CANADA
DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY

MEMOIR 229

NORANDA DISTRICT, QUEBEC

BY
M. E. Wilson

OTTAWA
EDMOND CLOUTIER
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1941

Price, 50 cents No. 2461

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CHAPTER I

INTRODUCTION

GENERAL STATEMENT

The discovery of the extensive deposits of gold-copper-bearing ore of the (Noranda) Horne mine in 1923 was an outstanding event in the history of the Canadian mining industry, not merely because of the extent and grade of the deposits themselves, but because of the prospecting activity that ensued in adjacent territory. Up to that time there had been practically no mineral production from western Quebec. Now (1940) there are in this territory twenty-five operating mines, from which copper, gold, and other metals having a value of over $43,000,000 were produced in 1939; and the Horne has progressed from an undeveloped prospect to a mine ranking second in Canada in its output of copper, third in gold, and third in the total value of metals produced.

The district of about 45 square miles (Figure 1) to which this report refers includes the Horne and three other producing mines, the Amulet, the Waite-Ackerman-Montgomery, and the Powell-Rouyn. It is 10 miles long from north to south, 4 to 5 miles wide, and lies in the province of Quebec about 20 miles east of the Ontario boundary and 60 miles northeast of Lake Timiskaming. Its geology is shown in the five maps on the scale of 1 inch to 800 feet that accompany the report.

FIELD WORK AND ACKNOWLEDGMENTS

The field work upon which this report is based was carried on during the field seasons of 1931 to 1935.

The writer is especially indebted to his field assistants, whose painstaking and energetic performance of their duties made possible the completion of the geological outcrop maps. The names of the assistants for each year are as follows: 1931, J. S. Stevenson and J. D. Turner; 1932, N. S. Beaton, R. C. Hart, and J. D. Turner; 1934, D. W. Atchison, G. L. Brossard, A. G. Darling, E. J. Hazen, P. M. Malouf, and R. M. Sternberg; 1935, S. T. Ballantyne, M. J. Barry, I. Gringorten, F. S. Hutton, A. Cameron, and A. T. Prince.

Space does not permit the inclusion of the names of all those residents of the district from whom information or other assistance was obtained. All of the mining companies and their officials kindly placed their mine plans and other data of geological interest at the writer's disposal and co-operated in every way to make the work a success. Thanks are especially due to Oliver Hall, consulting engineer, and Ernest Hibbert, former consulting engineer, of Noranda Mines, Limited, to H. L. Roscoe, manager, and R. V. Porritt, assistant manager, of the Horne mine, and to John C. Rogers, consulting engineer of the Powell-Rouyn mine. It is a pleasure to acknowledge the assistance given by Peter Price, G. G. Suffel, and the other members of the geological staff of the Noranda Company, also by Mr. Roger Taschereau, resident mining inspector for the Bureau of Mines of Quebec.

BIBLIOGRAPHY

The titles of publications having reference to individual properties within the area are given either as references or under the heading " Previous Descriptions " in the chapter of this report entitled " Descriptions of Properties." These are, therefore, not included here. The principal reports or papers having reference either to the area studied or to adjacent territory are as follows:

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CHAPTER II

PHYSICAL FEATURES

Noranda district lies well within the deeply eroded Canadian Shield that occupies so much of northeastern Canada, and on the southeast slope of the height of land between the St. Lawrence and James Bay basins, the drainage of the area flowing southward into the upper Ottawa by way of Kinojevis River and its tributaries. The lowest elevation within the area, the surface of Lake Trémoy (Osisko Lake), is 947 feet above sea-level, the highest point the top of Beaver Hill, a part of the Waite range of hills, is 1,510 feet. The difference, therefore, amounts to 563 feet, a local range in elevation considerably greater than that of most parts of the Canadian Shield.

The normal topography of the Shield has been considerably modified in Noranda district by the deposition of stratified clay in its depressions. These clays were laid down by Lake Ojibway-Barlow, a post-Glacial lake that occupied a large area in western Quebec and northeastern Ontario, following the melting away of the last continental ice-sheet. The surface of this lacustrine clay throughout most of the area has a more or less rolling aspect. This arises from the fact that the clay, which was widely deposited both in depressions and on the slopes of rock ridges, is not sufficiently thick, except in the lowermost parts of the area, to fill in more than the minor inequalities of the bedrock or Glacial drift surface on which it rests. The irregularity of the clay belt topography has been further increased by the streams that have cut valleys 10 to 20 feet deep in places. The elevation of the clay surface within the area ranges from 950 feet to 1,070 feet above sea-level. The territory underlain by clay is now being rapidly cleared for farming, so that the rocky uplands are becoming much more accessible than formerly.

Along the western edge of Waite map-area there are ridges of sand up to 60 feet high, most of which have in plan a U-shaped form. The apex of the U in each case points towards the southeast. The crest of the ridge attains its highest elevation at the apex of the U and from this point slopes gently towards the northwest. The form of these ridges suggests that they are sand dunes. As these dune ridges until very recently were thickly wooded, they are not of recent origin. It is probable that they formed during the withdrawal of the Glacial ice-sheet.

The close relationship of physiography to bedrock formations is strikingly illustrated in Noranda district. In the northern part there is a roughly circular depression 3 to 3½ miles in diameter surrounded by rugged ranges of hills. The bottom of this amphitheatre-like depression, one of the most extensive lowland areas in the district, is underlain by the Lake Dufault granodiorite mass. The surrounding hills, which include some of the highest uplands in western Quebec, on the other hand, are composed mainly of andesite. It seems evident, therefore, that the Lake Dufault granodiorite is much less resistant to erosion than the andesite. Not only do the different rocks of the area vary in their resistance to erosion, but the surfaces of some are more irregular than others. This is illustrated by the belt of diorite that extends along the boundary line between Dufresnoy and Duprat townships. This intrusion, although fairly resistant to erosion, has a surface so much more uniform than the adjacent volcanic rocks that its boundaries can be determined from the change in the contours of the topographic map.

