up to 3 inches thick cut veins and country rock. The latest fissures are less than ½ inch wide and filled with calcite or pyrite.

The vein on the east side of the main drift is about 2 feet thick, striking northeast, and dipping about 60 degrees south. On the east it is cut off by a small fault whose plane strikes about north 70 degrees east and dips 73 degrees north. Later work is reported to have recovered the vein about 10 feet to the north of the drift. The vein cuts a fine-grained silicified phase of the granodiorite, which carries pyrite in considerable amount. Good values are reported from the country rock where it is mineralized near the vein. The vein quartz is greyish and holds tourmaline and some pyrite. Free gold is said to have been noted during the work in the drift.

The long crosscut that runs southwest from the shaft to the granodiorite-Keewatin boundary cuts a vein known as "K" which seems to follow that boundary. It lies within a zone of highly metamorphosed talc and chlorite schist developed along the contact. On the accompanying sketch map (Figure 21) this contact zone is included within the boundary of the granodiorite mass. The dip of the vein is about vertical; and the strike, as measured by the direction of the drift, about north 63 degrees west. Where intersected by the main crosscut, it has a width of 2½ feet. Drifting has followed the vein in both directions from this point. In a southeast direction, the vein narrows within a length of 20 feet to a width of 1 foot, where it pinches out for a distance of 10 feet. It is again picked up on the same strike with a width of 4 inches, and in the remaining 40 feet of the drift attains a width of 16 inches. In a northwest direction from the main crosscut the drift follows the vein for a distance of 105 feet. West of the crosscut the vein narrows rapidly and in the face of the drift is 4 inches wide. On the southern wall of the drift, 20 feet from the face, another similar vein runs parallel to the K vein for about 40 feet. It varies in width from 3 to 9 inches. K vein is formed of glassy, white quartz separated into sections 1 to 2 inches wide by thin seams of chloritic material running parallel to the vein walls. Pyrite occurs in the white quartz, but seems to be chiefly associated with the chloritic partings. A very small amount of chalcopyrite occurs in fine fissures in the vein quartz. Some fragments of chloritized country rock occur within the vein. The country rock is the highly sheared talc and chlorite schist mentioned as being present near the contact of the dioritic intrusive and the volcanics.

Near the vein the wall-rock is mineralized with coarse pyrite. Good values are reported from the vein and adjacent wall-rock, but it is not known over what widths the values occur.

Though no evidence of displacement has been detected, it appears that the band of highly altered schist is a shear zone developed in a contact fault. The vein may well be expected to be found intermittently along the length of the fault. In the crosscut to the south of K vein are found some zones of gouge and some slickensided surfaces that indicate crumpling and faulting. Some dyke-like masses of feldspar porphyry have also been intruded along the lines of weakness of the fault.

In 1927 active development on the "C" shaft and vein was recommenced. Prior to 1919 this vein had been trenched and stripped, and an inclined shaft had been sunk on it for about 100 feet, following the dip of the vein. Since renewing operations the shaft has been continued to a depth of 500 feet, and much lateral work done at the 170-, 300-, 400-, and 500-foot levels, according to a statement received from the president, Mr. J. T. Tebbutt. Published reports of the company indicate that the vein, or the valuable part of it, has a length underground of about 600 feet, an average width of 3½ feet, and an average tenor of over $20 in gold a ton.

When the property was examined in 1923 and 1926, the vein could be seen only at the surface. There it is only about 12 inches wide. It strikes north 10 degrees east, dips about 40 degrees west, and had been stripped for about 200 feet. It cuts the coarse, basic granodiorite. The vein filling is quartz, sliced parallel to the strike by shearing stresses. The fissures made by the shearing are filled with black tourmaline and a little quartz, and in places the tourmaline forms tabular masses up to an inch thick. The walls of the tourmaline-filled fissures are strongly slickensided, and the striæ dip 38 degrees toward the north end of the vein. The vein contains much free gold, both coarse and fine, but practically no sulphides. J. A. Bancroft, who examined it in 1919, observed free gold occurring within nests of tourmaline. Bancroft also reported the occurrence of scheelite in this vein.

It seems probable, from the strike and composition, that the quartz part of the vein belongs to the first or north-striking group of small fissures around D shaft; and that the tourmaline veinlets in it are contemporaneous with the second set around D shaft.

On the strike of C vein, some 750 feet to the south, a similar white quartz vein outcrops, in the Keewatin volcanics. The vein is very short.

The A vein located in the central part of the island cuts Keewatin volcanics. A vertical shaft, reported to be 45 feet deep, has been sunk on the vein, but it was full of water when visited. The vein is visible on the surface for about 50 feet east of the shaft and strikes north 65 degrees east and dips 80 degrees south. It has a width of from 1 to 2 feet, is irregular, and encloses many fragments of greenstone. The vein matter is sugary quartz, with considerable coarse pyrite and tourmaline, and some chalcopyrite. The sulphide is confined chiefly to fissures in the vein quartz. This vein when sampled by Prof. Bell and Mr. J. A. Dresser showed an average value of $26.50 a ton over a width of 13 inches, the samples being taken at points 9 and 14 feet below the surface. In the shaft, 34 feet below bedrock, the vein has a width of 12 inches, and an indicated value of $2.80 a ton. A sample of a 9-inch width, taken from the vein at 29 feet below surface, showed values of $13.60 and $3.10 a ton.

B shaft, which was full of water at the time of the visit, has been sunk to a depth of 30 feet on a porphyry dyke adjacent to which is a 1-foot quartz vein. A sample of the dyke taken by J. A. Dresser gave 80 cents a ton in gold across 4½ feet; a sample of the country rock near the vein gave values of $2.40 a ton over a width of 4 feet.

On the main shore north of Siscoe island a large, mineralized zone has been disclosed by stripping on lot 39, range I, Varsan township. The country rock is a granite, somewhat porphyritic in habit, and mineralized with pyrite and carbonate. The mineralized zone is 100 feet wide with an east-west strike. The discovery lies just at lake level, and on the shoreward side is covered by a clay bank, so that very little of it can be seen. Within the zone numerous, reticulated masses of glassy white quartz enclose elongated masses of the granite. The quartz carries some pyrite, and a little free gold. Tourmaline occurs within the quartz in seams up to 3 inches wide parallel to the general strike of the zone. Small seams of carbonate locally form a selvage to the quartz masses; other veinlets are composed of tourmaline and carbonate, the carbonate being later than the tourmaline. Pyrite occurs also in the carbonate. Sufficient sampling to determine the extent of the gold values has not yet been done, though samples of small widths are said to carry good values.

The Siscoe property is of interest in that it shows quite definitely the relation of gold mineralization to the granodiorite intrusive which is of widespread occurrence in the district. There is, therefore, a possibility that zones of similar mineralization may be found, in addition to those discovered. The present work on the Siscoe property has disclosed several small bodies of high-grade ore. The chief problems seem to be: the mining on a small scale of these high-grade sections without too much dilution by low-grade material or waste; and the economical treatment of the ore mined. If mining can be carried on profitably, there is the additional prospect that other ore-bodies may be discovered in the course of the work.

Sullivan Claims

The claims staked by J. J. Sullivan and H. Authier in July, 1911, were the first on which gold was discovered in this district. They lie on the east shore of De Montigny lake, and occupy the west part of lot 53, range X, and the north part of lots 48, 49, 50, and 51, range IX, Dubuisson township.

The veins are on a rocky knoll measuring some 1,500 feet from north to south, and 500 to 600 feet from east to west. It forms a point projecting into the lake, which borders it on the north and west sides; on the other two sides the knoll is bounded by swamp.

The rock is a rather coarse-grained, grey granodiorite, composed mainly of crystals of albite or albite-oligoclase up to 4 mm. in length, altered to mixtures of sericite and epidote. Hornblende was probably

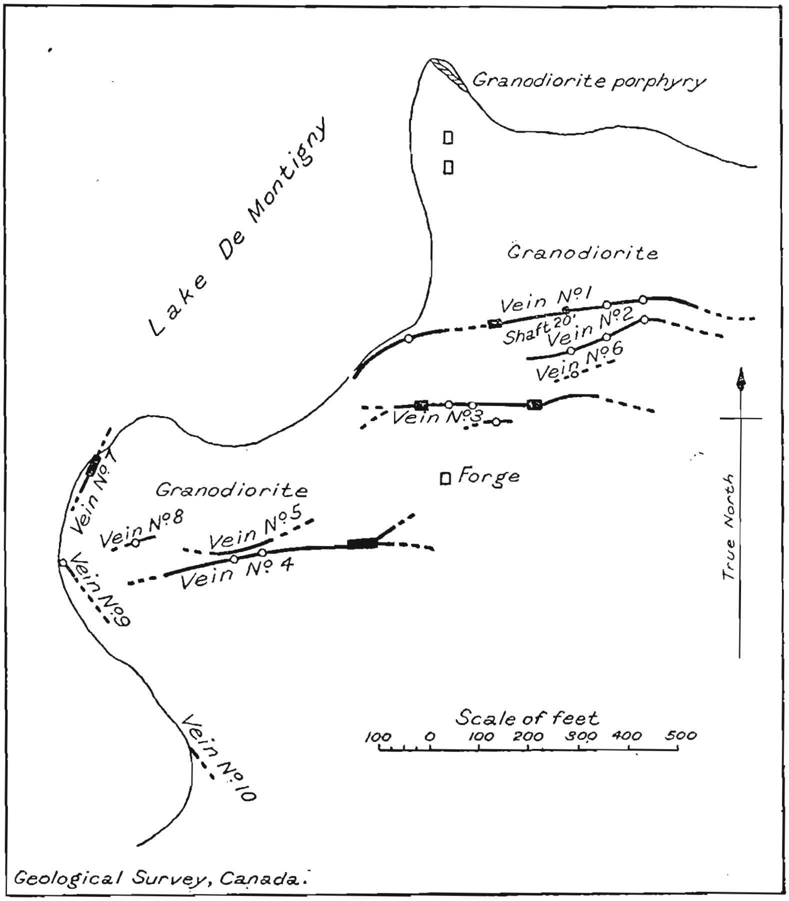


Figure 22. Plan of Sullivan claims, De Montigny lake, Dubuisson township (After Mailhiot).

the original basic constituent, but is now completely altered to chlorite and epidote. A little quartz is present in the spaces between the feldspar crystals, and Bancroft states that a little orthoclase occurs similarly. None was identified, however, in the one thin section examined. Toward the eastern edge of the knoll the granodiorite appears to grade into a rather highly siliceous granite containing much free quartz. The rock, however, is greatly altered. On the shore at the northern end of the knoll a dyke of granodiorite porphyry cuts the granodiorite. It is a rather coarse-grained porphyry.

Prospecting has revealed several small veins and stringers, indicated by number on the accompanying sketch, Figure 22, taken from Mailhiot. Vein No. 1, the initial discovery, has a general strike of north 75 degrees east, and a nearly vertical dip, swinging from steeply north to steeply south. It occupies a fracture zone in the granodiorite, which is crushed and even rendered schistose in places for a few inches from the vein. It has been stripped for about 600 feet and tested further by several shallow pits and a 20-foot shaft. The average width is about 3 or 4 inches, although parts are as much as 2 feet wide. Mailhiot states that the width in the shaft is 5 feet; unfortunately the shaft was half full of water when examined in 1923, so that the lower part could not be seen. Inspection of the part above the water-level seemed to indicate, however, that the reported 5-foot vein is made up of three or four parallel stringers of quartz enclosing more or less sheared granodiorite between them.

The vein material is chiefly quartz, with a little pyrite and chalcopyrite, and a very little tourmaline. Mailhiot also reports the presence of galena and blende. Native gold in small flakes is the principal economic constituent. Samples taken by Mailhiot and by Bancroft indicate that the average tenor of the quartz is about $7 a ton, although selected samples have yielded much higher values. The wall-rocks are more or less impregnated with sulphides for a few inches from the vein.

The remaining veins are hardly worth detailed description. Like No. 1, they are narrow cracks in the granodiorite, filled with somewhat discontinuous lenses of quartz. Most of them contain a much higher percentage of tourmaline than No. 1. No. 4 vein is a few inches to 2 feet in width, and has been stripped for about 500 feet. It strikes north 75 degrees east, and dips 70 degrees south. Like vein "C" on the Siscoe property, and also like one or two of the other veins on this property, it consists of quartz sliced parallel to the strike, with black tourmaline filling the fissures so produced. Striæ on the walls of the fissures dip 40 degrees to 50 degrees toward the west end of the vein. In other places tourmaline is mingled with the quartz. The No. 4 vein affords a third example, of which two have already been described from the Siscoe, of a double period of mineralization following the intrusion of the granodiorite. In the first period, quartz veins carrying a little tourmaline and carbonate were formed; then followed a small faulting that sliced and shattered the old veins and formed new fissures, and the openings so produced were sealed with tourmaline and a little quartz.

In a test pit on this vein quartz-tourmaline material forms the matrix of a breccia, enclosing fragments of a hard, white rock, apparently an earlier vein material. In thin section it is seen to be practically all albite ($Ab_{90}An_{10}$), in small crystals 0·03 mm. in diameter. Thus again there is evidence of the highly sodic character of the solutions that preceded the tourmaline veins.

Stabell and Legault Claims

The Stabell and Legault claims are adjacent to one another, and the main workings of both are on the same ridge, so that they are best described together. The principal features are shown on the accompanying sketch (Figure 23).

J. B. Legault's claims include the north half of lots 51 and 52, range VIII, Dubuisson township. The claims known as the Stabell group adjoin these on the east, and include the north half of lots 53-56, range VIII, together with the south half of lots 52 and 53, range IX, and a small fraction of the south half of lots 54-56, range IX. These claims, formerly the property of J. F. Stabell, were bought early in 1922, by W. F. Greene and associates, and incorporated under the name of Stabell Gold Mines, Limited. Access to the properties is had by launch from Amos to the head of Blouin lake, whence a road about a mile long leads to the mine.

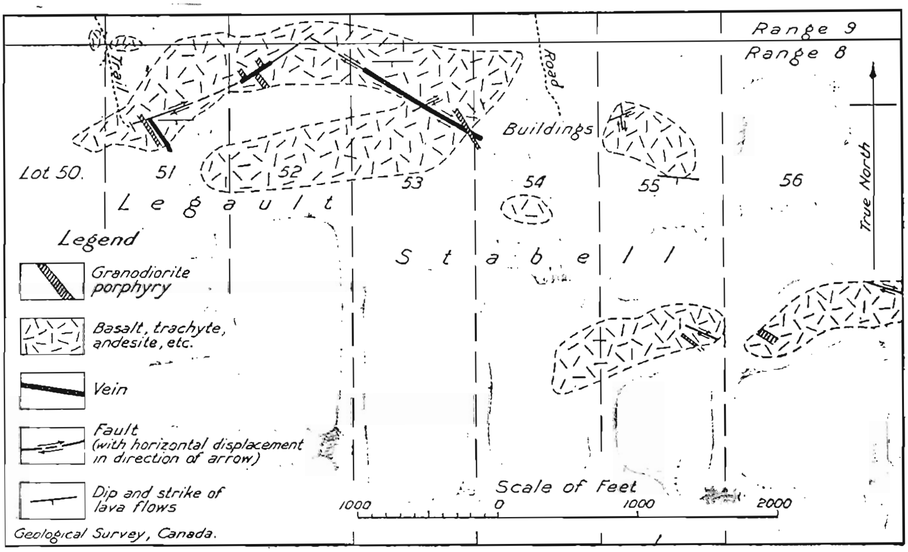


Figure 23. Plan of Stabell and Legault claims, Dubuisson township.

A detailed examination of these properties was made early in the summer of 1923, at which time only surface work had been done, and drilling on the Stabell vein was in progress. Later in 1923 shaft-sinking was begun, and by the autumn of 1924 had been carried to a depth of 600 feet. At 285 feet a level was run, and some 700 feet of lateral work was completed. On this level fairly promising results were obtained, but apparently these did not continue to the 600-foot level, as work was discontinued after reaching that level and nothing has since been done. According to recent press reports, however, the mine was dewatered and further explored in 1928. A rather brief visit to the mine was made late in 1924, before the 600-foot level was reached, and the workings on the 285-foot level were inspected.

The rocks are mainly Keewatin lavas, cut by a few dykes of a rather fresh porphyry. The lavas include almost all the usual types, of which the commonest is a dark green, basic, rather fine-grained rock, that may be termed an altered basalt. It consists mainly of partly chloritized, fibrous hornblende, probably secondary after augite, with about 35 per cent of andesine feldspar ($Ab_{65}An_{35}$), altered to epidote. In drill-cores this rock was observed to grade into hard, light green bands that vary from a few inches to several feet in width, and consist of the epidote pistacite with 20 to 25 per cent of quartz. No evidence is yet available as to the cause of this alteration of the "basalt."