The most conspicuous physiographic features of the area are the successive, unsymmetrical, sawtooth-like ridges present in territory underlain by the lavas. They are most strikingly developed in Waite and Amulet Hills. In both of these, the ridges trend north or north-northwest, have gentle slopes towards the east parallel to the dip of the lavas, and all are cut off steeply on the west by westward-facing scarps, many of which are over 200 feet high. East and southeast of Vauze Lake, in the northeastern part of Waite map-area, a band of northeastward dipping andesite has been offset to the northeast by an intrusion of diorite that crosses it obliquely. The unsymmetrical forms of the dislocated parts of this belt are so similar that the presence of the dislocation is indicated by the topographic forms alone.

Many of the faults or fault zones of the area are indicated by linear depressions. This is illustrated by the depression along the Horne Creek fault at Noranda, by the valley along the fault zone that extends in an east-west direction across the central part of Waite map-area, and by some of the linear depressions along faults in the territory adjacent to the Waite mine. There are also some linear depressions that may be related to faults, the presence of which because of the uniformity of the formations on either side of the depression cannot be determined from the bedrock geology.

CHAPTER III

GEOLOGY

GENERAL STATEMENT

With the exception of the nearly flat-lying strata of the Cobalt series that form Kekeko Hills, and some or all of the numerous dykes of diabase that extend in various directions across the region, the bedrock formations of western Quebec belong to the Archæan basal complex. The superficial rocks of this complex, that is the lavas and sediments, are usually divided into two groups, the Keewatin and Timiskaming. In the Keewatin it is customary to include all or most of the volcanic rocks and subordinate amounts of sediments that occur interstratified with the volcanics. To the Timiskaming is assigned all or most conglomerates and associated sediments, and, in some places, lavas that occur interbedded with them. This is, to a considerable degree, however, a lithological rather than a stratigraphical classification.

In Noranda district, the superficial rocks of the Archæan are wholly volcanic and, therefore, belong to the Keewatin as here defined. They consist of a conformable succession of lava flows, stratified tuff, pyroclastic breccia, and chert, having a total average thickness of about 25,000 feet. As all the rocks of this succession follow one another conformably, they form a part of a series the upper and lower limits of which lie outside the area mapped, and are as yet undetermined.

The chief intrusive rocks occurring within Noranda district, named in the probable order of their age from oldest to youngest, are: (1) quartz diorite, gabbro, and related rocks; (2) granodiorite; (3) albite granite; (4) syenite porphyry; and (5) diabase. All of these except the last belong to the Archæan. In addition to these more important intrusives, there are numerous dykes, sills, and small masses of other rocks, which, classified according to their age, belong to four groups: (1) those that are cut by the quartz diorite, and hence were intruded before the diorite; (2) those intrusive into and, therefore, younger than the quartz diorite; (3) dykes of lamprophyre intrusive into the granodiorite; and (4) dykes of andesite and rhyolite that intrude the albite granite.

Table of Formations

Cenozoic	Post-Glacial Glacial	Stratified clay and sand Boulders, gravel, sand, and boulder clay
Proterozoic (Late Precambrian)		Quartz diabase and gabbro dykes
Archæan (Early Precambrian)		Syenite porphyry dykes and masses Rhyolite porphyry dykes Andesite dykes Albite granite (alaskite) Pyroxene lamprophyre dykes Granodiorite Dacite (feldspar) porphyry dykes Andesite dykes Quartz diorite, diorite, gabbro, diorite porphyry, albite, granite, granodiorite Rusty weathering, epidotized dyke rock Andesite dykes, and sills Rhyolite (quartz-albite) porphyry dykes and small masses Andesite dykes and sills Amphibole dacite (quartz-feldspar) porphyry Quartz diabase dykes, sills, or masses Andesite dykes and sills Siliceous rhyolite Rhyolite, rhyolite flow breccia, rhyolite tuff, and pyroclastic breccia Andesite, andesite flow breccia, andesite tuff, and pyroclastic breccia Chert

VOLCANIC ROCKS

DISTRIBUTION

The greater part of the territory mapped is occupied by volcanic rocks. These consist largely of lava, but in places, chiefly in the southern part of the district, include pyroclastic breccia and stratified tuff. They occur in an uninterrupted succession of lava belts (Figure 1) that have been folded with increasing intensity from north to south into eastward plunging anticlines and synclines. In the northern part, where they have been gently folded, they trend with a sinuous course from north to south, whereas in the southern part, where they have been intensely folded, they trend east-west. The structural complexity has been further increased by numerous faults and by extensive intrusions of diorite, granodiorite, and granite.

LITHOLOGICAL CHARACTER

The volcanic rocks belong lithologically to three groups: (1) normal rhyolite; (2) siliceous rhyolite; and (3) rocks of andesitic composition. The siliceous rhyolite occurred originally in a single belt, but is now divided, partly by faulting and partly by intrusions of quartz diorite, into three areas. The number of belts of the rhyolitic rocks of group 1 and of the andesitic rocks of group 3 is about the same, but the total thickness of the rhyolitic members exceeds that of the andesitic.

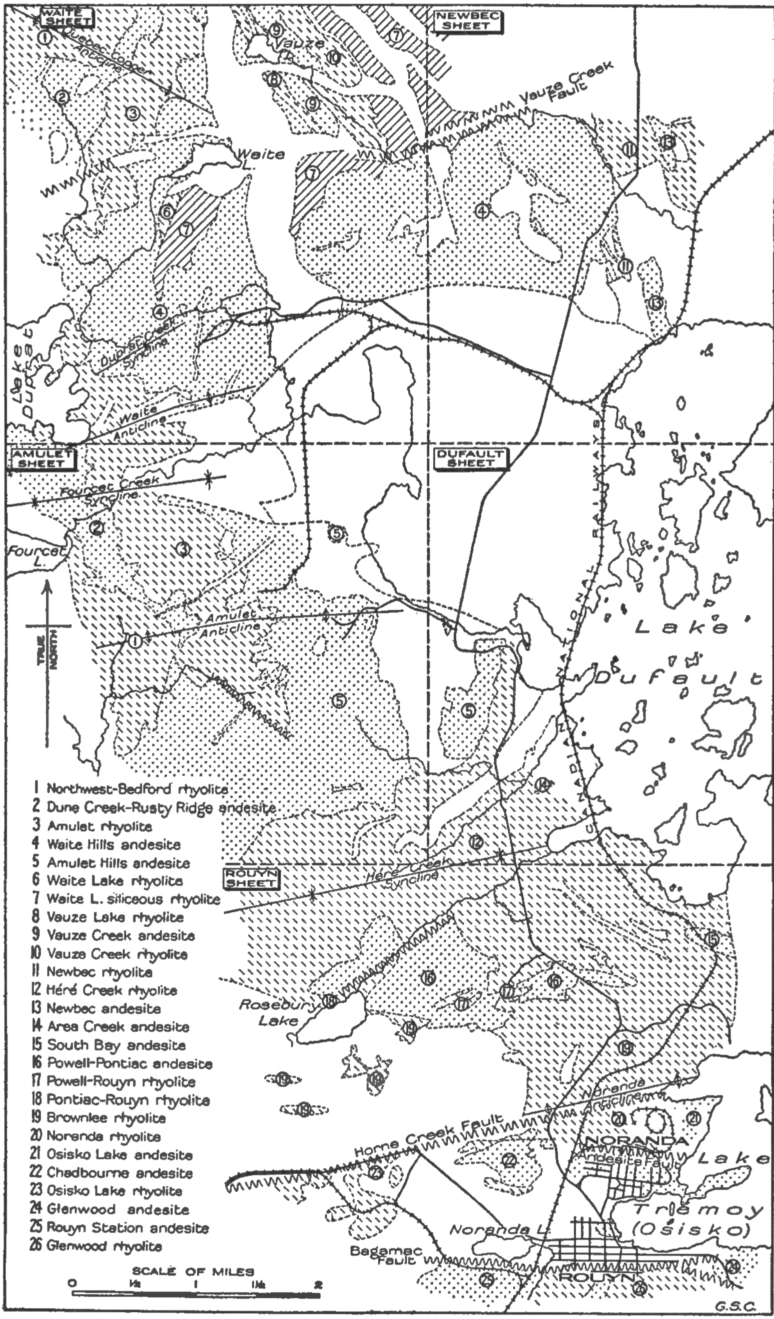

Figure 1. Noranda district, Quebec, showing distribution of lava belts.

Rhyolite, Rhyolite Flow Breccia, Pyroclastic Rhyolite Breccia, and Rhyolite Tuff

The variations or phases exhibited by the rhyolitic rocks that merit description are the following: (1) massive rhyolite; (2) mottled, hackly and mesh-weathering rhyolite; (3) spherulitic rhyolite; (4) bluish grey weathering rhyolite; (5) rhyolite flow breccia; (6) dacite and trachyte; (7) pyroclastic rhyolite breccia and rhyolite tuff.

The massive rhyolite is a pale grey weathering rock and is commonly porphyritic. On its freshly broken surface it has usually a fine-grained, grey to dark grey, siliceous, flinty appearance with a well-developed conchoidal fracture. In most of the rhyolitic belts the massive rhyolite occurs here and there in areas of varying size. It occurs most extensively in the western and central parts of the Héré Creek belt (*See* Figure 1). Throughout a considerable part of this area the rock has minute pits on its weathered surface, probably due to the weathering out of the small phenocrysts of feldspar that it contains. For the most part, the phenocrysts of quartz and feldspar are small, but in places, as in the outcrops of the Newbec rhyolite (*See* Figure 1) that lie between the Macamic highway and Vauze Creek, the quartz phenocrysts attain a diameter of one-eighth inch and the feldspar phenocrysts a maximum length of one-eighth inch and a maximum width of one-sixteenth inch. This phase of the Newbec rhyolite occurs in isolated outcrops in which relationships cannot be determined. It is sufficiently coarse in texture to be intrusive, but the Newbec rhyolite farther south where it rests on the Waite Hills andesite, is also porphyritic and is undoubtedly extrusive, so that the coarsely porphyritic phase probably belongs to the interior more coarsely crystalline part of an unusually thick flow at the base of the Newbec belt of rhyolite. In places the massive rhyolite is finely laminated and in other places amygdaloidal.

Examined microscopically the massive rhyolite is found to consist chiefly of phenocrysts of quartz and albite enclosed in a matrix of finely granular quartz and albite. In many thin sections there are also round, radial intergrowths of quartz and albite, known as spherulites. In some thin sections the quartz phenocrysts are irregularly enlarged by the addition of quartz or micropegmatite. All of the quartz phenocrysts are traversed by a network of fine cracks. The rhyolite contains varying amounts of sericite, less commonly chlorite or carbonate; all of these are products of alteration.

Intimately associated with the massive rhyolite in many of the belts are less uniform phases. These are especially abundant in the Amulet belt (*See* Figure 1). One variation is a cavernous, variegated weathering type that is grey to green and mottled on its freshly broken surface. This variety is amygdaloidal in places, and in other places laminated. It was probably originally a vesicular lava. Another phase has a hackly weathered surface, and a fine brecciation faintly visible where freshly broken. This is rusty weathering here and there from the presence of pyrite. A third common variation is dull grey and is intersected by minute fractures so arranged as to give the rock a mesh-like appearance (*See* Plate XI A). This mesh-weathering type in places is laminated or amygdaloidal.

In all the belts of rhyolite there are areas of considerable extent in which the rock on its weathered surface is seen to consist of round grains, which microscopic examination shows to be radial intergrowths of quartz and albite (Plate XII). These spherulites as a rule are one-sixteenth inch or less in diameter and of uniform size. In the Amulet belt (*See* Figure 1) west of the Amulet mine, however, there are zones of banding and lamination in which spherulites up to one-half inch in diameter were observed. The masses of spherulitic rhyolite within the rhyolite belts all grade into normal rhyolite, and doubtless are only local variations within the rhyolitic lava flows.