Both on the Stabell-Legault claims and throughout Dubuisson township there is found a basic rock of much the same composition as the basalt described, but showing on the weathered surface a coarse grain and a clotting of the feldspar crystals into masses up to the size of a silver dollar. The coarse grain has caused some writers to term the rock gabbro or diabase. In several places, however, the rock passes without a break into a finer-grained rock characterized by pillow structures, so that it is, therefore, undoubtedly a lava. A large number of the veins of Dubuisson township have been found in this rock, a fact that seems to be significant. The reason may be that the rock is harder and tougher than other types in the neighbourhood, and consequently fractured cleanly under stress instead of yielding by flowage or by the formation of many small, discontinuous fissures that would afford no good channel to ore-bearing solutions.

The more acid types of lavas are light grey rocks that might be termed oligoclasites, dacites, or trachytes. There are many types, but the original composition can rarely be determined, for the primary minerals are commonly to a large extent replaced by chlorite, epidote, kaolin, and other secondary minerals.

Forest fires have removed the vegetation completely from much of the area, and thus an opportunity was afforded to make five or six excellent structure determinations on the lavas. The strike is in general east and west, swinging from north 82 degrees east near the west end of lot 53, through due east in the middle of lot 54, to north 83 degrees west at the east side of lot 55. Dips are nearly vertical, and the upper sides of the flows face south.

The porphyry is a grey, fresh-looking rock, containing many medium-sized phenocrysts of white feldspar and hornblende. One dyke that crosses the Stabell vein will hereafter be referred to as the Stabell dyke; there are also several dykes on the Legault claims. The feldspar phenocrysts consist of andesine or oligoclase-andesine, around $Ab_{60}An_{40}$, and may form up to 20 per cent of the rock; the hornblende phenocrysts rarely form more than 1 per cent. In the most siliceous dyke examined, a few phenocrysts of biotite were also found. The groundmass is mainly albite feldspar ($Ab_{90}An_{10}$), with about 5 per cent hornblende and biotite, and varying amounts of quartz. The Stabell dyke contains no quartz, and most of the dykes carry less than 1 per cent, but one of those on the Legault claim has about 15 per cent. The rock may, therefore, be termed a granodiorite porphyry.

Most of the dykes are quite fresh, but the Stabell dyke is much altered. In specimens taken from the drill-cores at depths of 200 to 300 feet the hornblendes are almost completely chloritized and the feldspars replaced by epidote.

The principal outcrop, on which nearly all of the work on both groups of claims has been done, is a ridge about 3,200 feet in length from east to west, and 1,600 feet in width. The ridge occupies the northern end of lots 51, 52, and 53, range VIII, and is surrounded on all sides by lower land heavily covered with drift. A shallow depression, also filled with drift, occupies the middle of the ridge. The south side slopes gently downward, but the other three sides are steep. The east end, in particular, is a steep cliff 50 to 100 feet in height, overlooking a drift-filled valley that occupies most of lot 54. Attempts made to pierce the soil in this valley, in order to trace the vein eastward by diamond drilling, showed a depth of more than 200 feet, mostly fine quicksand.

The Stabell vein crosses the main outcrop at the north end of lot 53, with a general strike of north 60 degrees west and a steep dip to the north. It fills the fissure of a large, pre-existent fault. By projecting the strike of a well-defined bed of trachyte breccia from the outcrop in lot 55 across the fault to the outcrop in lot 53, it was found that the bed in lot 53 is 200 feet farther north than it would be if no displacement had occurred. Assuming that the fault under discussion has caused this displacement, and not some unknown fault now hidden beneath the drift in lot 54, it is concluded that the south side of the fault has moved west, relative to the north side, for nearly 400 feet measured along the fault-plane. Striæ observed at one or two places indicate that the movement was nearly horizontal. That the displacement really is caused by this fault, in great part at least, and not by some unknown fault, is shown by the visible lack of correspondence of the rocks on the two sides of the fault on the outcrop in lot 53.

The sheared zone of the fault could not be traced more than 100 feet into lot 52, so that the fault probably disappears on the west side by branching.

The Stabell dyke of porphyry, very irregular in shape, crosses the fault close to the eastern end of the outcrop. It strikes southeast in a general way, but is very crooked. It has not been displaced or sheared by the fault, and was, therefore, intruded after the faulting. In fact, the vein has been slightly displaced where the dyke crosses it and the part northeast of the dyke has been moved 2 or 3 feet northwestward. Evidently the fracturing that permitted the injection of the dyke was later than the large fault and was accompanied by small, lateral movement.

Although the vein is apparently faulted where the dyke crosses it, this does not indicate that the dyke is later than the vein. On the contrary, veinlets of quartz mineralized with pyrrhotite and chalcopyrite were seen in several places in the underground workings to project from the main vein into the porphyry, and a contact between the vein and porphyry is not clean-cut and sharp, as if the dyke intruded the vein, but is irregular, embayed, and rather vague, as if the vein-forming solutions had eaten into the porphyry and partly silicified it. It must, therefore, be concluded that the vein filled the fault fissure after the latter had been cut and displaced by the porphyry dyke; in other words, that the sequence of events was faulting, intrusion of the porphyry, and vein filling.

The vein consists of quartz with sulphides and a little calcite, forming a succession of lenses of varying length and width. The lenses vary in width from 1 to 3 feet, averaging nearer the smaller figure. Near the dyke they are connected to form a continuous vein that widens and narrows again; but about 800 feet from the dyke they begin to be entirely unconnected with one another and form isolated masses. The sheared wall-rock is more or less impregnated with sulphides for a few inches from the vein, although in one place where a subsidiary veinlet joins the main vein there is a sulphide impregnation 20 feet or more wide. The sulphides of the vein are chiefly auriferous chalcopyrite and pyrrhotite; they fill cracks in the quartz which has been rather badly shattered. The main values are found in the chalcopyrite, pure specimens of which are said to assay $200 to $300 a ton in gold. The pyrrhotite carries very low values, from $1 to $2 a ton.

The vein has a length of about 1,000 feet from the porphyry dyke to the point on the west where it dies out. On the surface the width close to the dyke is 2 to 3 feet, and this width gradually decreases until at the west end the vein consists of only a few discontinuous lenses of quartz, averaging about 1 foot in length and 2 or 3 inches in width. Auriferous chalcopyrite, the principal constituent of value, practically disappears from the vein about 600 feet from the dyke. Pyrrhotite begins to appear in quantity about 200 feet from the dyke, and increases in amount westward. It continues in quantity to a point 960 feet from the dyke, or 40 feet from the west boundary of lot 53, where it begins to diminish rather rapidly, forming isolated lenses that disappear altogether at the western boundary of the lot. This mineral tends to be concentrated along the walls of the vein, particularly the hanging-wall, and to occur in subsidiary veinlets.

On the 285-foot level the vein is somewhat wider than on the surface, with a maximum of 4 feet. The manager stated that over this width its average tenor is $15 a ton in gold, throughout a length of 310 feet. Of this length, 220 feet lies east of the shaft, and 70 feet west of it. An offshoot from the porphyry dyke follows the vein, on this level, and extends some 90 feet beyond the western end of the enriched part before pinching out.

The minerals of the porphyry dyke are largely replaced by epidote, and the basalt near the vein is filled with hair-like cracks, some of which contain pyrrhotite, others epidote and quartz. The solutions that deposited the pyrrhotite and those forming the epidote appear, therefore, to be closely associated. As both epidote and pyrrhotite are minerals characteristically deposited by hot solutions, it is probable that the same set of solutions deposited both, although perhaps not at exactly the same time.

On the Legault claims there are two veins, one on lot 51, the other on lot 52. That on lot 51 is a clean-cut fissure vein about 4 feet wide, striking north 38 degrees west, and dipping vertically or nearly so. It is composed of clear, rather glassy quartz, much rusted for a depth of several inches. Mineralization is not heavy, and no information as to values was obtained. The vein has been stripped for about 250 feet. At the south end the strike swings to the south, and the vein disappears beneath drift. At the north end it terminates abruptly against the narrow, sheared zone of a small fault that strikes north 75 degrees east and dips vertically to 70 degrees south. In the acute angle between the vein and the fault the lavas exhibit well-developed flow textures, the strike of which is north 82 degrees east a short distance from the fault, but changes abruptly to north 38 degrees west close to the fault. On the north side of the fault the top of the same flow is found 25 feet to the east of its position south of the fault; so that the change in strike of the flow textures is clearly due to drag exerted as the north side moved eastward relative to the south side. The vein does not appear on the other side of the fault, and hence is almost certainly a tension fissure opened by the strain of faulting. In these circumstances it will probably prove to have no great length.

A dyke of granodiorite porphyry parallels the vein, and cuts across the fault without being displaced. Small tongues and dykes of porphyry also follow the fault and cut across its schistose zone without being themselves rendered schistose. The porphyry is, therefore, later than the fault. It forms striking contact breccias with the greenstone in this vicinity. The porphyry dykes are fissured with small, discontinuous cracks filled with quartz and tourmaline, and similar material forms veins a few inches wide filling the fault. The fissures in the porphyry resemble cooling cracks.

The fault is traceable eastward for some 400 feet, then passes under drift. Its apparent continuation outcrops on the west side of lot 52, where it is filled with a quartz-tourmaline vein about 5 feet wide, striking north 56 degrees east. The vein has been stripped for about 200 feet. It was not seen on the outcrops farther east, although the sheared zone in which it lies is traceable for a farther 150 feet before it becomes too poorly defined to be followed. The vein matter, therefore, forms a lens, probably of no great length. The vein mineral is chiefly quartz sliced by somewhat irregular cracks filled with tourmaline, pyrite, and some pyrrhotite. No definite information could be obtained as to the gold values, but they are said to be low.

Three dykes of granodiorite porphyry are found close to this vein or lens, each of them striking nearly at right angles to it and ending abruptly at it (Figure 24). The relations are suggestive of faulting, but in view of the clear evidence elsewhere that these dykes are later than the faulting, such a conclusion is inadmissable. It must be concluded, therefore, that the dykes occupy fissures ending at the fault-plane and probably, therefore, produced by the strains of faulting, like the vein fissure on lot 51.

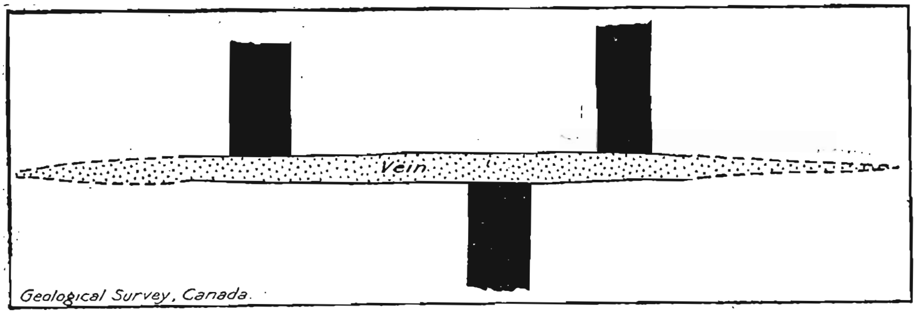


Figure 24. Diagram showing relations of porphyry dykes (solid black), and vein (dotted), Legault claim, Dubuisson township.

Clark Claims

The Clark property lies in the northwestern quarter of Bourlamaque township, about 3½ miles from the north boundary and 1½ miles from the west boundary. A road about 3 miles long runs from the property to the head of Blouin lake, from which point navigation is uninterrupted as far as Amos on the National Transcontinental railway. A discovery of gold on the property in 1924 attracted a good deal of public attention to it, and, accordingly, the claims were examined in September of that year.

The rocks on the claims are mainly trachytic lavas and tuffs. In places the lavas contain numerous large phenocrysts of white feldspar, giving them much the appearance of some varieties of syenite porphyry. No evidence could be obtained, however, that the porphyritic rocks are really intrusives; on the contrary, they passed wherever examined into lavas of normal appearance. One small dyke of true syenite porphyry was found.

A number of veins have been found, of which only two appeared of prospective importance. One of these, known as "E" vein, strikes north 70 degrees west, and dips 45 degrees south. At the time of examination, the "E" vein had been uncovered for about 30 feet along the strike. Its outcrop width at this point is 9 feet, so that its thickness, measured at right angles to the dip, is 6 feet. The vein material is principally white quartz sliced, slickensided, and shattered. The slickensided cracks are filled with chlorite or hornblende and a little tourmaline, and also contain in places much fine-grained pyrite, some chalcopyrite, and much native gold. There is also a great deal of fine-grained native gold throughout the quartz. The miners stated that quartz containing no sulphide or visible gold yields a heavy tail, on panning. Chip samples from which visible gold was carefully excluded assayed about $50 a ton. The wall-rock for about 1 foot from the edges of the vein is heavily mineralized with fine-grained pyrites.

About 400 feet to the east, along the line of strike, a barren quartz vein 1 foot wide outcrops on a small knoll. It seems likely that this is the same vein as that described. If so, the part described in the last paragraph is merely a highly mineralized enlargement.

About 1,600 feet eastward along the strike of the vein low ground gives place to higher, and a vein is found, which may be the continuation of "E". It is known as "A" vein, and has been exposed by trenching for 150 feet. It strikes north 75 degrees west, and dips 57 degrees south. It is 2 to 3 feet wide, is much less heavily mineralized than "E" vein, and its tenor is comparatively low. The composition is much like that of "E", except that there is present a good deal of ferruginous carbonate, which is practically lacking in "E".

Vein "C" lies about 1,200 feet southwest of vein "A". It is not a well-defined fissure vein, but a network of stringers and small branching veins surrounding and including large and small fragments of country rock. The general strike is north 80 degrees east. The vein materials are chiefly quartz with a great deal of hornblende and some tourmaline; but in places pure hornblende forms veinlets up to ½ inch wide, which here and there have little lenses of quartz in the centre. In September, 1924, the "vein" had been exposed by trenching for about 150 feet, within which distance the greatest visible width is 12 feet. Somewhat greater widths were said to have been found in the main trench which when the property was examined was filled with debris from the shaft.

The wall-rocks and the included fragments of country rock are highly mineralized with fine-grained pyrite and some chalcopyrite. The quartz is less shattered than in vein "E", and is not sliced or slickensided. A little visible gold has been reported. No reliable information regarding values was obtained; they are believed to have been rather low.

Since 1924 two shafts have been put down on the property, one near the south boundary of M.L. 2053a, the other, 78 feet deep, about 29 chains to the southeast of the first, in claim M.L. 2051. It is not known on what veins they have been sunk, but their relative position suggests that they are on veins "E" and "C".

Lake Fortune Mine

The Lake Fortune mine is of some historical interest as it was the first discovery of value to be made in this part of Quebec. Gold was found in the summer of 1906 by Messrs. Olier and Renault in the large shear zone between Renaud and Fortune lakes. Their discoveries attracted a number of other prospectors to the locality, who carried on work in adjacent territory without finding anything of value. Meanwhile, in 1907, the original discovery was taken over by the Pontiac and Abitibi Mining Company, and later, about the end of 1910, transferred to the Union

Abitibi Mining Company. The latter company proceeded vigorously with development work, built and equipped a mill, assay office, engine house, sawmill, and camp buildings. They sank an inclined shaft about 140 feet and ran crosscuts for several hundred feet to the north and south. The commencement of the war put an end to the work, and the company afterwards went into liquidation. The property was then taken over in great part by the Lake Fortune Mining Company, who re-opened the property in 1922, dewatered the shaft, and sampled the underground workings.

In 1923 a controlling interest in the company was given to the Towagmac Exploration Company on condition that development work should be carried on. A good deal of trenching and stripping was done in 1923. Since that time a new shaft has been sunk at the east end of Fortune lake to a depth of 150 feet, and some 550 feet of lateral work done, together with some 6,000 feet of diamond drilling. The company's annual report for 1927 states that the drilling has opened up an ore-shoot between the 300- and 500-foot horizons at least 500 feet long and averaging 3 feet 7 inches wide, with an average tenor of $10.71 in gold.

The principal workings and the buildings lie in the small area between Fortune and Renaud lakes. The rocks are Keewatin basalts, cut by two dykes of syenite porphyry, highly irregular in shape, and very variable in width. The larger dyke has an average width of 12 to 15 feet, but widens in one place to more than 100 feet; the smaller is about 15 feet wide at its largest exposure, but narrows to a stringer less than 1 foot wide. The ore deposit lies in a strongly sheared zone, presumably formed by faulting, that strikes slightly north of east and has been traced from the middle of the east side of MacDonald lake as far as lake Renaud, where it passes beneath the lake. It averages 6 to 12 feet in width, for the most part, except for a distance of some 400 feet at the eastern end, where the sheared belt is 200 to 300 feet wide. Throughout the greater part of the observed length there is very little vein material in the sheared zone; between Renaud and Fortune lakes, however, it contains much quartz, carbonate, and sulphides. The larger of the two porphyry dykes is cut by the shear zone in one place, and altered to sericite schist; so that the period of vein formation must have been later than that of the dykes.

The principal vein materials are quartz, a carbonate (ankerite with more or less calcite), fuchsite (a chromelithium mica), pyrite, chalcopyrite, tellurides, and free gold. Robert Harvie, who examined the deposit in 1910, succeeded in separating a small quantity of the telluride, and found by analysis that it contained about 25½ per cent gold and 42 per cent silver, corresponding approximately to the formula for petzite $(Ag\ Au)_2\ Te$. Mr. V. Dolmage examined a polished surface of the same ore under the reflecting microscope and determined that two tellurides are present, which appear to be petzite and sylvanite $(Au\ Ag)\ Te_2$. The precise determination is difficult, however. These tellurides are dark grey to black, opaque minerals, occurring in very small grains, as far as observed. They are slightly softer than calcite.