Throughout most of the high ridge that lies southeast of Lake Duprat, in the northern part of the Amulet property, and in other parts of the Amulet rhyolite belt (*See* Figure 1) a blue-grey, variegated or mottled weathering type of rhyolite occurs. This on its freshly broken surface has a dark grey, flint-like aspect and conchoidal fracture. It is porphyritic or laminated in places and nearly everywhere is amygdaloidal. Under the microscope it is not greatly different from normal rhyolite either in texture or composition, except that it contains scattered radial or sheaf-like aggregates of colourless actinolite and its plagioclase ranges from albite to oligoclase.

In most of the rhyolite belts the predominant rock is a breccia composed of angular to subangular fragments of rhyolite, from an inch or less up to 20 feet in diameter, enclosed in a rhyolitic matrix (Plate X B). The presence of amygdules, flow lamination, and porphyritic texture within both the fragments and matrix of the breccia, and the similarity in the composition of the enclosed fragments and the matrix, prove that this rock is not a pyroclastic breccia but a breccia formed during extrusion. Along the eastern margin of the Vauze Creek rhyolite and rhyolite breccia (*See* Figure 1) there is a single lava flow in which the fragments are thin and ribbon-like (Plate IX B). It is noteworthy that in this breccia many of the inclusions are sharply defined on one margin and poorly defined on the other. Where lamination is present in the breccia inclusions, it, in most cases, trends across the fragment but in a few places was seen to trend parallel to the margins of the blocks. The matrix of the breccia where freshly broken exhibits all the characteristics of normal rhyolite, but on its weathered surface it may be hackly, laminated, or cavernous, the latter feature indicating that it was originally vesicular or scoriaceous. Microscopic examination of the matrix of the flow breccia shows that there is little difference in composition between matrix and fragments, except that where the fragments are paler grey on the weathered surface they have been sericitized. The rhyolite flow breccia occurs for the most part irregularly through the lava flows without relationship to structure.

In several of the rhyolite belts of the western part of the area, and at one point in the Newbec rhyolite (*See* Figure 1), the rhyolite includes dark greenish grey, andesite-like phases, which under the microscope are seen to consist of minute, rod-like crystals of plagioclase heterogeneously arranged. They thus differ texturally from the normal rhyolite. In all but one of these variations from the normal rhyolite the plagioclase is oligoclase. In the irregular area mapped as rhyolite lying southwest of Waite Lake the rock consists largely of albite and contains no quartz. This rock is, therefore, an albite trachyte. All these varieties pass gradationally into the normal rhyolite and, apparently, were a part of the rhyolite magma when it was extruded.

In places, chiefly in the southern part of Rouyn map-area, there are zones of fragmental rhyolitic material interbedded with the lavas. These are stratified in part and are, therefore, presumably pyroclastic. There are also outcrops of unstratified rhyolite breccia, such as that shown in Plate X A, that consist of fragments closely compacted together and lie in zones along the contacts of rhyolite and andesite flow belts (*See* Figure 1). It is probable that these occurrences are also pyroclastic. The most extensive areas of pyroclastic rhyolite breccia and tuff are the two zones that lie within the wedge-shaped, faulted block in which the (Noranda) Horne ore deposits occur. These consist of bands of stratified tuff or fine breccia up to 10 feet wide interbedded with unstratified breccia at intervals of 10 to 40 feet or more. The easterly zone crosses the fault block in a northwesterly direction adjacent to the No. 3 and No. 4 shafts. It has a variable dip, but in general its attitude is vertical or very steep to the southwest. The westerly zone extends in a west-northwest direction across the Horne property on the north side of the andesite fault (*See* Figure 1). Its dip is 80 degrees to the north, and hence about parallel with that of the fault. When the map of Rouyn area was prepared this zone was known to be exposed in outcrops and in the mine workings from the Canadian National Railway eastward to a point south of the mine office building. Recently, however, in excavating for a tailings pipe-line a new exposure of stratified rhyolite tuff and breccia was laid bare adjacent to the Macamic highway. It is probable, therefore, that the zone extends northwesterly to meet the Horne Creek fault at the eastern end of Tailings Lake. The lithological similarity of the two zones of stratified rhyolite tuff and breccia suggests that they were originally parts of the same band and have been crumpled into their present positions by folding.

In the extreme northeastern part of the Newbec area of rhyolite and rhyolite breccia, and in the areas of Powell-Rouyn rhyolite (*See* Figure 1), there are zones of stratified material, presumably tuff, included in the rhyolite. The peculiar features of this rock are its fine-grained texture, its finely cavernous or pitted, weathered surface, and the presence of disseminated blebs of quartz, presumably phenocrysts. The zones of banding and lamination in the Powell-Rouyn rhyolite with one exception trend northeasterly across the schistosity and have been more or less crumpled or faulted. The bands vary in colour from dark to light grey and range in width from one-sixteenth inch to 6 inches. Some of the zones have a sharply defined contact on the southeast side. One of the banded zones contains blebs of quartz similar to those present in the rhyolite elsewhere. Microscopic examination of this rock shows it to consist of phenocrysts of quartz and albite in a matrix of granular quartz and feldspar. The quartz grains are cracked or in some cases broken, and the albite phenocrysts are in places crossed by zones of granulation. The phenocrysts, in places, occur in areas that appear to be separated from the surrounding matrix by a boundary indicated by a change in texture. Minute fractures filled with sericite traverse the section.

Siliceous Rhyolite

This rhyolite differs from the rhyolite previously described in having a much higher silica content, in the greater abundance of spherulitic structure present, and in the entire absence of the coarse breccia phase so characteristic of the more nearly normal rhyolite. In places the weathered surface has a hackly appearance or exhibits numerous, irregular, rusty weathering depressions about one-half inch deep, suggesting that the rock was originally vesicular to scoriaceous. In many of the siliceous rhyolite outcrops lamination is strikingly developed. The laminæ range in width from one-twentieth to one-one hundredth of an inch and lie one-twentieth inch or less apart. In places they occur in curving zones up to 10 feet wide and continue for 20 or even 30 feet. The spherulitic structure where most strikingly developed consists of an abundance of circular grains, about one-thirtieth inch in diameter, closely compacted together. Examined microscopically the siliceous rhyolite, where not wholly spherulitic, is found to consist of numerous, small, micropegmatitic intergrowths of quartz and feldspar, in part spherulitic, intermingled with irregular grains of granular quartz. In some thin sections small phenocrysts of quartz and albite, for the most part less than a millimetre in diameter, are present. Some of the phenocrysts of quartz are enclosed in micropegmatite that has grown radially around their margins. The quartz is all minutely cracked. Areas of disseminated microlites of sericite are present in places even in the least altered phases. A few aggregates of a green, chlorite-like mineral are also present.

Andesite, Andesite Flow Breccia, Pyroclastic Andesite Breccia, Andesite Tuff, and Chert

The belts of these rocks consist almost wholly of a grey-green to rusty brown weathering andesite of uniform composition, but of variable physical character. The most common of these physical variations are massive andesite, pillowed andesite, rounded andesite breccia, and angular to sub-angular andesite breccia. Other features confined largely to the massive or pillowed phases are columnar jointage, amygdaloidal structure, lamination, and mesh fracturing. Most of these are structural rather than lithological variations and are, therefore, described in the part of the report having reference to structural features of the rocks.

The massive andesite is a uniform-textured variety and constitutes about one-third of the area occupied by the rock. It may form almost an entire lava flow, but more commonly occurs either at the top or bottom of a flow or in irregular masses mingled with pillowed andesite. Where all but a few inches of breccia at the top of a lava flow is massive, the flow is thin, as in the Rouyn Station andesite (*See* Figure 1). Except for columnar jointing (Plate VA) in places and the presence of amydules, the massive andesite is uniform without variations of any kind.

Some of the lava flows occurring in the vicinity of the Waite mine are composed of an exceedingly variable andesite having a light green-grey, variegated appearance on its weathered surface. It is usually amydaloidal, contains aggregates or zones of flow breccia in places, and in most of its outcrops is characterized by concentric lamination, pillow structure, pahoehoe structure, and other evidence of flowage. The amygdules are for the most part small, but in places range in size up to 3 inches in diameter. On its freshly broken surface this rock is dark grey, fine grained, and, except for the amygdules, uniform, the brecciated structure and other variations seen on its weathered surface being indiscernible. Under the microscope, this phase of the andesite is seen to consist of lath-like crystals of feldspar (oligoclase to andesine), pale blue to yellow-green, fibrous actinolite, usually some granular quartz, a few grains of a black, opaque mineral, presumably magnetite, scattered aggregates of biotite, and, in some sections, epidote. The last two minerals are products of rock alteration.

In the eastern part of Waite Hills, a few hundred feet west of the Macamic highway, there is a north-northwesterly trending andesite flow about 200 feet thick that weathers paler grey than the normal andesite. It is very fine grained, roughly jointed, and flinty looking. Under the microscope it is seen to consist of phenocrysts of andesine and quartz in a matrix of small, rod-like crystals of andesine and aggregates of actinolite. The andesine is largely altered to epidote.

For about 1,000 feet along the Pontiac-Rouyn road, to the north of the east shaft in the Powell-Rouyn property, there are outcrops of a grey-green weathering, andesite-like rock in which zones having a banded structure alternate with zones having round, sericitic protuberances up to one-half inch in diameter. The banded zones consist of light grey bands one-sixteenth to one-eighth inch wide alternating with darker bands one-eighth inch to 2 inches wide. The strike is north 55 degrees west, and the dip steep to the northeast. Across the Macamic highway to the east of these outcrops, banded, andesitic rock, almost certainly the continuation of the same zone, outcrops beneath the Héré Creek rhyolite breccia (*See* Figure 1). It is intruded by diorite, but in one locality is almost continuous over an area about 400 feet long by 100 feet wide. The strike of the banding is north 68 to 73 degrees west, and the dip 65 degrees to the northeast. In a stripped area about 1,000 feet farther to the southeast there is an isolated exposure of the banded, andesitic rock in contact with diorite. In this occurrence fine-grained bands 1 inch wide alternate with bands of a more massive, coarser phase up to 2 inches or more wide, but within the coarser bands subsidiary laminæ are present in places. The strike of the banding and lamination is north 58 degrees west, and the dip steep to the northeast.

In the Glenwood property, at a point about 300 feet west of the Rouyn Lake road and between the Glenwood rhyolite and andesite (*See* Figure 1), there is a group of outcrops in which two flows of massive andesite are interbedded with a breccia consisting of subangular fragments of rhyolite and andesite in an andesitic matrix. The succession across the outcrops, from south to north, is as follows:

Glenwood rhyolite breccia	Feet
Unexposed	7
Massive andesite	26
Andesite-rhyolite breccia	27
Unexposed	5
Massive andesite	30
Andesite-rhyolite breccia	20-30
Massive andesite	16

The contacts of the andesite and the breccia are irregular in detail and in places are marked by rusty weathering, schistose zones. The contact at such places is indefinite and cannot be fixed within 2 or 3 inches. The fragments of andesite within the breccia for the most part range up to 2 to 3 feet in diameter. The proportion of rhyolite to andesite fragments varies greatly, but on the whole the andesite is more abundant in the northern part whereas the rhyolite predominates in the southern part of the breccia zones. The fragments of andesite are relatively coarse in texture. Lamination was noted in the andesite flows in places along their contacts with the breccia. The heterogeneity in the composition and texture of the fragments of breccia, the fragmental character of the matrix as shown by microscopic examination, and the absence of lamination or other characteristics of flows in the matrix indicate that this rhyolite-andesite breccia is of pyroclastic origin.

In the Chadbourne andesite belt to the west of Noranda and the Macamic road, and in the South Bay andesite (*See* Figure 1), there is an interbedding of andesite flows with breccia in a manner very similar to that just described in the Glenwood property. In the Chadbourne andesite ten or more flows of andesite 50 to 400 feet thick are separated by zones of rhyolite, rhyolite breccia, or andesite breccia ranging from 4 to 100 feet thick. All but one of these are too thin to show on the Rouyn area map and are indicated merely as flow contacts. The breccia in the three northern zones is andesitic; in the remaining zones, either the fragments or both the matrix and fragments are rhyolite. The fragments of the rhyolite breccia range up to 6 inches in diameter. The presence of lamination in the rhyolite in places indicates that these bands, in part at least, are lava. The breccia zones, however, may be of pyroclastic origin. Along the southern margin of most of the andesite flows there is a zone 10 to 20 feet wide of well-developed pillows; the remainder of each flow is massive. In the South Bay andesite belt (*See* Figure 1) zones of rhyolite breccia similar to those in the Chadbourne andesite were noted in four localities. They range in width from 5 to 40 feet. Pillow structure is common in the western end of the belt, but is absent in the eastern.