The gold values in the veins, according to Harvie, are obtained from the tellurides and the free gold. He states that the pyrite and chalcopyrite in the veins, on being assayed, yielded very low values.

Montreal Exploration Company Claims

The claims of the Montreal Exploration Company lie in Bousquet township about $1\frac{1}{2}$ miles west of mile-post VII on the east boundary of the township. Development work on them has been carried on by Mr. H. L. F. Blake. The overburden is extensive and in some places deep, so that much trenching has been required. More than 2,000 feet of trenching has been done on claims A232, A233, A234, A235, A240. The principal work has been done on claim A235.

The claims are underlain by Timiskaming rocks. The depression which crosses the O'Brien and Thompson claims apparently passes through this group. The shallow valley is occupied by the same eastward-flowing stream, but the drift is too heavy to determine if a similar zone of sheared rock underlies the valley. The strike of the formations is practically east. The southern part of claims A234 and A235 to a line about 400 feet north of the southern claim line is underlain by a coarse feldspar porphyry, much sheared in many places. To the north is a band of basic lavas about 200 feet wide. Within these lavas are some well-developed pillows. North of the lavas fine sediments with some conglomerate occur over a width of 150 feet, beyond which a heavy drift cover extends to a point 600 feet north of the northern boundary of the claims.

A mineralized zone lies within the volcanics just south of their contact with the sediments. It consists of an irregular, shattered zone bearing quartz and carrying some sulphides and some values in gold, but is not in itself important. The mineralization and the probability of locating the O'Brien fault just to the north, make it seem advisable to diamond drill the mineralized zone and to pierce the possible fault zone at some depth, in search of a mineralized zone within the faulted area.

Graham-Bousquet Mining Corporation

Graham-Bousquet Mining Corporation owns ten claims totalling some 400 acres on the east side of Bousquet township, tieing on the east to the property of Thompson-Cadillac Mines. The O'Brien, Thompson-Cadillac, Graham-Bousquet, and Montreal Exploration Company's claims are all staked on a single east-west belt of mineralization.

The property was staked in June, 1924, but for two years only assessment work was done. In 1926 a more extensive program of development was initiated and, favourable results having been obtained, is still vigorously prosecuted. All the following information has been obtained through the courtesy of the president of the company, Mr. P. T. Graham.

The early development consisted chiefly of surface trenching and stripping, which had been carried on mainly on claim A182. The original discovery, known as No. 1 vein, was made in June, 1924, near the west side of A182. In the autumn of the same year No. 2 vein was found, about 60 feet north of No. 1. Most of the work has been devoted to tracing and opening up these veins. A third vein some 28 feet wide has been found about 500 feet south of No. 1, but it appears to consist of barren quartz and has not been explored.

According to Mr. Graham, both No. 1 and No. 2 veins lie within a band of greatly sheared porphyry 225 to 250 feet wide. He believes this porphyry mass to be continuous with the porphyry of the Thompson claims to the east, although the width on the Thompson is very much less. It will be noted, however, that the porphyry on the Thompson claim 1402 widens from 30 to 50 feet within a distance of 200 feet from east to west; and that 25 feet south of the wider western exposure there is a porphyry tongue 25 feet wide that does not extend into the eastern exposure. It is quite possible therefore, that the main mass of porphyry lies on the Graham-Bousquet claims, and that only tongues of it extend into the claims to the east.

The No. 2 vein on the Graham-Bousquet property lies in the sheared northern edge of the porphyry mass. North of this lies a width of about 400 feet of ground mainly drift-covered, in which there are a few small outcrops of greywacke. Then follows the creek flowing east to Blake river, which on the Thompson-Cadillac claims is underlain by a wide fault zone. The supposed fault zone has not yet been explored on the Graham-Bousquet property. North of the creek conglomerate outcrops.

The No. 2 vein is composed of quartz stringers injected into the schistose porphyry and following the strike of the schist. The largest of the stringers is some 18 inches wide, and the total width of quartz and country rock, according to Mr. Graham, is 8 or 9 feet. The minerals present, in addition to quartz, are free gold, pyrite, pyrrhotite, and fine arsenopyrite. The country rock is heavily mineralized, more so than the quartz which in the wider veinlets shows a tendency to barrenness.

The No. 1 vein is of a similar character, but narrower. It has a central vein of quartz varying in width from 1 to 4 feet, and the sheared porphyry on each side is filled with quartz stringers to a total width of 4 or 5 feet. The vein minerals and general mineralization are the same as in No. 2.

In the spring of 1928 necessary drilling and other machinery was brought in, and shaft-sinking commenced. By May 6 the shaft was down about 12 feet. The shaft is located on vein No. 1, about the middle of claim A182, or about 30 chains west of the east boundary of Bousquet township. It is planned to sink first to the 125-foot level, then crosscut to vein No. 2.

Thompson-Cadillac Mines

The Thompson property in Cadillac township consisted originally of three claims in the northwest corner of the township. In recent years, it is understood, further ground has been obtained, bringing the total area to about 600 acres. The original claims are Nos. 1402-4, of which No. 1404 is bounded by the west boundary of Cadillac township, No. 1403 adjoins No. 1404 on the east and is adjoined, in turn, by No. 1402. The claims are reached by way of Blake river and a trail which runs westerly along the northern boundary of the claims to the buildings and workings. The claims are square and approximately 50 acres in area. Development work has been confined chiefly to the easternmost claim, No. 1402.

The group was staked in the early summer of 1924 by E. J. Thompson and Austin Dumond, and was later optioned to the Victoria Syndicate, by whom a small amount of development work was done. During the winter of 1924-5 further work was performed by the Anglo-French Exploration Company. By the autumn of 1925 an area some 1,500 feet from east to west and 300 feet from north to south had been explored by trenching and stripping. In many places 6 to 10 feet of clay had to be removed before reaching bedrock.

The zone of mineralization has been traced almost continuously for about 900 feet. It is a sheared zone lying within an east-west band of porphyry, and has a width of 2 to 9 feet. The porphyry along the zone is sheared, carbonated, and mineralized with sulphides and arseno-sulphides. Within the zone are lenses and stringers of quartz. In the eastern part of the mineralized zone, the quartz attains a width of 4 feet and holds this width for approximately 50 feet along the strike. The quartz is usually dark and glassy, but white quartz is also found. Associated with the quartz lenses and stringers are pyrite, arsenopyrite, and a little pyrrhotite. Free gold occurs within the quartz, locally in considerable amounts. The richest showings are at the west and east ends of the mineralized zones. The rich deposit of the eastern end is located where a minor fault cuts across the vein. In the fault gouge dendritic masses of gold have been deposited. The free gold seems to be confined chiefly to the quartz.

According to information received in May, 1928, from the head office of the company, a vertical shaft, known as No. 2, was sunk to a depth of 100 feet near the westernmost exposure of the mineralized zone, and about 40 feet of crosscutting was done at this level. The shaft followed the vein to a depth of 95 feet. The vein then dipped out to the south and was picked up in the crosscut 15 feet away. The vein maintained its width to this depth, or widened somewhat.

Early in 1928 a new three-compartment shaft was commenced, some 900 feet east of shaft No. 2. It is now down to a depth of 300 feet, and lateral work is being undertaken at the 150- and 300-foot levels. The report states that this shaft followed the vein from 45 to 300 feet, and that the average width is about 9 feet.

A large strike fault, also found on the O'Brien claims to the east, on claim 1402 underlies the bed of a small creek flowing east into Blake river. Drill records show that it is wider here than on the O'Brien claims, totalling about 300 feet, although this width includes some 80 feet of an unsheared porphyrite which has evidently been intruded into the fault zone. This porphyrite is a white, comparatively unaltered rock, consisting of angular or embayed phenocrysts of plagioclase 1 to 2 mm. in length, embedded in a fine-grained groundmass of acid plagioclase with a little quartz. The rock is not sheared, and hence must be younger, not only than the faulting, but also than the sheared porphyries found elsewhere on the Thompson and O'Brien claims.

South of the fault zone, 400 feet from the eastern side of the claim, are found successively 30 feet of sheared greywacke, 160 feet of drift, then 30 feet of porphyry. The mineralized zone on which mining operations have been concentrated lies within this porphyry band. South of the porphyry again are widths of 80 feet of a basic, dioritic rock, then 40 feet of conglomerate, followed by greywackes enclosing small lenses of conglomerate. The general strike is a few degrees north of east, the dip vertical.

Two hundred feet to the west the section differs somewhat. The porphyry band containing the mineralized zone is 50 feet wide. South of it are found, successively, 5 feet of massive greenstone, 20 feet of drift, 25 feet of porphyry, and 75 feet of diorite.

The porphyries on the south are much sheared, and appear very similar in composition to the sheared porphyry of the O'Brien claims, although it is impossible to compare such highly altered rocks with certainty. The bands on the Thompson are believed to be intrusive, because of their irregularities along the strike as disclosed by trenching, and because the greywackes close to them are noticeably altered to carbonate. No apophyses or stringers were found branching from them, but this may well be because the lengths of contact exposed in the trenches are small.

The greenstones on the property are schistose in many places, but resemble closely the andesites found within the Timiskaming sediments and observed to be pillowed at roughly the same horizon a few miles to the west.

O'Brien Claims

The claims of M. J. O'Brien, Limited, are in the northwest quarter of Cadillac township, just to the east of the Thompson claims, and about 1¼ miles north of the east-west centre line of the township. They were staked during the early summer of 1924, and shortly afterwards development work was begun. After preliminary trenching and stripping, shaft-sinking commenced late in the summer of 1925. The shaft was carried to a vertical depth of 110 feet, on an angle of 87 degrees, and a large amount of lateral work at this level has been done, mainly of an exploratory nature. In addition, some 6,000 feet of drilling was completed in 1926.

The property consists of ten claims, numbered 1488 to 1497. The shaft is placed near the south side of claim 1492, and most of the work has been concentrated on this claim, on veins that outcrop on a low, rocky ridge a few hundred feet north of the La Motte trail. The ridge dips sharply northward into a drift-filled depression, an extension apparently of the drift-filled valley of a stream that flows east across the Thompson property to Blake river. This depression is a valley eroded along a large fault, and has been traced over 3 miles.

The rocks near the shaft are Timiskaming sediments, porphyry dykes or sills, and greenstone bands, all striking about east. The vein on which the shaft has been sunk lies in a band of conglomerate 50 to 80 feet wide, and near the south edge of the band. The conglomerate consists of pebbles of greenstones, with a few of granitic rocks, up to 5 inches in length, embedded in a medium-grained arkose groundmass. It is quite schistose; most of the softer pebbles have been drawn out into oval shapes, though some of the more resistant have been little affected. Some pebble-like bodies of a coarse, porphyritic rock appear to have originated as injections from the intrusive porphyry bodies nearby. The conglomerate band is sandwiched between two sills or dykes of feldspar porphyry. The dyke on the south is about 15 feet wide, is composed of feldspar phenocrysts in a feldspathic, greenish groundmass, and is much sheared. The dyke on the north is 50 feet wide, of much the same composition, and is likewise badly sheared. The shearing has broken down the feldspar phenocrysts into long, thin plates, which under the microscope are seen to consist of a large, central fragment of the original crystal, tailing off into an aggregate of small grains at each end. The long axes of the plates are, of course, parallel to the schistosity.

To the north of the northern band of porphyry is a band of dark-coloured massive rock ranging in grain from fine to coarse, and having the composition of a diorite or basalt. It is exposed over a width of 70 feet, then dips down on the north into the drift-filled fault-valley mentioned above. Another band of similar diorite lies just south of the southern 15-foot dyke of porphyry mentioned above.

Outside of the area round the shaft, the outcrops on the north consist in general of interbedded greywacke and conglomerate, those on the south, of conglomerate.

The fault zone north of the shaft strikes approximately east-west, and dips steeply south. The underground workings and the drilling have shown that it consists, on the south, of a layer of clayey gouge 1 to 2 feet wide, north of which is a width of 140 feet of much contorted talc-chlorite schist, presumably produced by the intense shearing of the basic rock. A uniform width of this schist was encountered in every drill hole. North of this highly sheared zone the diamond-drill holes are reported to show igneous rock similar to that just south of the shear zone. Drilling in the schist showed the presence of several narrow, dyke-like bodies of porphyry, all somewhat sheared, but one small body little or not at all sheared was reported in the crosscut passing through the sheared zone.

Five principal veins are disclosed by surface and underground work and by diamond drilling. The No. 1 vein, which has a known length of 1,400 feet, lies almost entirely within the conglomerate band. Its strike is slightly undulating, but corresponds fairly closely with that of the conglomerate. It dips 87 degrees north. The width is irregular, ranging from 15 feet to a few inches, and is greatest at the contact of the conglomerate and the greenstone lying to the south of it. The quartz of the vein is dark and glossy, though some sections of white quartz occur within the dark quartz. Coarse, free gold is scattered through the quartz at intervals over its entire length. Arsenopyrite is the commonest mineral within the quartz, though some pyrrhotite was seen and a little chalcopyrite is reported to occur. The shaft and main drift have been cut in this vein.

No. 2 vein is of no importance. It is about 1 foot wide, and cuts the greenstones 150 feet southwest of the shaft. No. 3 vein is 225 feet northeast of the shaft, and is also unimportant.

No. 4 vein occurs within the porphyry 80 feet north of the shaft. It has been uncovered intermittently over a length of about 1,200 feet and follows the strike of the porphyry body. The width of the vein varies between 6 and 24 inches. In one section about 60 feet long it carries a large amount of coarse, free gold in small fissures within the quartz. The adjoining country rock is sheared and near the vein carries some free gold.

No. 5 vein has been encountered only by diamond-drill holes in the sheared zone. The indicated width is from 9 feet at a point 340 feet northeast of the shaft to a mere stringer towards the eastern boundary of the claim. The vein matter is quartz or silicified rock and is mineralized with coarse arsenopyrite.

St. Germain-Gale Claim

This claim is situated on the east shore of the narrows connecting De Montigny lake and Lemoine lake, and occupies lots 38 to 43, range VII, Dubuisson township. The rocks are basic lavas cut by two dykes of syenite porphyry similar to that found on the Martin claims. The veins are rather small and no information as to their tenor could be obtained. They are mentioned here principally because of the interesting relations of the porphyry dykes to the faulting.

The porphyry is very like that of the Martin claims in composition, as it consists mainly of albite phenocrysts in a matrix of albite with a little ferromagnesian material. It differs from the Martin porphyry in containing a little quartz, both as phenocrysts and in the groundmass, and also in containing a number of small hornblende phenocrysts, with a maximum length of 0·8 mm. They form about 10 per cent of the rock.

There were three faults observed on the claims, each of which cuts one or other of the dykes. One of the faults is a few feet west of the pit on the vein described by Mailhiot as No. 2. It strikes north 40 degrees east and dips vertically. The northwest side has been moved about 20 feet to the northeast, relative to the other side, as shown by the displacement of the pillow-textured top of a lava flow. A dyke of porphyry cuts across the fault but is not displaced by it, and is, therefore, later than the fault.

What Mailhiot has termed vein No. 3 partly fills a strong, sheared zone in which the massive andesite forming the country rock has been converted into a papery schist over a width of about 6 feet. The strike of the sheared zone varies from north 30 degrees east at one end of the exposure to north 60 degrees east at the other end, so that the fault probably belongs to the same set as the one just described. The dip is 55 degrees toward the northwest. The amount and direction of the movement were not determined, but striæ indicate it to have been vertical or nearly so. A dyke of porphyry 4 feet wide crosses the fault about 110 feet northeast of the 8-foot pit on this vein, and is not sheared or displaced, though somewhat jointed. The dyke is, therefore, of later age than the fault.

Between veins 2 and 3 a strong, sheared zone 2 to 3 feet wide strikes north 80 degrees west and dips about 75 degrees north. A dyke of porphyry follows it for some distance and is rendered highly schistose. The dyke was, therefore, intruded before the faulting.

On this property, therefore, there are two distinct sets of faults, one striking about north 40 degrees east, though varying somewhat from this, the other striking north 80 degrees west. The syenite porphyry was intruded between the two periods of faulting.

The veins are composed mainly of quartz and pyrites, like the Martin vein. There is no evidence as to their origin, except that they occur close to the dykes of syenite porphyry.

Arntfield and Francoeur Claims

The Arntfield claims were staked in October, 1923, by F. S. Arntfield. The group includes eleven full claims and some fractions, with a total area of 1,867 acres, lying in the northern part of the southwest quarter of Beauchastel township. The claims are numbered as follows: T 135, Block O (T 450), Block J (T 445), Block H (T 298), Block V (T 446), Block K (T 465), Block N (T 466), Block M (T 447), Block R (T 449 and 1163), Block P (T 448), and Block Q (T 559 and 1162). Most of the work has been concentrated on Blocks H and O, about a mile northeast of Renaud lake.