In numerous localities within the andesite, and in one case on its contact with rhyolite, there are zones of banded and laminated chert (Plate XIII). These obviously mark flow contacts and have been so indicated on the maps. The zones are, for the most part, 3 feet or less thick. They are usually rusty from the weathering of disseminated pyrite and pyrrhotite or less commonly chalcopyrite. In some places the lamination and banding of the chert is irregular or undulating following the surface of the underlying andesite. In other places the laminæ and bands converge into one another. The maximum continuously exposed length of chert observed was 200 feet, but in the territory southeast of the Waite-Ackerman-Montgomery mine remnants of chert occur here and there on an east dipping slope of andesite and andesite breccia for a length of 400 feet. In some of these localities the chert occupies depressions in the surface of the lava flow.

The greatest observed thickness of chert outcrops on the east slope of a knob of andesite about 50 feet north of the northwest shore of Turcotte Lake in Amulet map-area. In this locality the chert is rusty weathering, banded, and laminated. The bands range in width up to a maximum of 1 inch.

Some are impregnated with pyrrhotite. They appear to be gently folded so that on the surface the rock has a pattern like the grain of wood. The dip of the chert zone is in general to the southeast. The maximum exposed width is about 30 feet, but the thickness is only about 15 feet. In the high, rocky area at the extreme southeast end of the Rusty Ridge andesite belt, to the west of the Amulet mine, the easterly dipping contact of the andesite with the overlying Amulet rhyolite (*See* Figure 1) is marked by laminated chert irregularly interstratified with rhyolite breccia, probably of pyroclastic origin. A similar interstratification of rhyolite breccia and chert occurring along the southeast margin of the south ridge of andesite is shown in Plate XIII. At this point the dip is to the southeast, but in the next exposures to the southwest the bands of chert in the rhyolite breccia along the contact are vertical.

CHEMICAL COMPOSITION

Unusual features of the chemical composition of the lavas are: (1) the large proportion of soda in contrast with the small content of potash; and (2) the high silica content of the rhyolites. The chemical analysis in column 1 (Table I) is of typical siliceous rhyolite, that in column 2 of normal rhyolite, and that in column 3 of typical andesite.

TABLE I

—	1	2	3
	Per cent	Per cent	Per cent
SiO_2	85·11	78·78	54·02
Al_2O_3	7·97	11·21	15·67
Fe_2O_3	0·36	1·04	2·38
FeO	0·98	2·77	8·46
CaO	0·77	0·21	7·14
MgO	0·05	1·33	4·12
Na_2O	2·68	3·13	4·84
K_2O	0·89	0·80	0·64
H_2O+	0·50	0·56	0·77 }
H_2O-	0·03	0·19	0·04 }
Tio_2	0·25	0·28	1·63
P_2O_5	0·20	Trace	0·44
MnO	Trace	Trace	0·01
CO_2	Nil	0·22	Nil
S	0·07	0·02	0·09
Less O/S	0·05	0·01	0·07
Total	99·81	100·53	100·18

1. Spherulitic micropegmatitic rhyolite, from Duprat township, Abitibi county, Quebec, north of the Waite-Ackerman-Montgomery mine. Analysis by R. J. C. Fabry.
2. Rhyolite, Duprat township, Abitibi county, Quebec, west of the Amulet mine on the east of the Rusty Ridge a few hundred feet west of the Bedford trail. Analysis by R. J. C. Fabry.
3. Massive andesite, from Dufresnoy township, Abitibi county, 1,000 feet south of the Beaver Hill Geodetic Triangulation Station. Analysis by R. J. C. Fabry.

The siliceous rhyolite, of which column 1 is the analysis, consists chiefly of phenocrysts of quartz and albite in a matrix of granular quartz and micropegmatitic (partly spherulitic) intergrowths of quartz and feldspar, which the chemical analysis shows must be albite. The remaining constituents are a few scattered grains of iron ore, microlites of sericite partly disseminated and partly in aggregates, a few small scattered areas of a green, chlorite-like mineral, and widely scattered aggregates of carbonate. The rhyolite from which the sample for the analysis in column 2 was taken consists of phenocrysts of albite and spherulites in a matrix of granular quartz and micropegmatitic intergrowths of quartz and albite. The only other minerals noted are a few grains of magnetite and aggregates of sericite and chlorite. The andesite of column 3 consists chiefly of rod-like crystals of andesine, yellow-green to pale blue, more or less fibrous amphibole, and scattered grains of magnetite or ilmenite. The only other constituent observed is brown mica in scattered aggregates. It can be calculated from the chemical analysis that the andesine is of intermediate composition Ab_{67} An_{33}.

ALTERATION

The alteration that has taken place in the volcanic rocks may be classified as follows: (1) alteration occurring in contact zones adjacent to intrusives; (2) alteration found only in association with ore deposits; and (3) regional alteration not evidently associated with either intrusives or ore deposits. The alterations of the contact zone and ore deposit types are discussed in other parts of this report. Only the regional alteration, therefore, is described here.

The minerals resulting from alteration in the lavas are chiefly epidote, zoisite, chlorite, sericite, quartz, a carbonate (calcite or ankerite), brown mica, and albite. Most of these occur in both andesite and rhyolite, but epidote and quartz predominate in andesite whereas chlorite, sericite, and carbonate are most abundant in the rhyolite. Albite was observed as an alteration product only in the andesite.