The property was optioned for development purposes to the Pioneer Syndicate, afterwards the Towagmac Exploration Company, in 1924. The latter also owned the Francoeur claim, Block 27 (T 134), which adjoins Block O (T 450) on the west. A number of promising bodies of ore were opened up by the surface exploration, and these were afterwards drilled to determine their downward extension. The drilling indicated that the values and widths of the surface ore-zones decrease downward, so that the Arntfield option was dropped in 1927.

The property was examined in 1925, before drilling had been commenced, and the following description was made at that time.

Veins of potential value found on the F. S. Arntfield and Joe Baker claims, Nos. T 298 and T 450, respectively, follow fairly closely a base-line that strikes about north 80 degrees west. The Francoeur claim adjoins the Joe Baker claim on the west, and the ore-body on it lies on the westward projection of the same base-line. It is not yet known whether this line follows the general strike of a fracture zone filled with a vein or series of veins, or whether, as seems more probable, the veins are a series of lenses striking about east and west, and chancing to be crossed by this base-line.

The country rock of the claims is mainly Keewatin lava of about the composition of trachyte, but varying slightly to more basic and more siliceous varieties. Near the east side of claim T 298 and some 300 feet south of the base-line, there is also exposed a thick bed of coarse rhyolite breccia or agglomerate. The strike of the flows is nearly due east and west, the dip steeply northward, and the upper surfaces of the flows face toward the south. A few small dykes of syenite porphyry and of gabbro cut the flows, usually nearly parallel to their strike.

All the ore-bodies are replacements of the country rock by quartz, carbonates, and other minerals. Replacement seems to have occurred mainly at the flow contacts; perhaps because the upper surface of a flow is more readily replaced than any other part by reason of its fine-grained texture, or perhaps because the slipping of one flow on another during folding created a zone of fracture or shear through which solutions flowed readily. Whatever the reason, these contacts appear favourable to the localization of replacement ore-bodies, and consequently the dip and strike of the ore-bodies are controlled by the structure of the flows, and are parallel to it.

Three bodies of ore have been found, one at the east side of the F. S. Arntfield claim, T 298, one at the west side and extending across the line into the Joe Baker claim, and a third on the Francoeur claim near the east side. All these bodies, as previously mentioned, are close to a base-line run north 79° 55′ west from the east line of T 298 from a point 150 feet south of post No. 1.

The easternmost ore-body has been traced for some 300 feet by trenching the north slope of a low rocky hill. The drift is up to 6 feet in depth, and becomes deeper to the east and west, so that the vein has not been traced farther. The best exposures are in trenches 750 to 800 feet along the base-line from the east boundary of the claim. Here the exposed width of the ore-body is nearly 30 feet, and the north contact is still hidden beneath drift. The ore is a very fine-grained, light grey rock liberally sprinkled with very fine-grained pyrite, and weathering reddish brown. This material, which is much altered country rock, is traversed by ill-defined and discontinuous bands of lighter grey or white material, which appear to be vein material. The microscope shows that they consist largely of calcite, with a little quartz, pyrite, and a few grains of clear, fresh albite. The least replaced material between the veins is largely sericite with greatly altered fragments of the original feldspar of the rock, albite or oligoclase albite; in other parts of the thin sections the replacement of this sericite-albite mixture by the carbonate and pyrite of the veinlets may be observed in all its stages. The average tenor of the replacement ore on the surface is $7 a ton in gold.

There are two rather interesting occurrences near this ore-body which, although not of economic importance, appear to throw some light on the origin of the ore-bodies. About 115 feet south of the vein a dyke of feldspar porphyry, 4 feet wide, runs east and west, and dips about 70 degrees north. It has been traced in the trenches for a distance of 250 feet. The porphyry is a coarse-grained, reddish rock, composed of stout crystals of albite up to an inch in length in a finer-grained albite groundmass. It is cut by numerous veins of quartz up to a foot in width, very irregular in shape, and running across it at various angles. Particularly interesting is the fact that the veins are practically confined to the dyke; only two or three were observed to cut across the contact and extend into the wall-rock, and those that do so continue only for short distances, a few inches or a foot or two, before ending. The vein material, though largely quartz, also includes some ferruginous carbonate and some coarse pyrite. A sample of the pyrite, freed as well as possible from quartz, assayed $10.60 in gold a ton.

The porphyry is partly altered to carbonate, a thin section showing the presence of 25 to 30 per cent of that mineral. The wall-rock on each side of the dyke for distances of more than 20 feet is similarly altered, and converted into a fine-grained, reddish rock very like the material of the ore-body, but more thinly sprinkled with pyrite. Under the microscope the replacement is seen to be like that of the ore-body, but less complete; the feldspar-sericite mixture composing the country rock is only about one-third replaced by carbonate, and there is no albite in the veinlets as there is in the ore-body. Assays of the altered rock on each side of the dyke yield gold values of 40 cents to $2 a ton.

Between the dyke and the ore-body, about 8 feet south of the latter, there is a vein of white, glassy quartz, ferruginous carbonate, and pyrite, identical in appearance with the veins in the porphyry dyke. The vein is about a foot wide, strikes north 65 degrees west, and dips almost vertically. The country rock on each side is altered to carbonate like that on each side of the porphyry dyke, and, like it, carries low values in gold.

Some 800 feet farther west, or 1,500 feet from the east boundary of the claim, measured along the base-line, another small porphyry dyke is found. It lies 75 feet north of the base-line, strikes due east and west, and has been traced nearly 300 feet by trenching. This dyke is not cut by quartz veins, but is bordered by bands of partly carbonated rock. These are only 3 or 4 feet wide, however, instead of 20 to 25 feet.

These observations, therefore, bring out a very suggestive group of facts: (1) The ore consists of the country rock largely altered to carbonate and fine-grained pyrite, and the veinlets causing the alteration contain albite as well as quartz and calcite. The presence of the albite and the completeness of the alteration of the country rock indicate that the vein-forming solutions were hot. (2) A similar alteration, but one much less complete and accompanied by much less deposition of pyrite and gold has been caused by veins of quartz and iron carbonate, without albite. The lack of albite and the decreased intensity of alteration point to solutions like those forming the ore, but cooler. (3) The occurrence of the quartz veins in the porphyry dyke shows that the veins and alterations are younger than the porphyry intrusion. (4) The presence of the altered bands on each side of the porphyry dykes suggests some connexion between the porphyry and the alteration. It may be that the alteration was caused by solutions given off by the dykes on cooling, but the small size of the dykes coupled with the large quantity of altered rock is against this conclusion. It is difficult to conceive that so small a volume of normal igneous rock could have held in solution the large amounts of carbonate and, presumably, water necessary to complete this alteration. Also, other quite similar porphyry dykes in the neighbourhood are not bounded with bands of altered rock. It is probable, therefore, that these particular dykes were injected into some zone, such as the belt of schist between two flows, through which ore-bearing solutions could also penetrate; so that the altered zones are not associated with the dykes because the dykes cause alteration, but because both alteration and dyke intrusion were conditioned and localized by a common cause.

The whole association is very similar to that observed at Matachewan,[1] although the sequence of events is not so completely displayed as at Matachewan. In both places the country rocks have been replaced very largely by calcite and mineralized with fine-grained auriferous pyrite. In both places the most extreme alteration and highest mineralization are caused by pegmatite veins, made up of quartz and albite as well as calcite. In both places cooler solutions emanating from quartz veins without albite have caused alteration to carbonate with little mineralization.

It was definitely proved that the ore-bodies at Matachewan were deposited from solutions that emanated from a large body of syenite porphyry during its cooling. No such proof of the origin of the Arntfield ore-body has yet been worked out. However, the presence of a very large body of syenite porphyry only a mile northwest of the Arntfield, and the likeness of the Arntfield occurrence to that at Matachewan, suggest rather strongly that these ores likewise originated from the porphyry.

The second ore-body is at the west end of the F. S. Arntfield claim, T 298, extending west into the Joe Baker claim. It has been traced for some 400 feet, and runs into low ground at both ends. The known eastern extremity of this body is 200 feet south of the base-line and 3,000 feet from the eastern side of the claim. The stretch of swamp east of it is 850 feet wide, and in a trench just beyond the swamp, or 2,150 feet from the east side of the claim, there have been discovered some bands of similarly altered rock that may possibly represent the eastern end of the ore-body. The ore-body has a maximum width of more than 50 feet 3,000 feet from the east end of the base-line, and narrows on the west to 6 or 7 feet. In the wide part the tenor averages $8 a ton in gold, throughout an 8-foot section.

The third ore-body lies near the east side of the Francoeur claim. It crosses the base-line about 4,300 feet from its eastern end, and has been traced west about 250 feet. Like the others it has the shape of a lens, 22 feet across at the widest part. The gold values vary from $7 to $9 a ton.

The second and third ore-bodies are so similar in their essential features that they can be described together. Like the first they are replacements of the country rock, but unlike the first the prevailing colour of the ore is red, though grey phases also occur. In fact the ore both in hand specimen and under the microscope is closely similar to the ore found in the Crown Reserve and Associated Goldfields mines at Larder Lake.

[1] Cooke, H. C.: "Geology of Matachewan District, Northern Ontario"; Geol. Surv., Canada, Mem. 115, pp. 49-56 (1919).

The country rock is a trachyte composed where freshest of phenocrysts of albite-oligoclase ($Ab_{90}An_{10}$) up to 1·3 mm. in length, embedded in a finer-grained matrix of the same mineral. Somewhat more basic varieties carry 3 or 4 per cent of chlorite, probably secondary after hornblende, and 2 or 3 per cent of fine-grained ilmenite. Types as fresh as this are rare, however, and are found only where the fine-grained upper parts of flows have been preserved unsheared. Almost everywhere the feldspar of the lavas has been largely replaced by secondary mica which forms half or even more than half of a thin section.

Around the edges of the ore-bodies the course of alteration and ore deposition can be readily observed. The trachyte altered to secondary mica as above is sliced by numerous small joints, most of which run east and west parallel to the main trend, and the remainder ramify in every other direction. Through these fissures the ore-bearing solutions evidently travelled, depositing minerals in them and altering the country rock on each side. As a result the grey country rock is now traversed by numerous, narrow, reddish bands, each with a hair-line veinlet at the centre. The individual bands average perhaps one-fortieth to one-eighth inch in width, and their colour fades rapidly at the irregularly-outlined edges into the colour of the country rock. Much wider bands are formed by the coalescence of two or more bands where they approach or cross one another. The ore-bodies are formed merely by the coalescence of a large number of such altered bands.

The composition of the central veinlets varies a good deal. Some consist almost wholly of fresh, clear albite, muscovite, much pyrite, and a little hematite and calcite; the rock on each side of these is intensely reddened, due to the presence of a very fine, reddish dust, too fine for microscopic determination, but which is probably hematite, judging from the colour and the presence in the vein and the rock of a few larger crystals that are undoubtedly hematite. In addition to the red mineral a little calcite and some pyrite have been introduced into the rock, but on the whole it is not highly altered. The composition of the feldspar of these veinlets varies from $Ab_{80}An_{20}$ to $Ab_{90}An_{10}$.

The veinlets described are found in the 2,160-foot trench (i.e. the trench opposite a point on the base-line 2,160 feet from the east end) and of all the veinlets examined most nearly approach the composition of igneous rock. Among the thousands of other veinlets all gradations of composition may be found from that described to almost pure calcite. In general, however, they may be subdivided into three other main types, those containing no mica, but some albite accompanied by quartz and calcite; those containing quartz and calcite, but neither mica nor albite; and those containing calcite, with or without a little quartz.

The veins composed of albite, quartz, and calcite commonly also carry auriferous pyrite in considerable quantity and redden the rock on each side of the vein. In the altered and reddened band no chlorite is to be found, although much may be present in the adjacent unaltered lava, and iron has also been abstracted from the ilmenite crystals, leaving them represented by whitish patches of leucoxene. The sericite and albite of the rock are little affected if at all. Some calcite and pyrite, commonly not more than 3 or 4 per cent, have been introduced. Beyond the removal of the iron and the consequent change in colour, therefore, the rock has not been greatly altered in composition.

The veinlets carrying quartz and calcite in approximately equal proportions appear to have exercised the most powerful alterative effects. They have commonly reddened the wall-rocks on each side. Like the last, they removed chlorite and the iron of the ilmenite, and in addition attacked the sericite or paragonite, completely removing it in the neighbourhood of the veinlets. The veinlets carry a good deal of pyrite, and a considerable amount of the same mineral is introduced into the altered country rock. The further alteration of the country rock varies a good deal from place to place. In some instances the feldspar is either unchanged or is partly recrystallized; in others it is largely or wholly replaced by quartz, calcite, or a mixture of the two.

The fourth class of veinlets, those composed largely of calcite with or without a few grains of quartz, carry very little pyrite and have had practically no effect on the surrounding rock. Veinlets running about at right angles to the general trend were traced from the ore-body several feet out into the country rock. Close to the ore-body they had the quartz-calcite composition of the veins of the third class, and altered the wall-rocks accordingly; farther away the composition gradually changed to the calcite composition of the fourth class of veins, the alteration of the wall-rock gradually decreasing to zero accordingly. The calcite veins are, therefore, evidently deposited from the residues of the solutions that formed the quartz-calcite veins, and represent a later, lower temperature type of deposit.

The composition of the veins found in these ore deposits, therefore, indicates that the solutions depositing them varied from very hot and concentrated, almost igneous, in character, to cool and dilute. The veins might be arranged according to composition in a continuous series, each member of the series differing only slightly from the next. There can be little doubt, therefore, that they all have a common origin, and that the differences in composition are to be ascribed wholly to temperature differences. The presence at one end of the series of such minerals as hematite, albite, and mica is good evidence that the solutions were of juvenile origin. There are no facts definitely connecting them with any igneous mass in the vicinity, although the probability is that they arose from the mass of syenite porphyry to the north.

Huronian Belt Mining Company Claims

In 1925 the Huronian Belt Mining Company did considerable work on claims Nos. T 412-415, with some intervening fractions, lying close to the east boundary of Beauchastel township, west of Pelletier creek; the discoveries were examined at that time. Work on the property was discontinued a few months later.

The principal gold discovery lies in the southeast corner of claim No. T 412. It is a lenticular body striking north 80 degrees west and dipping about 60 degrees north. It has a maximum width of about 8 feet, and up to about the end of August, 1925, had been traced for some 350 feet without finding the east end. The work done at that time consisted of a number of cross-trenches and shallow pits, with one inclined shaft 29 feet deep. A 5-foot channel sample across the ore-body in this shaft assayed $15 a ton in gold.

The country rock consists of thin-bedded, fine-grained, altered tuffs interbanded with one or more thin flows of dacite lava. The latter is distinguished in places by a variolitic texture. The tuffs are made up of chlorite, leucoxene, calcite, sericite, and a little quartz, together with the remains of the original feldspar, oligoclase ($Ab_{80}An_{20}$), which has been partly replaced by the calcite and sericite. The proportions of these minerals vary from bed to bed. The dacite consists of a few phenocrysts of quartz and oligoclase embedded in a flow-textured matrix of feldspar with a little chlorite, sericite, and leucoxene.

The ore, as on the Arntfield claims, is formed by the replacement of the country rock. The latter is cut by small veins and veinlets, on each side of which the rock is bleached and partly altered. The veinlets vary in composition much like those described on the Arntfield. One of the most pegmatitic consists of oligoclase, $Ab_{80}An_{20}$, and calcite in approximately equal proportions, with a little chlorite probably secondary after hornblende and a little garnet. Others are made up of quartz and calcite in about equal proportions, with or without a little feldspar, and there are many made up mainly of quartz with some ferruginous carbonate and a little hornblende, now altered to chlorite. All of these veins carry some pyrite. The country rock has not been as intensely altered as on the Arntfield property. Its chlorite is largely removed, and in places the sericite, also, and accompanying these changes there seems to have been some recrystallization of the feldspar into fresher, somewhat larger individuals. A certain amount of calcite and pyrite have been introduced, but on the whole not a large amount. The sum of these changes has been to produce a rock somewhat lighter in colour than the country rock, and one rather liberally besprinkled with auriferous pyrite, but whose original composition is by no means utterly destroyed.

No evidence was obtained to suggest the possible origin of this ore-body. On the Bathurst claims a mile or two to the southeast, however, there are some masses of syenite porphyry from which ore-bearing solutions of this type might be expected to come.

J. C. MacCormack Claims

The claims prospected by J. C. MacCormack include lots 13 to 20, range I, and lots 20 to 26, range II, Manneville township. The claims thus border Kinojevis river above and below Cascade rapids. The camp buildings are on the north side of the river above the rapids, near the east side of lot 23, range II.

The property was examined in 1923, and again in 1924. Little has been done in the way of development since that time, so far as can be learned.

The rocks are of three types. The oldest are the Keewatin series of lavas, including both basic and acid types. The acid types predominate, particularly in the area north of the river where there are striking outcrops of light-coloured lavas, originally about the composition of trachyte. The upper parts of the flows are filled with rounded nodules, some several feet in length, though mostly only a few inches, of light-coloured cherty material, made up of very fine-grained quartz and albite in about equal proportions. Several good structure determinations were obtained on the lavas; strikes vary from north 55 degrees west to north 80 degrees west, and dips from vertical to 70 degrees north. The upper sides of the flows invariably face toward the south.

On the south side of the river, below Cascade rapid, a dyke or sill of altered basic diorite or gabbro, 120 feet wide, intrudes the lavas parallel to their strike. It has been intruded between a flow of brecciated cherty trachyte and one of pillowed andesite. The dyke is quite basic, and is characterized by the bunching together of the hornblende or augite crystals. They weather out on the surface in knots as big as peas, giving the rock a warty appearance.

On the north side of the river, there is a strong ridge of ferruginous dolomite, like that found at Larder lake. The ridge is some 400 feet wide, and may be traced westward as far as Kinojevis river below Cascade rapid, where it disappears beneath the stream. A small outcrop is visible in the river at low water about a quarter mile below.

The dolomite is entirely similar to the Larder Lake dolomite. Like it, the ridge contains large "horses" of partly carbonated country rock (in this instance trachyte), that grade on the outside into the pure "dolomite." Like it, there is strongly sheared country rock everywhere along the sides of the ridge, suggesting that the dolomitic alteration was localized along a belt of strong faulting. Like it, the "dolomite" is mainly an iron-magnesium-lime carbonate, coloured green in places by small flakes of chrome mica, or fuchsite, and cut by numerous, irregular veinlets of free quartz. Like it, too, the quartz-dolomite mixture carries small quantities of pyrite and small values in free gold. Assays of grab samples show values varying from 50 cents to $1.50 a ton.

The dolomite is cut by some small dykes of diabase, now completely altered to secondary minerals, and about 400 feet east of the line between lots 23 and 24 there is, also, within the dolomite mass, what appears to be a body of feldspar porphyry. It may be a dyke striking north 80 degrees east, but is so badly altered to carbonate that the boundaries are extremely hard to define, and even its identity is a matter of doubt. It is flanked by quartz veins of unusual size, the one on the south side 12 to 15 feet wide, that on the north, 4 to 6 feet.

Prospecting was being carried on in three places in 1923, on the dolomite, about a quarter mile north of the dolomite, and on the south side of the river about a half mile below the rapids. Operations had been confined to stripping and test-pitting.

The operations north of the dolomite are in lot 22, about 4,300 feet north of the river, where three rather thin lava flows grade from massive bases into flow-textured tops. The flow-textured upper parts have been somewhat sheared, and vein materials have been introduced along the planes of shear, forming nodular veinlets. Quartz, calcite, pyrite, and pyrrhotite are the principal vein constituents. The proportion of pyrrhotite is large, and this mineral in places forms lenses 1 to 2 feet in length. Gold values are said to be about $3 a ton in the better samples, and there is also a few cents worth of silver and copper present.

Prospecting south of the river below Cascade rapid has been concentrated on deposits of very similar character. In places along the contact of the previously described diorite dyke, the lavas have been highly mineralized with pyrrhotite and pyrite. Mineralization is not continuous, but is confined to small areas 20 to 40 feet in length along the strike, and up to 25 feet in width from the diorite contact. The heavy mineralizations seem also to occur on the north side of the dyke only. On the south side some mineralization was observed in two or three places, but extending only 4 to 6 inches from the contact.

Somewhat farther west, on the brow of a prominent bluff overlooking the river, there are a number of sheared zones striking north 80 degrees east and dipping about 80 degrees north. They are evidently produced by faulting, but the direction and amount of movement were not determined. They are probably parts of a single distributive fault, as there appears to be one main shear, and others branch from it. The sheared material is mineralized with pyrrhotite and some pyrite, over an average width of 1 to 3 feet, although wider places occur. One lens about 30 feet in length and 10 feet in maximum width was observed. In places lenses of pure sulphide 2 or 3 feet wide have been found. Values are reported to be about $3 a ton in gold.

Malartic Gold Mines

Malartic Gold Mines, Limited, owns five claims, covering about 480 acres, in the north-central part of Fournière township. The claims are numbered M.L. 2128, 2129, 2130, 2132, 2134. Most of the development has been concentrated on M.L. 2129 and 2132.

The property was staked in 1923 by St. Barbe Sladen, H. S. Kennedy, and J. C. Carrol, acting for an Ottawa syndicate, but no important development work was done until the spring of 1926. Late in that year the claims were optioned to the Porcupine Goldfields Development and Finance Company, who carried on work until June, 1925. Some months later the property was sold to Malartic Gold Mines, Limited, by whom development has been continued until late in 1929. A shaft has been sunk to a depth of 375 feet, with levels at 130, 250, and 375-foot depths; and much diamond drilling has also been done. Work has since been discontinued.

A detailed geological examination of the property, for the company, was made in 1928 by W. F. James and J. E. Gill, and the company has very kindly given permission for the data then obtained to be published in this report. The following description, therefore, presents, in a summarized form, the facts as learned in this detailed examination.

The rocks on the property are the Timiskaming greywackes, cut by dykes and irregular masses of acid and basic intrusives. The greywackes are light to dark grey, commonly rather thin-bedded, although coarse-grained beds may attain thicknesses of 6 inches or more. Certain of the more argillaceous beds are extremely thin, scarcely thicker than a sheet of paper. It is common to find a series of beds of more or less the same composition forming a band, the composition of which may be noticeably different from that of an adjoining band. This banding is quite a prominent feature. Bedding is most easily observable on the surface, where weathering has emphasized slight differences in the colour and

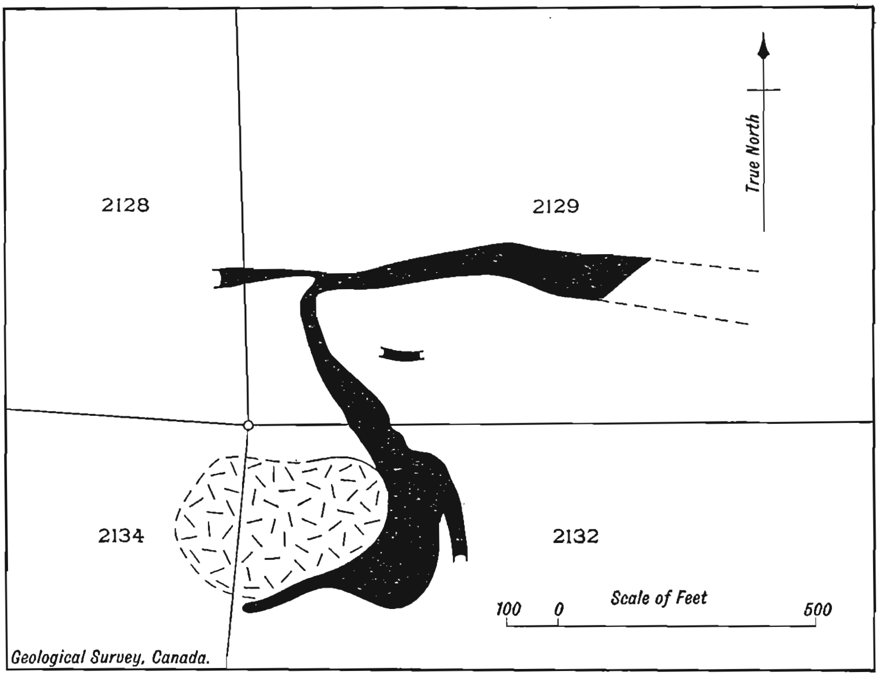


Figure 25. Plan of ore-body, Malartic mine, Fournière township, Quebec. Auriferous silicified greywacke shown by solid black; porphyritic syenite shown by irregular line pattern.

texture of individual beds. On fresh surfaces, and in the mine workings, bedding is usually distinguishable only with difficulty. The greywackes are now completely recrystallized, and are composed mainly of quartz and biotite, with some chlorite, sericite, and feldspar. The mica flakes are commonly parallel to one another and to the bedding, giving the rock a noticeable, but poorly developed, schistosity.

The local structure of the greywackes has not been thoroughly worked out, owing to scarcity of surface exposures and difficulty of determining bedding in the mine workings. Over most of the claims the beds maintain the regional strike, north 60 to 70 degrees west, with steep to vertical dip. There is some evidence, however, that near the ore-bodies the beds have been drag-folded throughout an area about 800 feet wide, so as to make those within the drag-fold strike north to slightly west of north. The drag has been caused by the tendency of the beds on the north to move west, relative to those to the south.

The greywackes are intruded by a number of dykes of amphibolite, varying in thickness from a few inches to a few feet. Two varieties are found. The older have been rendered schistose, along with the sediments, and are now biotite-hornblende schists. The younger are rather coarse-grained rocks, made up mainly of hornblende, with a little feldspar. Both are believed to be older than the acid intrusives next described.

Small bodies of porphyritic syenite, locally termed porphyry, form the principal igneous masses. They are probably marginal varieties of the large granite batholith to the south. There are at least four bodies more than 100 feet in diameter on the property, and many dykes or sills of smaller size. They are pink or grey rocks, commonly somewhat porphyritic, composed of small feldspar phenocrysts embedded in a groundmass of medium grain. The feldspar phenocrysts include both orthoclase and albite. The groundmass is made up of the same feldspars, quartz, and a little biotite or hornblende. In places the amount of quartz is so large that the rock becomes a porphyritic granite.

In addition to the porphyritic syenites, there are a few dykes so fine-grained that they might be termed rhyolite porphyries. They are never more than a few feet in width. They vary in colour from pink to dark grey, and contain a few very small feldspar phenocrysts in a dense, very fine-grained groundmass of feldspar and a large proportion of quartz. Their relations to the syenite porphyries have not been determined.

The ore zones are of the replacement type, formed by alteration of the greywackes and, also, to a small extent, of the porphyries. Where alteration has been extreme, these rocks are converted into masses of almost pure quartz, usually fine grained but in places sugary; the quartz is sprinkled with fine-grained auriferous pyrite and carries native gold.

Every gradation exists between the pure quartz rock and unaltered greywacke or porphyry. In places the change is very gradual, in others fairly rapid. It is common also to find without apparent cause considerable variability in the degree of silicification. Thus in drift 104 of the mine workings there are patches of highly silicified greywacke in the midst of greywacke scarcely silicified at all. In some places it can be shown that silicification has either stopped or changed markedly in degree at a slickensided slip plane, which apparently acted as a dam to the silicifying solutions, but in most places the reasons for the differences in degree of alteration have not been determined.

The proportion of pyrite has no uniform relation to the degree of silicification. In places the highly silicified rock contains much pyrite, in others little; and there are certain places where greywacke that is only slightly silicified carries considerable quantities of pyrite. The proportion of pyrite is not an index of the gold content. High gold values may occur where pyrite is inconspicuous, and low gold values where it is abundant.

Gold values are likewise rather variable, and not proportioned to the degree of silicification entirely. It is unusual to find high gold values without moderate to high silicification, but high silicification may occur without high gold values.

The main ore-body is an S-shaped mass (Figure 25). The north limb of the S is locally referred to as zone 1, the south limb as zone 3, and the intermediate part as zone 2. Zone 1 strikes east, dips vertically, and varies in width from a few feet to 100 feet. It has been traced for 800 feet along the strike, and to a depth of 400 feet. The north boundary of the zone is sharply defined by a dyke of porphyritic syenite, but there is no sharp boundary on the south, and the silicification dies out gradually in that direction. The presence of the dyke thus seems to have been a determining factor in the location of the ore zone. In many places the dyke itself has been partly or almost completely silicified. Gold values throughout this zone average, on the first and second levels, about $3.50 a ton, but sections or "shoots" of higher grade, up to $8 a ton, are found.

Zone 2 strikes about northwest, dips 67 degrees northeast, and is about 600 feet long. It varies from 25 to 140 feet in width. The greatest width is at the eastern end of a lenticular body of porphyritic syenite. In depth the dip of the porphyry contact changes from steeply east to west, at a low angle, as if the bottom of the porphyry body were near; and the silicified zone follows the porphyry contact, suggesting a close genetic relationship between the two. The nature and values of zone 2 are much the same as in zone 1.

Zone 3 has not been explored to any great extent as yet, except at the surface. It joins zone 2 at the end of the porphyry body, where it is 140 feet wide, and narrows rather rapidly toward the southwest. The last outcrops obtained, on the southwest, show a narrow, ill-defined zone of silicification which appears to be dying out.

An irregular, vein-like body, zone 4, lies in the area between zones 1 and 2. It furnishes much the highest-grade ore on the property, as yet. It appears to consist of a central vein of quartz, very irregular both in strike and dip, on each side of which the wall-rock has been silicified and pyritized. The vein has been explored by drifting for a length of about 150 feet. The average grade, over a 4-foot width, apears to be about $13, and widths of 3 to 5 feet averaging $20 a ton are not uncommon. Small amounts of chalcopyrite and galena, and possibly some gold telluride, occur in this vein, in addition to the usual pyrite and free gold.

Two sets of later veinlets cut the ore-bodies. The earlier, which vary from a fraction of an inch to 8 inches in thickness, consist of coarse, glassy, or milky quartz, with small amounts of feldspar, mica, tourmaline, galena, chalcopyrite, sphalerite, and native gold. In places, replacement of these earlier minerals by brown or pinkish carbonate is conspicuous. The presence of the feldspar and mica indicates that these veinlets are pegmatitic in origin. The veinlets of the second set are composed of white or pinkish calcite. They are narrow and discontinuous, and evidently fill small slip planes, as the pegmatitic quartz veins are offset in many places where crossed by the calcite veinlets.

The time when the ore-bodies were formed is thus fixed between the time of intrusion of the porphyritic syenites and that of the pegmatitic quartz veins. As the porphyritic syenites are probably an early phase of the great granite intrusions, and the pegmatitic quartz veins are almost the latest phase, it would seem likely that the ore deposits themselves are connected genetically with the granite intrusion.

Gouldie Claims

The Gouldie claims are in the north-central part of Fournière township, and adjoin the Malartic claims on the south. The property comprises four claims, Nos. 2115-8, of about 200 acres each. Most of the development has been concentrated on claim 2116. The claims were first staked in 1924 or late in 1923, and some rather spectacular gold discoveries were made on them during the early development. Unfortunately, later exploration indicates that the ore-bodies are too small to be profitably worked. The property has been extensively trenched, more than 3,000 feet of diamond drilling has been done, and a shaft 60 feet deep has been sunk.

The rocks and alterations are identical with those on the Malartic claims to the north. Near the south boundary of claim 2116 there is a body of porphyritic syenite 800 feet long, 400 feet wide, and elliptical in outcrop. Toward the east end of the ellipse the Timiskaming greywackes are highly silicified, the silicified material has been fractured, and considerable free gold is found in the fractures. From this point a " vein " runs eastward, and was traced by trenching for about 1,900 feet. The " vein " consists of a series of quartz stringers in the greywacke, over a maximum width of 30 feet; it is well mineralized with pyrite. Small amounts of free gold were found in it for about 120 feet east of the porphyry, but for the most part the tenor is low.

A second area of mineralization was found about 1,200 feet north of the first, where a number of dykes and small masses of porphyritic syenite are found, and the greywacke is more or less silicified and mineralized. Only low values were obtained.

Mine d'Or Abitibi

The property locally known as Mine d'Or Abitibi was held, when examined in 1926, in the name of Sinai Rousseau. It lies in the southern parts of lots 8 and 9, range IV, Landrienne township, just to the north of a road from Landrienne which runs along the line between ranges III and IV. The exposures consist of a series of whale-backed outcrops mostly on lot 9, within an area 400 feet by 500 feet. Much of the rock surface has been exposed by a fire that removed the vegetation almost completely. A small amount of stripping had been done, and a shallow test-pit sunk on the northern margin of the largest outcrop.

The rocks are volcanic flows, mainly andesites, slightly sheared in a direction north 80 degrees east with a dip of 60 degrees north. The flows have been much altered to carbonate along two zones which likewise strike north 80 degrees east. The northern zone is at least 40 feet wide, and may be wider as it runs down into drift on the north. The southern zone is 300 feet wide, and is separated from the northern by 50 feet of normal andesite.

The chief area of mineralization is the northern part of the 300-foot zone, exposed for about 350 feet east to west and 80 feet from north to south. It is cut by three sets of veins. The veins of the principal system vary in width from 2 to 5 inches, strike north 87 degrees east, and dip about 70 degrees north. They are regular, though slightly sinuous. A second system consists of contorted veins ½ to 12 inches wide which strike north 37 degrees west and dip 65 degrees east. A third system similar in width is composed of slightly sinuous veins that strike north 67 degrees east and dip 75 degrees north. In addition there is a large number of irregular stringers. The carbonated zone on the whole consists of from 7 per cent to 15 per cent of vein matter. All the veins are considered to be of practically the same age, though the contorted system designated as the second is cut by the other two systems and is, therefore, at least slightly older.

This older vein system carries about 2 per cent of tourmaline in aggregates of needle-like crystals. Chlorite masses, a few inches in diameter, form 20 per cent to 30 per cent of the vein matter and reddish carbonates, in small masses, about 6 per cent. Pyrite and chalcopyrite, in the proportion of 2 to 1, form about 1 per cent. The pyrite is in compact masses and the chalcopyrite in small, dendritic masses. Quartz is the other vein mineral.