Alteration in the andesite may be of a moderate type in which the original texture of the rock remains, or it may be extreme, in which case the original textural character of the rock has disappeared, either in places or throughout the whole rock. Where the original texture remains, the principal changes are the partial or complete replacement of the plagioclase by epidote, zoisite, chlorite, and sericite. The sericite where present usually occurs as microlites. The amphibole contained in the andesite is usually a fibrous actinolite. It is probably a recrystallization product derived from an original ferromagnesian mineral not now present. In some thin sections the amphibole is partly altered to chlorite. Brown mica in scattered aggregates was noted in some specimens examined microscopically. This mineral, however, characteristically belongs to the changes associated with ore deposits and is not typical of the regional alteration.

Examples of the more extreme type of alteration were observed in almost every part of the district, but chiefly where the andesite is cut by numerous fractures or by small faults. In a thin section of rounded andesite breccia occurring west of the Macamic highway to the south of Vauze Creek, the normal fine felt of plagioclase crystals is traversed by irregular zones composed of epidote, quartz, sericite, and albite. In the southwestern part of Dufresnoy township about 1,500 feet south of the McDougall shaft a group of outcrops of the Amulet Hills andesite (*See* Figure 1) are buff to dull grey weathering. This rock under the microscope is seen to consist of abundant chlorite in irregular areas and zones, sericite sparingly disseminated or concentrated in areas, granular quartz, and irregular grains of feldspar too much altered for further identification. Texturally the rock resembles rhyolite. A vein of quartz cuts across the thin section of the rock examined. In places in the Powell and Pontiac-Rouyn properties there is andesite with round or elliptical-shaped protuberances on its weathered surface, which microscopic examination shows to consist predominantly of green chlorite and of sericite in isolated microlites, streaks, or aggregates. The lighter weathering areas seen as protuberances on the weathered surface are highly sericitic. The rock also contains irregular areas of granular quartz.

One of the most conspicious and widespread changes in the andesite is the development of epidotic rock or epidosite. This occurs chiefly in masses up to 8 feet long and 4 feet wide, but also along seams and fractures. Under the microscope the epidosite is found to consist of irregular, interlocking grains of epidote and irregular areas of granular quartz, the epidote forming three-quarters of the rock. Small masses of epidosite are also present in the rhyolite and rhyolite breccia in places, but they are far more abundant in the andesite. They are especially common where pillow structure is present, as many as three masses occurring within a single pillow. In places they lie along the contacts of pillows or cut across the contacts. In a rock face about 1,800 feet east-southeast of the Waite-Ackerman-Montgomery shaft, elongated masses of epidosite occur at regular intervals in uniform rows about 1 foot apart, parallel with the strike and dip of the lava flow.

The intensity of alteration in the rhyolite and rhyolite breccia is directly proportional to the degree to which they have been deformed, so that in the rhyolite belts of the Amulet and Waite map-areas where the rocks have been gently folded, alteration is moderate, whereas in the region south of the Horne Creek fault where the rocks are highly folded and much sheared the alteration has been intense.

As the typical rhyolite consists mainly of quartz and albite, alteration of moderate intensity occurs almost wholly in the feldspar and has resulted chiefly in the formation of microlites of sericite. These are especially abundant in the phenocrysts of albite. Small, scattered, irregular areas of carbonate are also present in many thin sections. In a few sections the sericite follows an irregular fracture or forms solid aggregates either in the plagioclase phenocrysts or in the matrix. In the latter case replacement of both quartz and albite has taken place. Other less common alteration products are a few scattered areas of epidote or green chlorite (penninite).

Wherever the rhyolite or rhyolite breccia has undergone deformation it is intersected by roughly east-west trending, anastomosing, greenish yellow weathering zones of schistosity up to one-half inch wide. These occur in places in the Newbec and Héré Creek rhyolite areas, but are especially common in the Glenwood and Lake Trémoy rhyolite areas (*See*

Figure 1). Under the microscope the schistose zones are seen to consist almost entirely of sericite. Between the sericite zones, areas or zones of green chlorite (penninite) are abundant. In most of the thin sections the sericite zones appear to enclose the chlorite and carbonate areas. The only other alteration products noted in the highly altered rhyolite are epidote in scattered grains or aggregates of grains and a few aggregates of brown mica.

STRUCTURAL FEATURES

The features of the volcanic rocks that are usually classed as structural or are of use in determining structure are: (1) structures developed internally in the lavas because of the presence of volatile constituents, because of movement in the lava, or other causes; (2) flow contacts within lava belts; (3) the lava belts; and (4) the bedding of pyroclastic rocks.

Amygdules. Amygdules are exceedingly abundant in both the rhyolite and andesite. They range in size from one-sixteenth inch or less up to 3 inches in diameter, but are for the most part small. They are filled chiefly with quartz, epidote, or amphibole. In many, quartz and epidote occur together, the epidote as a rule occupying the central, and the quartz the outer, part. Many of the amygdules, especially in the rhyolite, have an elliptical form throughout considerable areas, due presumably to movement in the lava after the cavity occupied by the amygdule was formed. In places in andesite the amygdules in pillows are elongated radially from the interior towards the margin of the pillows. These belong to the type known as pipe amygdules.[1] In many pillows the amygdules are either restricted to the outer part or are more abundant in the outer part. In a very few pillows the amygdules are confined to the upper part.

Spherulites and Related Micropegmatitic Intergrowths. Micropegmatitic intergrowths of quartz and albite, a large part of which have a spherical form and radial structure, are exceedingly common in the normal rhyolite, and are especially abundant in the siliceous variety. They do not occur in andesite. Spherulitic intergrowths of quartz and feldspar are a characteristic feature of acid lavas and have been described by numerous geologists and petrologists. Practically all authors agree that spherulites and related micropegmatitic intergrowths form during the late stages of crystallization of rhyolite and that their formation is promoted by the presence of volatile components. This conclusion is confirmed in the case of the rhyolites of Noranda district by the finely cracked condition of the quartz, which according to Wright and Larsen is evidence that this mineral has crystallized at a temperature above its inversion point of 575 degrees Centigrade.[2]

Columnar Structure. Columnar jointing is well developed in places both in andesite and rhyolite. In andesite it is most common in the Rusty Ridge and the southern part of the Amulet Hills belts (*See* Figure 1). In rhyolite it was noted in the Amulet belt to the west of the Amulet mine and throughout a wide area in the Héré Creek rhyolite (*See* Figure 1) in the northwest part of Rouyn township. The individual columns in

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[1] Du Toit, A. L.: Pipe Amygdaloids; Geol. Mag., vol. 4, 1907, pp. 13-17.