In the other two vein systems mineralization is similar, except that chlorite and tourmaline are present in much smaller quantities, the chalcopyrite is in more rounded masses, and pyrite is scanty. Here again the sulphides form about 1 per cent of the vein material. The carbonated wall-rock in the vicinity of all the veins is mineralized with cubes of pyrite to about 5 per cent of its volume. Pyrite throughout the carbonated areas forms up to 2 per cent of the rock.

No values have yet been reported from the deposit. The mineralization is heavy and should the sulphides carry any considerable amount of gold the outlook for the property is good, since the extent of the mineralized area is large. No intrusive was noted close to the mineralized area, but the character of the mineralization suggests that an intrusive, probably acid in composition, cuts these older rocks but is hidden by the drift.

Lot 35, Range II, Landrienne Township

In the northern part of range II, Landrienne township, in lots 32 to 35, a large outcrop rises 50 feet above the surrounding swamp and sand-plains. It is roughly circular, about half a mile in diameter, and it is composed of rhyolite and quartz porphyry flows that apparently strike north 50 degrees west and dip steeply north. The outcrop near its northern boundary is sheared in a direction north 70 degrees west, with a dip, 40 degrees north.

Four mineralized zones were seen in the northern part of the outcrop on lot 35. They follow the strike of the shearing and from north to south are 20 feet, 5 feet, 20 feet, and 40 feet, wide, respectively. The length of the zones is unknown, but is more than 200 feet. The country rock is sheared rhyolite. The shear zones contain little or no quartz in veins, but the rock is heavily mineralized with fine-grained pyrite. A few glassy quartz stringers were seen in the southern part of the outcrop. No acid intrusives were seen in the immediate vicinity, though it may well be that such an intrusive is present nearby under the extensive drift cover, and has produced the mineralization. The large granitic intrusion of LaCorne is about 2 miles to the south. As in the case of the mineral deposit on lots 8, 9, range IV, Landrienne township, if gold values are associated in quantity with the sulphides, mineralization is sufficiently heavy to indicate a workable deposit.

Fisher Quebec Gold Mines, Limited

The claims of Fisher Quebec Gold Mines, Limited, are located in the townships of Landrienne and Barraute. The following are the lots held in September, 1926:

Lot 54, range III, Landrienne tp., eastward to lot 9, Barraute tp.
Lot 48, range IV, Landrienne tp., eastward to lot 12, Barraute tp.
Lot 48, range V, Landrienne tp., eastward to lot 6, Barraute tp.
Lot 56, range VI, Landrienne tp., eastward to lot 2, Barraute tp.

The area held is thus 4 miles from north to south and at its greatest width about 4 miles from east to west. The geological examination here described was made during the summer of 1926.

Initial prospecting was begun in 1924 when large boulders of quartz carrying free gold were found on the property. Development work has been concentrated chiefly on lots 59 and 60, range V, Landrienne township, in an area about 1,000 feet square on the western edge of a ridge largely covered with moraine and rising some 40 feet above the muskeg country that borders it on the north and west. The rock composing this outcrop is an equigranular dacite with a grain of 1 mm. The constituent minerals are 60 per cent oligoclase, 20 per cent quartz, and the remainder granular epidote, chlorite, carbonate, and pyrite, with a concentric structure and containing numerous inclusions of the rock minerals. Towards the north of the outcrop is a small exposure, several feet wide, of an acid carbonated volcanic which microscopic examination determined to be a tuff. It is fine grained and very high in quartz which occurs as larger grains in a fine groundmass, principally quartz.

Two zones of carbonated rock appear in the workings. The northernmost occurs in the northeast corner of the rock area and has been exposed for a length of about 50 feet, but passes beneath the drift cover in both directions. It has an approximately east-west strike. To the south of it is a width of about 300 feet of dacite that is little or not at all carbonated. The larger carbonated zone occurs south of the dacite and is at least 500 feet wide at the eastern edge of the workings. Towards the west it narrows rapidly to about 100 feet. These zones trend roughly east and west and in them the rock, now about 70 per cent carbonate with quartz, epidote, and pyrite grains, was evidently a dacite in which carbonate has completely replaced the feldspar.

Within the larger carbonated mass are a number of shear zones with an east-west strike and a steep dip. They seem to be intensely sheared sections of larger zones that cannot be traced continuously across the property. The largest shear zone in the vicinity of the shaft is about 8 feet wide and within it are lenses and irregular bodies of quartz up to several feet wide and a few feet long connected by narrow stringers of quartz. The quartz carries large masses of chalcopyrite associated with pyrite. Carbonate is also a gangue mineral. The rock is intensely sheared near the edges of the quartz-bearing zone and east of it along its strike. The schist is said to carry good values in gold. Four other shear zones, narrower but similar in character, were noted in the altered dacite.

In a few instances, flat-lying quartz veins, 3 inches to 12 inches wide, were noted. In the southern part of the rock area, in a rock cut, a vein forms a small saddle of which the north limb follows the schistosity and the south limb dips 35 degrees south and cuts the schistosity.

As on other claims in the neighbourhood, the mineralization is later than the shearing, but tends to follow the strike, though not the dip, of the planes of shearing. The operators report values up to $14.46 in gold a ton over 3 feet of mineralized schist near the shaft, and up to $29.75 over 3·6 feet of mineralized quartz. A $50 assay is reported from a picked sample of chalcopyrite in the shaft and $27.10 a ton over a width of 2·5 feet in the bottom of the shaft.

The most easterly workings of the syndicate are on lot 9, range III, Barraute township, just west of the Gillies workings and 1,000 feet south of the north boundary of the range. They consist of preliminary, irregular surface stripping and have disclosed areas of sheared carbonated greenstone.

About 300 feet west of the east boundary of the lot is a quartz vein, designated as No. 9, which for the most part strikes and dips with the schistosity of the rock (north 75 degrees west, dip 55 degrees north), though locally it is oblique to the shearing. It has been exposed over a length of 30 feet and has a width of 10 inches to 3 feet. The vein quartz is glassy white and carries some pyrite and tourmaline. The wall-rock is highly carbonated andesite, with some pyrite mineralization. Free gold has been found in the vein. Ten feet to the south is a nearly flat-lying vein 6 inches wide. It strikes approximately north-south and dips about 10 degrees west. The vein is of glassy white quartz containing tourmaline, pyrite, and chalcopyrite. The foot-wall is slightly sheared and contains about 20 per cent of pyrite in coarse cubes. Good assays are reported from samples taken over a width of 2 feet.

Trenching in the northern parts of lots 55 and 56, range IV, has disclosed a number of quartz veins and mineralized areas. The rocks are basic volcanics, pillowed, amygdaloidal, or massive, cut by basaltic dykes and later porphyry. The whole exposed area several hundred feet square is an area of shattering and mineralization. Shear zones and shattered zones are numerous, and adjacent to vein material the country rock has been greatly carbonated. The mineralization in these zones is presumably associated with the intrusive porphyry dykes, which are about parallel to the shearing and shattering that strike between 40 and 50 degrees south of east. The shape of the quartz masses corresponds to the shape of the shear or shatter zone in which they have been deposited. In one of the shear zones observed the vein varies in width from 3 inches to 16 inches and has fairly regular walls. Partings of tourmaline within the vein are parallel to the walls. In the same zone small, narrow stringers of quartz are parallel to the shearing. Several irregular quartz masses within shatter zones have been exposed by stripping and are from a few inches to 6 feet wide, though none has been traced for a length of more than 18 or 20 feet. A number of the masses are 3 to 4 feet wide. The quartz contains pyrite, some chalcopyrite and tourmaline, and iron-rich carbonate in good crystals. Carbonate has strongly impregnated the wall-rock near the quartz masses and has undoubtedly been an original constituent of the vein. It is reported that free gold has been found in some of these masses and that some good values have been shown by assays of the vein matter. One assay reported shows $10 a ton over a width of 3·5 feet of mineralized schist, and smaller values are said to occur in the quartz.

Continental Gold Mines

The claims of the Continental Gold Mines, Limited, are in Barraute township, range II. The lots on which the principal work has been done are numbers 8, 9, and 10. The country is quite low and the outcrops are low and flat, but over considerable areas the rock is covered by a relatively thin coating of drift. The area explored is about 1,500 feet square and sections between natural outcroppings have been exposed by a number of shallow trenches, aggregating more than 2,000 feet in length; most of the work has been concentrated on lot 9.

The country rock is chiefly volcanics, with some acid dykes of rhyolitic composition that may be associated with the porphyry intrusions that occur in the general district, and some basic, irregular dykes identical in composition and appearance with the andesite and basalt lava flows. In one locality adjacent to the largest vein the andesites are pillowed and associated with fragmental beds similar in mineral composition. The acid volcanics are rhyolitic, the bulk of them are acid porphyritic flows, but undoubtedly some of the more sheared and altered varieties are tuffaceous in origin.

The rocks are highly sheared in a general direction north 70 degrees west and dip 45 degrees north. About 80 per cent of the exposed rocks are carbonated, an alteration that has probably been contemporaneous with the injection of the quartz veins and other mineralization. The rhyolite seems to have been more extensively carbonated than the more basic volcanics. The intrusive acid dykes seem to have been little carbonated.

The veins are numerous, but most are small. The principal vein has been exposed for slightly more than 260 feet and strikes roughly north 70 degrees west and dips south across the dip of the shearing planes of the rocks, which have a parallel strike but a dip of about 35 degrees to the north. The vein is about 1 foot wide and at its western end forms a facing on the southern edge of the rock outcrop. It apears to have formed in a fault-plane parallel to the strike of the schist, but of opposite dip. A few cross stringers, 5 or 6 inches wide, extend from the vein into the country rock.

The vein material is glassy white quartz, containing tourmaline, a small amount of pyrite, and some chloritized greenstone fragments. Values up to $27.50 are reported from assays of grab samples of the vein material. The wall-rock near the vein is highly carbonated and is mineralized with pyrite, some of it in cubes one-quarter inch in diameter.

A short distance to the west is a 2-inch quartz-tourmaline vein that is almost flat and outcrops at intervals over an area of several hundred square feet. In the western trenches at least four veins are disclosed and range in width between 6 inches and 2 feet. These veins have been exposed only over short lengths, and from the work done, their full lengths have not been established. In addition there have been uncovered many small, narrow veins. Carbonate and sulphide mineralization on the walls of all these veins has been intense. High assays up to $127 have been reported from grab samples of vein matter and wall-rock taken at several points. Free gold is associated with some of the vein matter.

None of the veins so far examined appears to constitute a deposit of workable size, but the mineralization is promising.

La Mine d'Or Venus

The Foisie claim, now transferred to La Mine D'Or Venus, Ltée, consists of lots 13 and 14, range II, and lots 12, 13, 14, 15, in range I, Barraute township. The initial work on the property was begun early in the season of 1925.

The principal rock area lies about 1,000 feet south of the line between ranges II and III, on the northern edge of a ridge that is but thinly drift covered. The rocks are chiefly volcanics of medium to basic composition, in which some pillowing is developed. Shearing in a direction north 70 degrees west and dipping 60 degrees north has been impressed on the rocks that are locally carbonated. Some acid porphyritic rocks of doubtful origin occur within the greenstones, and are sheared to the same extent as the greenstones.

In all, seven veins were examined in the surface workings. The largest lies at the northern edge of the outcrop. It occurs in the form of a saddle with a strike of about north 70 degrees west, and pitching at about 15 degrees towards the east. The surface of the outcrop coincides practically with the top of the saddle, which has locally been truncated to show the north and south limbs with dip 45 degrees north and 45 degrees south, respectively. The thickness of the limbs is about 18 inches, but the crest in one place measures 4 feet. The vein has been exposed over a length of 60 feet to where, in the east, it pitches beneath the rock. The limbs diverge towards the west and their length has not been traced.

The vein is composed of glassy white quartz containing tourmaline, ferruginous carbonate, pyrite, and chalcopyrite. The pyrite occurs in cubes up to one inch in size. Free gold occurs in association with the tourmaline and carbonate. The gold is very pale in colour. The country rock in the vicinity of the vein is highly carbonated and is mineralized to a considerable distance with coarse cubes of pyrite. Small quartz veinlets cut the country rock and have selvages of almost pure carbonate. Assay values of vein or wall-rock have not been reported. The vein has been trenched to a depth of 6 or 8 feet.

South of the main vein a trench has been dug southward for about 500 feet. At 250 and 400 feet south of the main vein are two quartz veins striking with the shearing and dipping 45 degrees south, with widths of 3 and 6 inches respectively. Nearly 600 feet south of the main vein, two apparently intersecting veins occur. These have opposite dips and may be the limbs of a saddle vein similar to the main vein. The width of the veins is between 16 and 24 inches. Thirty feet farther south is another vein exposed for 60 feet. It is 14 inches thick at the western end, increasing to 3 feet in the central part, and pinching out toward the east. It strikes north 60 degrees west and dips 65 degrees south.

Three hundred and fifty feet south of the last-mentioned vein are two veins striking north 70 degrees west and dipping steeply to the south. Each has a maximum width of 8 to 10 inches and the more northerly vein is exposed over a length of 30 feet. The composition of these smaller veins is in general similar to that of the main vein to the north, except that in them the proportion of ferruginous carbonate is higher. Tourmaline forms heavy masses in the vein. The mineralization of the wall-rock is similar to that observed elsewhere and there seems no doubt that the alteration of the rock is due to the action of the vein solutions.

Though considerable free gold occurs in the veins, no systematic assays have been reported. Mineralization within and near the main vein is heavy and merits investigation as a possible ore-body of economic proportions. It is significant that the veins on this property dip across the schistosity as on other properties nearby. The presence of the saddle vein suggests that other similar veins may be encountered at depth. The saddles are due to the influence of the shearing in providing for the vein solutions, channels other than the south-dipping fissures in which the veins usually lie. A series of steep diamond-drill holes should yield considerable information concerning the nature of the mineralization of the veins at depth and would probably also indicate the presence of other veins which do not outcrop on the surface.

Gillies Claim

Work on a claim on lot 10, range III, Barraute township, is being carried on by the Gillies interests. Stripping and trenching amount to about 350 feet and the workings lie about 1,000 feet south of the northern boundary of lot 10. The workings at the time of examination were partly filled with water.

The country rock in the trenches is greenstone, most of which is sheared parallel to a plane striking north 75 degrees west and dipping 55 degrees north. Some of the andesite shows poorly developed pillows. The rock is considerably altered to carbonate and in the vicinity of quartz veins carries large cubes of pyrite. About 800 feet north of the workings near the cabin is an outcrop of a quartz porphyry strongly sheared and similar to many seen along the railway in the vicinity. The rock is probably of volcanic origin, though its relations have not been clearly determined.

Three veins were exposed in the workings. At the north end of the property is a flat-lying vein 4 inches thick, with a slight dip towards the west. Thirty feet south is a 3-inch vein striking east and west and containing free gold; farther south again is a third vein 10 inches thick. The vein material consists of quartz, glassy white to colourless, containing pyrite, chalcopyrite, tourmaline, carbonate, and inclusions of chloritized country rock. It is reported that samples showed some values.

CHAPTER XII

MOLYBDENUM DEPOSITS

INTRODUCTORY

In 1901 J. F. E. Johnston of the Geological Survey first reported the presence of molybdenite and bismuthinite in quartz veins on the shore of Indian peninsula in Kewagama lake. Since that time these minerals have been found in several places in Preissac township, and a number of attempts have been made to work the deposits. The discoveries have been described by T. L. Walker,[1] J. A. Bancroft,[2] and V. L. Eardley-Wilmot.[3] Walker and Bancroft visited the properties and described their personal observations; Wilmot's description summarizes these earlier descriptions and includes such additional material as he was able to obtain from property owners and other sources.

As most of the properties have been closed for many years no new examination of them was made by the writers other than a brief study of some of the principal occurrences; and no new information was added. As, however, both Bancroft's and Walker's reports are out of print it seems desirable to summarize the earlier observations so that they may be more readily available than at present.

Height of Land Mining Company

The property of the Height of Land Mining Company was first staked in 1906 by C. S. Richmond. It lies on the west bank of Kinojevis river, at the second rapid below Kewagama lake. This location is in Preissac township, about half a mile from the north boundary and 3½ miles from the west boundary.

The rocks consist of biotite schist with a general north-northeast strike, and dipping steeply west. These are cut by dykes of granite, pegmatite, and quartz, the offshoots of a granite batholith on the east side of the river. Near the river the dykes are so numerous that they predominate over the schist in volume. The general strike of the dykes is north-northeast, parallel to that of the schist, but they are very irregular. The granite dykes are cut by those of pegmatite, and the pegmatite dykes in turn by the quartz veins. All gradations in composition between the true granite and the quartz veins may be found.

Near the southern end of the area of biotite schist a vein of quartz 15 feet wide rises from the river, striking north-northeast and dipping 58 degrees east. The vein is bordered by an irregular selvage of muscovite

[1] Walker, T. L.: "Molybdenum Ores in Canada"; Mines Branch Pub. No. 93, 1911.
[2] Bancroft, J. A.: "Mining Operations in the Province of Quebec for 1911"; pp. 186-201.
[3] Sardley-Wilmot, V. L.: "Molybdenum"; Mines Branch Pub. No. 592, 1925.

up to several inches in thickness, which contains large crystals of molybdenite. Some molybdenite is also scattered irregularly through the quartz of the vein, associated with bismuthinite. It is said that at low water a good showing of molybdenite is visible at the river's edge.

To test the vein further, a shaft 74 feet deep was sunk close to the river bank, and drifts run from it in opposite directions. One was driven for 60 feet at south 60 degrees east, the other for 27 feet at north 60 degrees west, in other words, nearly at right angles to the general strike of the schists. These drifts were examined by Bancroft, who gives the following section from west to east.

Face of western drift in biotite schist; then 7·5 feet of granite; then 4·5 feet of biotite schist; pegmatite dyke 2·5 feet wide, carrying a few flakes of molybdenite and bismuthinite; 16 feet of granite, cut by a 7-inch vein of quartz; 3 feet of pegmatite, carrying a few large crystals of molybdenite and a little bismuthinite, and some crystals of beryl; 16 feet of biotite schist; 17 feet of quartz carrying a little bismuthinite and molybdenite, with some beryl; 20·5 feet of granite. All the dykes, veins, and bodies of schist dip at high angles toward the northwest.

Toward the northern end of the property a shaft, said to be 50 feet deep, has been sunk in a quartzose pegmatite. The materials on the dump consist of quartz carrying crystals of molybdenite, mica, chalcopyrite, and fluorite. A short distance south, presumably on the same dyke as that which the shaft penetrates, a large open-cut has disclosed two large pockets of ore, from which crystals of molybdenite up to 2 inches across were taken, as well as large crystals of beryl. Some 500 pounds of molybdenite, it is said, were taken from one of these pockets.

St. Maurice Mines Company

The property of the St. Maurice Mines Company consists of five claims, aggregating some 680 acres, situated on the northwest part of Indian peninsula, Kewagama lake, Preissac township. The principal claims are the Huestis, Sweezey, and Doucet.

The rocks of the claims are granite and mica schist. The granite forms a high ridge, known as Burnt mountain, where the well-exposed granite is cut by a remarkable display of quartz veins with a general northwest strike. The contact between the granite and schists crosses the northeastern corner of the Sweezey claim, and thence in an irregular curve, convex northwards, across the Huestis claim. The mica schists strike more or less parallel to the granite contact, and are intruded by numerous dykes of pegmatite and quartz. The best deposits appear to lie in the schist areas near the contact.

Much work was done on this property for a number of years. Development consisted chiefly of test pits and trenches, with one shaft on the eastern part of the Sweezey claim, said to be 70 feet deep. According to Wilmot, some work was carried on up to 1921; but since that time nothing has been done, the buildings have largely rotted away, and much of the plant has been removed.

In 1912 A. T. Mansure and A. E. Lehman mapped these claims, showing a total of almost 16,000 feet of quartz veins. These are of all sizes up to 16 feet in width, and lengths of 500 to 2,000 feet are claimed for some of them. The great majority are barren or contain only a few flakes of molybdenite; about twenty have been found that carry molybdenite in larger proportions. The molybdenite, as usual, tends to follow the micaceous edges of the veins, and a good deal of bismuthinite is also present. Bulk samples of picked ore shipped in 1911 to Queen's University for assay ran from 1·8 to 7·4 per cent molybdenite. The best veins found are on the eastern part of the Sweezey claim.

Peninsular Mining Syndicate

The Peninsular Mining Syndicate formerly held eight claims on Indian peninsula, lying south of the property of the St. Maurice Mining Company. The veins on the property were neither so large nor so rich as those on the Sweezey claim, so work was discontinued, and the ownership has lapsed. The main work was done on the McDougall and Smith claims.

O'Brien Claim

The O'Brien claim lies on the southeastern side of Indian peninsula, where a prominent outcrop of granite rises abruptly from the water. Four small veins, the largest 1½ feet wide, cut the top of this outcrop. They consist of rose quartz carrying disseminated molybdenite and muscovite in places, with small quantities of other minerals. Some distance inland three larger veins have been found, 3, 5, and 10 feet wide respectively. Some molybdenite and a good deal of bismuthinite were found in them.

Molybdenite Reduction Company

Molybdenite Reduction Company, Limited, own a number of claims in La Corne township. The property was first examined, and briefly described, by Professor Mailhiot[1], of l'Ecole Polytechnique, Montreal. In 1926 it was studied in detail by W. Gerrie, senior assistant to W. F. James. His report follows:

The claims of the Molybdenite Reduction Company are in the southwest corner of La Corne township and the northeast corner of Malartic township. One group comprises the southern half of lots 1, 2, and 3, range I, La Corne township, and the other the northern half of lots 62, 63, and 64, range X, Malartic township. The property is reached from Amos by Harricanaw river to the north bay of Malartic lake, thence by a good road 3 miles long.

Molybdenite was first noticed by an Indian in the area of vein-group B, and, as a result, a second Indian and Hugh Gilligan staked, in

[1] Mailhiot, A.: "The Gold Deposits of Lake De Montigny, Abitibi"; Rept. on Mining Operations, province of Quebec, for 1919.

1915, the south halves of lots 1 and 2, range I, La Corne township. In the following year, L. N. Benjamin, now a director of the Molybdenite Reduction Company, bought the property and with his associates held it until 1921. The Molybdenite Reduction Company was then incorporated to take over the claims, which have since been increased to their present number. Mr. James O'Sullivan has been in charge of development work since 1916.

Stripping has disclosed three groups of veins, which are known as A, B, and C. Trenching, however, has been carried on only where the soil is less than 2 feet deep. Test pits up to 5 feet deep have been sunk on the more important veins, and a shaft on the largest. According to information received in May, 1928, from H. H. Claudet, consulting engineer for the company, the shaft was then 150 feet deep, and is inclined at an angle of about 60 degrees, following the dip of the vein. A small amount of crosscutting has been done at the 100- and 150-foot levels. No ore has been shipped except a test lot of 10 tons, sent to the Mines Branch, Department of Mines, Ottawa.

The property lies about 1½ miles west of the western margin of the La Corne intrusive, which varies in composition from a biotite granite to a hornblende syenite. The molybdenite veins occur in an area of sedimentary biotite schist invaded by dykes or sills of fine-grained granite, and some thin sill-like masses of what appears to be an altered basic intrusive. The succession of events was as follows: (1) deposition of a banded argillaceous sediment which has been metamorphosed to biotite schist, with schistosity parallel to the stratification; (2) intrusion of these sediments, along bedding planes, by thin sills of pyroxene lamprophyre; (3) intrusion, along bedding planes, of thin sills of the La Corne granite; probably some buckling of the strata; (4) injection of the pegmatitic quartz veins, carrying molybdenite; (5) period of shearing, which may have begun when the veins, or even the granite dykes, were being injected; but which continued after the period of vein injection.

The sedimentary schist is a dark, crystalline biotite schist of uniform texture. Its sedimentary origin is revealed by fine and coarse banding, visible where the rock has not been too severely metamorphosed. Darker bands are comparatively rich in biotite, paler bands in quartz and feldspar. Schistosity is parallel to the banding wherever the later schistosity is not developed. The bedding strikes about north 35 degrees east, and dips northwest at about 60 degrees.

Biotite and quartz constitute the greater part of the schist. In thin sections the biotite shows many small pleochroic haloes centred by tiny crystals of zircon. The quartz exhibits strain shadows. Orthoclase and plagioclase are present in small amounts. Epidote and chlorite are prominent in some sections; the chlorite is particularly abundant near pegmatite contacts. Sericite, titanite, and some iron ore are common accessories, and pyrite, apatite, rutile, and zircon rarer ones.

Pyroxene lamprophyre occurs in the biotite schist as dark green bands usually less than 2 feet thick, although one of 5 feet is noted in the area of vein-group B. The bands follow the strike of the biotite schist, and seem to represent altered basic sills injected along the bedding planes of the sediments. They are composed mainly of secondary hornblende, along with biotite, pyroxene, epidote, fine-grained interstitial quartz, and perhaps feldspar. Titanite, rutile, calcite, and sericite are present in small amount.

On range line I-II, La Corne township, just west of lot post 2-3, there is a small outcrop of green schistose rock, and a small outcrop of similar rock lies 500 feet to the south. Both are much like the lamprophyre. The rock of the outcrop on the range line is chiefly secondary hornblende, with altered plagioclase, orthoclase, and some quartz. It is coarser than any of the sill rocks.

Granite forms two large masses, one in the area of vein-group A, and one in the area of vein-group C. It also forms a number of sills or dykes, paralleling the strike of the biotite schist. The two large masses of granite appear, from field observations, to be merely the large outcrops of comparatively thin sills with locally low westward dips.

The granite is fine-grained and somewhat gneissic, with a marked tendency to porphyritic texture. It is composed of orthoclase, albite-oligoclase, quartz, and biotite, with accessory zircon, titanite, and apatite. Chemical analyses of this granite are given on page 137.

Pegmatite veins, the end products of the crystallization of the La Corne intrusive, are numerous. The western part of the hills north of Baillargé lake, 2 miles or so north of the property, consist of coarse biotite granite containing innumerable vaguely outlined pegmatitic masses of pink feldspar, quartz, biotite, and small cherry-red garnets. Farther south in the granite the pegmatites are fewer in number and more vein-like; they contain muscovite instead of biotite, and carry molybdenite. The pegmatite veins on the property of the Molybdenite Reduction Company are of this type.

There are two sets of veins. The first, which includes the principal veins of vein-groups B and C, strike north 55 degrees east to north 80 degrees east, and dip south at angles between 50 degrees and vertical. The second set, especially well developed in vein-group A, strike about north 35 degrees west, and dip west at various angles. Veins of both sets are found in each vein-group.

The veins are essentially quartz pegmatites, of which quartz constitutes about 90 per cent. Nearly all the small veins contain feldspar, and so do the larger veins where they pinch out; but elsewhere in the larger veins muscovite largely takes the place of feldspar. In the area of vein-group C, the quartz-feldspar veins occur exclusively in the biotite schist, and the quartz-muscovite veins in the large granite mass. One vein, which crosses the contact, changes in type exactly at the contact. Where molybdenite occurs in the veins, it nearly always accompanies muscovite or feldspar. The quartz-muscovite veins, with their larger tonnage and greater persistency, are economically the more important; but the smaller quartz-feldspar veins are usually much the richer in molybdenite.

The following minerals have been identified in the veins: quartz, usually clear, but in some cases smoky; feldspar, chiefly white and pink microcline and orthoclase, but also a little plagioclase; pale, sea-green muscovite; molybdenite, chiefly associated with the muscovite, but also in bright scales in the feldspar and quartz; apatite, small, rude hexagonal prisms of beryl-blue colour; tourmaline, in masses of hair-like crystals, or rosettes of larger crystals, usually black; pyrite, in well-formed cubes near the vein walls; pale-coloured to deep violet fluorite; bismuthinite in bright, splintery masses up to half an inch in length, often tarnished blue; particularly common near fluorite; columbite, a rather rare mineral, forming black, submetallic masses up to 2 inches diameter; chalcopyrite, quite rare; molybdite, occurring in places on weathered surfaces.

The order of crystallization in the veins, beginning with the earliest, appears to be: (1) apatite and pyrite; (2) tourmaline and feldspar; (3) muscovite; (4) molybdenite, columbite, and bismuthinite; (5) quartz; (6) fluorite, quartz, chalcopyrite.

Apatite, pyrite, and feldspar invariably line the vein walls, and tourmaline usually does so, but also impregnates the wall-rock. The molybdenite, as stated already, usually accompanies feldspar or muscovite. In vein-group A, the intersections of veins seem favourable places for its occurrence. In vein-group B, the large veins are richer in muscovite and molybdenite where they cross granite sills; the small feldspathic veins of this group are rich in molybdenite. In vein-group C the quartz veins in the granite are barren, but the quartz-feldspar veins in the schist are in many places heavily charged with molybdenite close to the walls where the feldspar occurs.

Contact effects along the vein walls are not marked. Black tourmaline is developed abundantly in the biotite schist over a distance of about an inch. Chlorite and pyrite, the latter in cubes up to 5 mm. to a side, appear over distances of a few feet from the walls. In places the biotite schist is impregnated with feldspar and molybdenite. In granite, the veins are commonly edged with a wall of muscovite, and the granite itself, throughout a zone ½ inch to 2 inches wide, is paler in colour and carries more muscovite than usual.

The end of the period of vein formation was marked by the formation of a few small veins and vugs of fluorite and quartz. The quartz forms clear crystals up to 5 mm. in length.

Vein formation was followed by a period of shearing, which imposed on the biotite schist, locally, a new schistosity striking north 70 to 80 degrees east. This later schistosity is visible in the area of vein-group B, particularly near the veins and at the east end of the outcrop. The schist is noticeably flattened against the walls of the larger veins, and a thin section showed distinct crumpling of the biotite flakes. Small veins that run out at right angles from the larger ones are also crumpled. The later schistosity is also well developed in the area of vein-group C, where it obliterates, in places, the earlier schistosity. It is likewise to be seen in the outcrop south of vein-group A.

The granites have been but slightly affected by this later movement. The principal effect has been to fault slightly some of the smaller dykes. The pegmatite veins have yielded to the stresses much more readily. Their muscovite is sheared into flat streaks, and molybdenite is smeared into a powdery mass or broken into small grains. The quartz in many veins is severely fractured. Tourmaline needles in the veins are broken up, and tourmaline in the wall-rock is usually flattened against the vein walls. Small veins parallel to the new schistosity may be pinched into a row of lenses. Chlorite and pyrite seem to be largely developed in the wall-rocks at points of very severe shearing, as in the northeast corner of the area of vein-group C.

Twenty-four veins have been exposed to date. As stripping has been confined to areas where the overburden is less than 2 feet deep, many of the larger veins have not been traced for their entire length. The total stripping amounts to about 3,500 feet, distributed thus:

In the area of vein-group A, 750 feet, on seven veins.
In the area of vein-group B, 1,500 feet, on ten veins.
In the area of vein-group C, 1,300 feet, on seven veins.

The most important showings occur in vein-group B, where the veins are both larger and more numerous than elsewhere. The veins of group C, though rich, are too small, at the surface, to be economically worked. In vein-group A, vein 6 is promising, and the ore pockets on veins 1, 2, 3, 4, and 5 require investigation at greater depth.

It seems a reasonable conjecture that a great number of veins underlie the drift in the 300-foot stretch between groups A and C. Stripping southwest of group B may reveal many good veins.

The ore is remarkably free from sulphides other than molybdenite. Pyrite occurs in almost negligible amounts. Bismuthinite is rare. The gangue minerals are essentially quartz and mica with a little feldspar. Though all the rock in the veins is not ore, cobbing on this material is a simple practice. The ore runs from ½ to 10 per cent molybdenite, and averages 2 to 3 per cent.

W. B. Timm and C. S. Parsons of the Mines Branch, Ottawa, reported very favourably on the milling properties of a test lot of 10 tons of ore. A part of their report[1] is quoted:

" . . . . . it can be classed as a clean ore. It is very amenable to concentration by flotation. Its physical character and the absence of appreciable quantities of other sulphides such as copper and iron make it an attractive milling ore. It is not difficult to grind, the molybdenite being freed at about 40 mesh. These characteristics permit of an exceptionally high-grade product being produced, with a very high recovery of the molybdenite."

With a mill feed of 2·02 per cent molybdenite they produced a concentrate of 91 per cent molybdenite, or 6 per cent above the usual market requirements, and made a recovery of 95 per cent. They state that under continuous operations higher concentrations and recovery would be possible.

Surface conditions on the property are excellent for the location of a mining camp and mill. A spring on the township line gives an adequate supply of water for cooking and drinking purposes. With Lusignan lake about a mile away, a water supply for the mill is guaranteed. Though all the good jackpine was burnt, spruce is available to the south. The road over the sand and gravel is an excellent route to Malartic lake. For heavy haulage the construction of a light railway along this route would be feasible.

[1] Test No. 200—Federal Ore Dressing Laboratories, Ottawa.

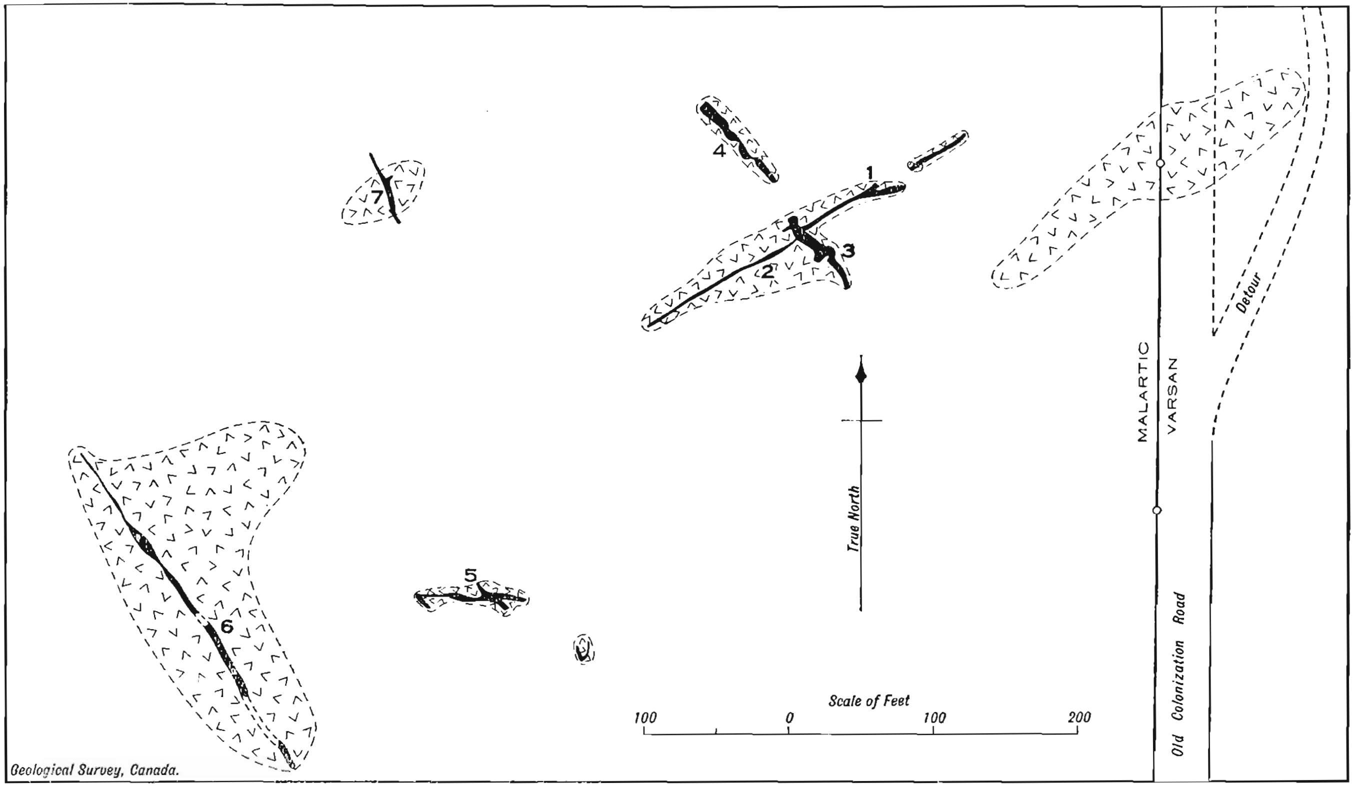


Figure 26. Vein-group A, Molybdenite Reduction Company. Granite outcrops shown by angle pattern; main parts of vein system shown by solid black.

Vein-group A (Figure 26). Molybdenite was first discovered on this vein-group by a "pop-shot" set off at the junction of veins 1, 2, 3, and 4. A rich pocket of molybdenite was uncovered, and two or three tons of high-grade ore were cobbed. The molybdenite lies in mica. Intense shearing effects are present, so that the molybdenite is pulverized. Pyrite, fluorite, and bismuthinite are present in very small amounts. The veins are of the quartz-mica type, but veins 1 and 2 show feldspar where they begin to pinch. Vein 3 has the greatest thickness, about 6 feet.

Vein 5 is really two veins. A rich pocket of ore occurs at their junction, over an area of 10 feet by 15 feet. The molybdenite occurs with mica, and a little pyrite is present.

Vein 6 is the best vein of this area. It has a maximum thickness of 4 feet. The quartz is inclined to be dark. Mica streaks carrying molybdenite are abundant. A little fluorite and bismuthinite are present in one place.

Vein 7 is short and lens-shaped, with a maximum thickness of 5 feet. It carries but little molybdenite.

A small group of thin, barren veins is exposed on the township line.

Vein-group B (Figure 27). Of vein 1, only the east end has been trenched. It is 2½ feet thick at the westernmost exposure. Muscovite is plentiful in it, but molybdenite is not. Apatite crystals are visible on the wall.

Vein 2 has a maximum thickness of 3½ feet. Where it cuts through granite dykes, mica and molybdenite are moderately abundant and at one such intersection a few rough crystals of columbite occur in the wall.

Vein 3 consists of two veins, with a maximum width of 4½ feet. Four pits on the vein in the granite zones have shown good ore. In this vein molybdenite is prominent in the quartz. Apatite is found in the micaceous wall.

The main part of vein 4 is 3 to 3½ feet wide. At the west end where it begins to pinch, another vein appears on the south side. Two pits have disclosed ore. Tourmaline is present in the feldspathic parts of the veins.

Vein 5, the largest on the property, is two veins. The maximum width is 7½ feet. The main shaft has been sunk on this vein, following the dip (60 degrees), but the vein passes out of the shaft at a depth of about 30 feet. The northern vein of this pair carries molybdenite to its eastern tip, and the southern to a point about 50 feet east of the shaft. The ore carries a little pyrite, columbite, bismuthinite, fluorite, and blue apatite. Tourmaline occurs at the western end of the vein.

Vein 6 traverses a granite-schist contact, and lies at right angles to vein 5. Its maximum thickness is 3 feet, and it narrows in the middle of the exposure. The part of the vein in the granite contains much mica and is rich in molybdenite and blue apatite. About 2 tons of very high-grade ore has been removed from a 4-foot pit.

Vein 7 comprises three veins of the quartz-feldspar variety. The greatest width is 2 feet. Where the veins cross granite dykes, muscovite is present, together with rich pockets of molybdenite.

Vein 8 has a maximum width of 3½ feet. Three pits have been sunk on it and some good ore removed. Mica is not prominent.

Vein 9 consists of one main vein and three minor veins to the northwest. The main vein, over a considerable part of its length, is 3 feet

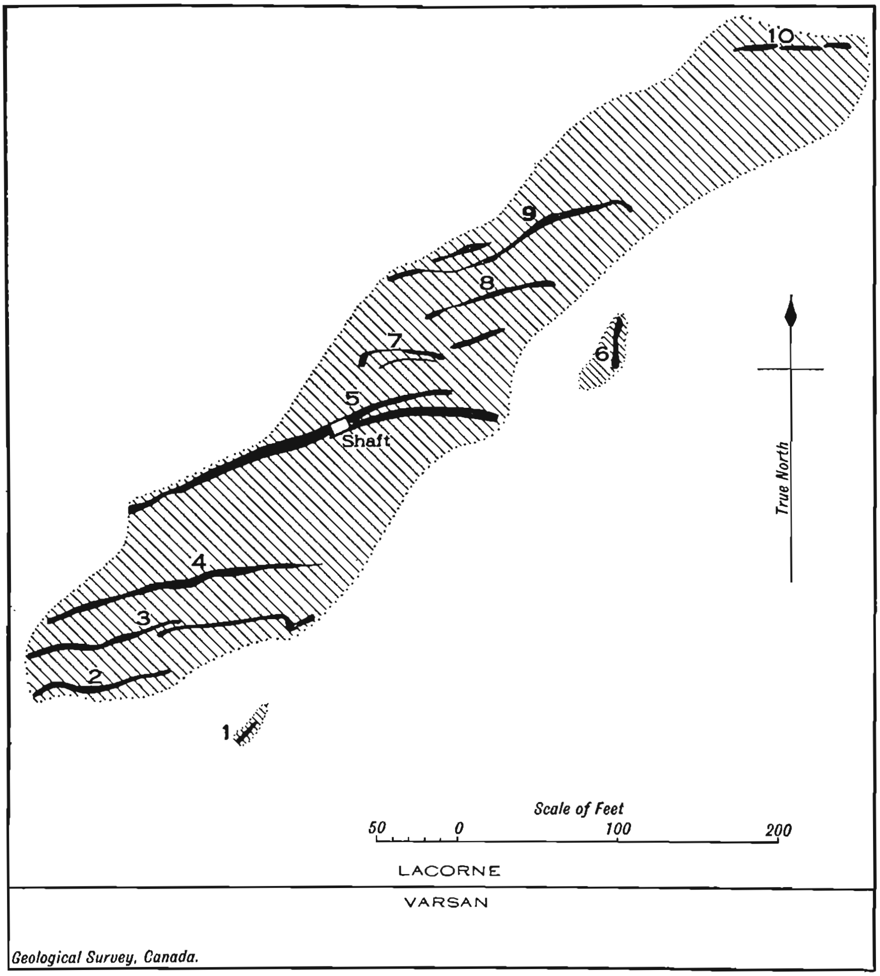


Figure 27. Vein-group B, Molybdenite Reduction Company. Schist and granite outcrops shown by diagonal ruling; main part of vein system shown by solid black.

thick. Two pits have disclosed some fair ore. Feldspar and tourmaline are rather abundant.

Vein 10 is a group of thin quartz-feldspar veins in the northeast corner of the outcrop. The main vein widens eastward to a quartz-mica vein 2½ feet thick. Feldspar everywhere lines the walls and carries tourmaline. Many rich pockets of ore occur in the narrow veins.

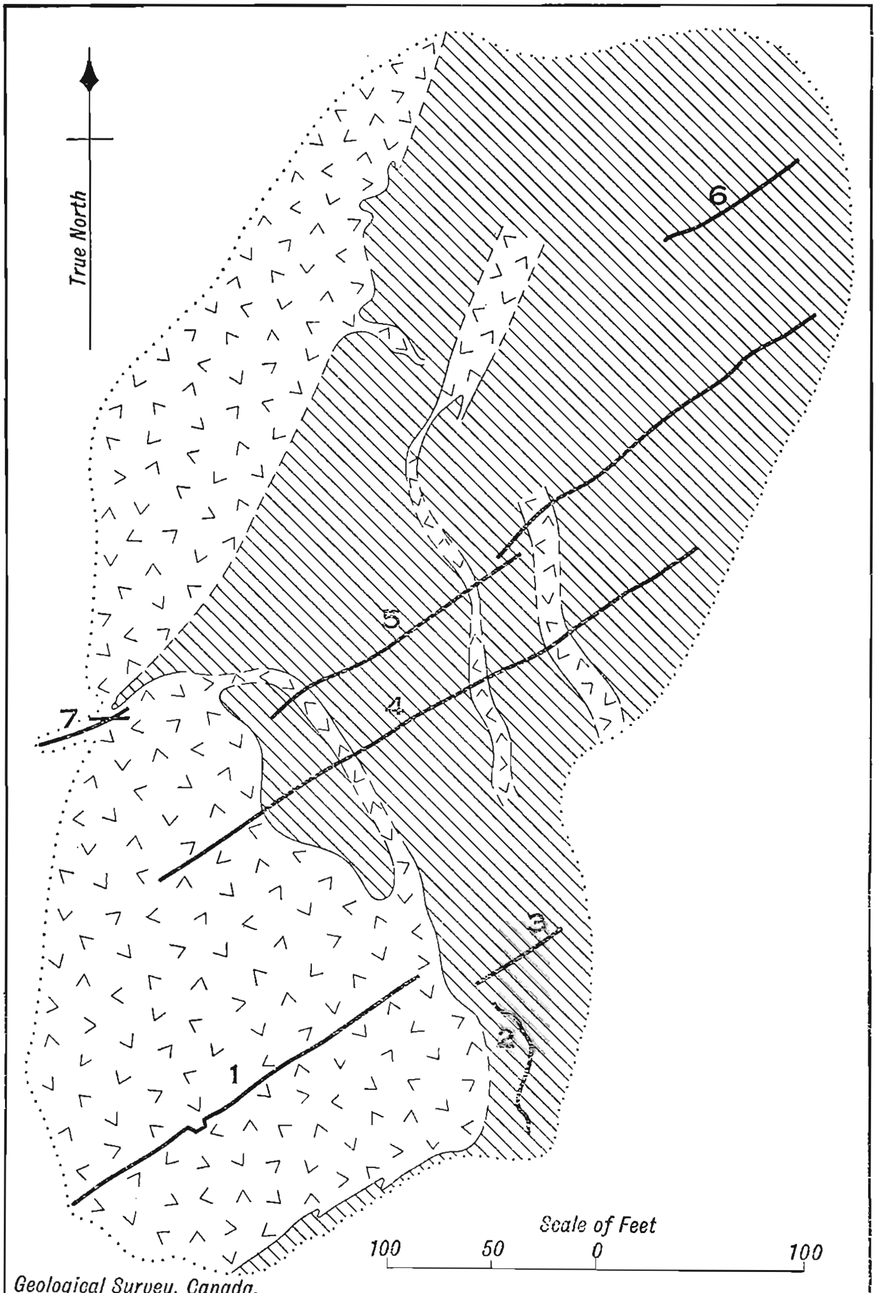


Figure 28. Vein-group C, Molybdenite Reduction Company. Granite (main bodies) shown by pattern of angles; schist and minor granite bodies shown by diagonal ruling; main part of vein system shown by heavy lines.

Vein-group C (Figure 28). Vein 1 is a thin, straight vein with a maximum thickness of 10 inches. It consists almost wholly of quartz with a few streaks of sheared mica, and is barren of molybdenite. Tourmaline is present. The vein has numerous short offshoots, and is slightly faulted in places. Other small veins in the granite nearby are like it, and require no description.

Vein 2 consists of two small, tortuous veins and some smaller ones. The maximum thickness is one foot. The veins follow the original bedding of the biotite schist and have suffered equal distortion. They are quartz-feldspar pegmatites with apatite, tourmaline, and a little pyrite. Rich nests of ore occur along the veins, from which the best specimens of ore on the property may be obtained. Fluorite, quartz, and a little chalcopyrite fill a small fault at the north end of this group.

Vein 3 is not more than 7 inches wide, and is like vein 2.

Vein 4 is a long vein with a maximum thickness of one foot. Its western part is in granite, and is barren. Molybdenite and feldspar appear where the vein enters schist, and molybdenite values are good throughout its length in the schist. Tourmaline and apatite are common, and a little pyrite is present. Close to the east end green tourmaline occurs over a length of 8 feet.

Vein 5 is the longest vein of this group. It has a maximum thickness of 10 inches. It is much like vein 4 in composition, and the molybdenite content is good. Black tourmaline, in fractured bunches, is common.

Vein 6 is 10 inches wide. It is remarkable for its tourmaline content, and for the tourmalinization of the schist walls. The schist nearby is also chloritized, and carries much pyrite. A trench 20 feet long shows a fair molybdenite content.

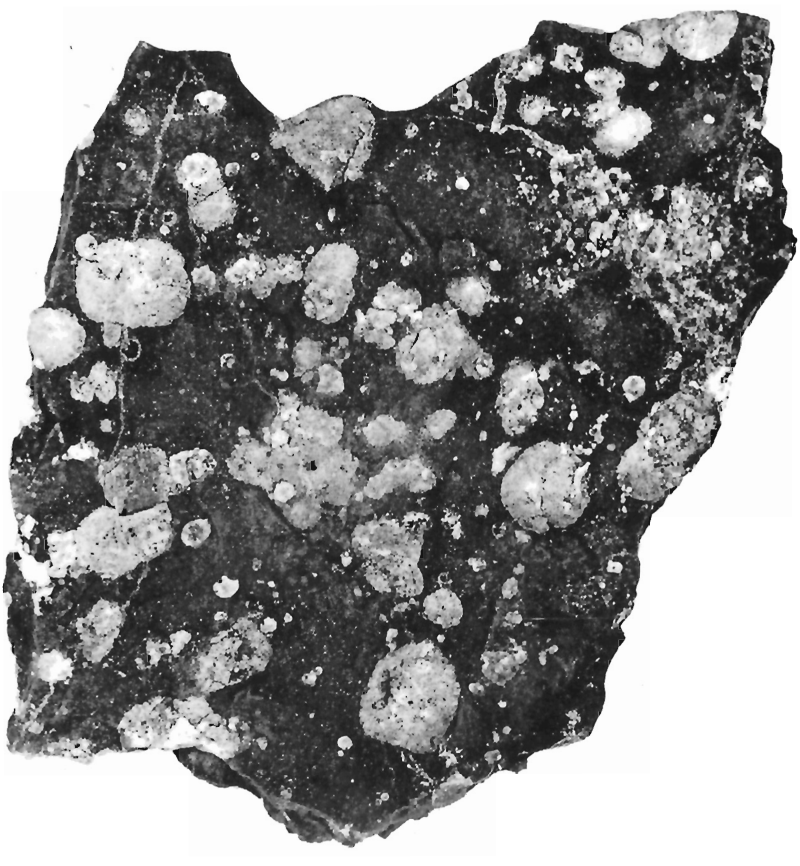
Vein 7 is an irregular vein that seems to consist of two veins crossing each other. The maximum width is 2½ feet. A 3-foot pit at the intersection shows a little molybdenite in sheared mica. The vein forks at the west end.

PLATE II

A. Thinly bedded tuff (Privat band), lot 43, range-line X, Poularies township.

B. Band of thinly bedded acidic tuff between bands of basic andesitic tuff (Privat band), lot 42, range-line X, Poularies township.

A. Pattern assumed by pillows in cross-section. Upper side of pillows tend to be rounded, lower sides run off to a point where the fluid lava entered inequalities of the surface on which the pillows were formed. This flow faces toward the lower side of the picture.



B. Dalmatianite showing spotted texture. Many of the smaller white spots are amygdules.

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