[2] Quartz as a Geologic Thermometer; Am. Jour., Soc., vol. 27, 1909, p. 437.

andesite range from 8 inches to 2 feet or more in diameter; those in rhyolite from 3 inches to 7 inches in diameter. At the highest point of the Rusty Ridge belt of andesite there are well-developed columns (Plate VA), along the contacts of which light grey weathering zones 2 to 7 inches wide are present. This is obviously the result of alteration. At another locality in the Rusty Ridge andesite belt a groove 2 inches deep occurs along the joint planes on the weathered surface of the andesite. If the columnar jointing in these lavas had originally, as is probable, a vertical attitude, then the present attitude of the columns indicates the dip of the lavas.

Pillow Structure. The most extensively developed structures in the volcanic rocks, and one of the most useful in determining the way in which the lava flows have been folded, are the forms known as pillows. They are present in at least half of the andesite exposed within the area mapped. They do not occur in rhyolite having a granular or micropegmatitic quartz-albite matrix. They were observed, however, in five localities in the dacitic phase of the rhyolite that occurs in places within the rhyolitic belts. They most commonly occur at or near the bottom of the lava flows but may occur at the top, or as in Vauze Creek area (*See* Figure 1) throughout an entire flow. Less commonly they form in the middle of a lava flow. In some flows a zone of massive andesite 20 feet or more thick intervenes between the pillows and the base of the flow. In an unusual flow along the east margin of the Waite Hills andesite area (*See* Figure 1) this basal massive zone is over 800 feet thick.

The pillows range in size from a diameter of a foot or less to masses 10 feet long and 3 feet or more wide. They are separated from one another by rusty weathering depressions normally from ¼ to 1 inch wide, which merge into gore-shaped areas several inches in diameter where three pillows meet. The margins of the pillows in many places are noticeably finer grained than their interiors, in many pillows there is a zone of amygdules along the margin or less commonly along the top. Where amygdules are present throughout a pillow, they are more abundant along its border. In many places the outer parts of the pillows are laminated, the laminæ trending parallel to the margin of the pillow (Plate VI A). In some pillows there is a buff or deep green zone up to 3 inches wide along the margin. These zones in some places are marked by intersecting grooves on their weathered surfaces similar to those observed along the borders of some of the basic dykes or sills.

Wherever pillow structure is seen in transverse sections, most of the pillows have round tops and are either flattened on their under sides (bun-shaped) or have adjusted themselves to fit the "V-shaped" depressions between the tops of the pillows below (balloon-shaped). In the rock face shown in Plate VI B there are three types of pillows: (1) large mattress-like pillows (in the lower right hand corner of the photograph) having flat surfaces both above and below; (2) bun-shaped pillows; and (3) balloon-shaped pillows. One of the balloon-shaped pillows rests on two bun-shaped pillows and has, therefore, a modified form with two V-shaped extensions at its base. At least two-thirds of the pillows seen in Plate VI B are bun-shaped and between one-third and one-quarter are balloon-shaped. In plan, that is in sections parallel to the dip of lava flows, the pillows are round or nearly round. The round tops, and the flat or V-shaped under sides of pillows resulting from their adjustment to the tops of underlying pillows, is important in ascertaining the structure of the rocks, for it permits the determination of not only the strike and dip of the pillow lavas but also the upper sides of the flows.

Lamination. Lamination is a common feature of both the rhyolite and andesite. It is especially common and finely developed in the siliceous rhyolite, the individual laminæ ranging from one-twentieth to one one-hundredth inch in width. Lamination associated with spherulites in normal rhyolite are shown in Plate XII. In places in the Amulet rhyolite west of the Amulet mine and near its contact with the Bedford rhyolite (*See* Figure 1), zones of banding and lamination outcrop at intervals for varying distances up to 600 feet or more. These zones range from 1 to 7 feet or more in width, strike east or southeast, and dip south at an angle of about 45 degrees. They are sharply defined along their north sides, but fade away into normal rhyolite along their south edges. They consist largely of thin, dark and light grey laminæ in bands a foot or more wide alternating with zones of spherulites up to 3 inches wide. The spherulites weather as small, round protuberances and range from one-twentieth to one-half inch in diameter, but are usually of uniform size in the same band. In one outcrop in the western part of the Amulet property the spherulitic zones are from one-fifteenth to one inch wide. In the Bedford rhyolite area (*See* Figure 1) adjacent to its contact with the andesite of the Rusty Ridge belt, the laminæ are about one-fortieth inch wide and are spaced about one-twentieth inch apart. Under the microscope the laminæ are seen to consist chiefly of the products of alteration, sericite and chlorite.

Concentric lamination is characteristically developed in andesite in many localities. The laminæ are spaced much farther apart than in the rhyolite and are more discontinuous. In some places they follow the margins of pillows (Plate VI A), but they are also common where pillow structure is absent. The laminæ are from one-fiftieth to one-fifth inch wide, the width increasing according to their distance apart. One of the best examples of widely spaced laminæ occurs near the crest of the andesite ridge south of the No. 4 shaft in the Amulet property. At this point, the laminæ are 2 to 3 inches apart and curve gently to the west for 30 feet. On the weathered surface of the andesite the laminæ appear either dark green or grey, chiefly the former. The grey laminæ consist of quartz and the green chiefly of amphibole with a small proportion of quartz.

Mesh-fracturing. Fractures along which silification has occurred are common in some belts of both the rhyolite and andesite. This feature is most characteristically developed in the rhyolite of the Amulet and Bedford areas (*See* Figure 1). In andesite it occurs most extensively in the Rusty Ridge belt and in the southern part of the Amulet Hills belt (*See* Figure 1). The typical mesh-fracturing in the rhyolite consists of minute branching fractures. A more strongly developed variety in amygdaloidal rhyolite is shown in Plate XI A. In andesite the mesh-fracturing takes the form of a rough network. Where it occurs in pillows (Plate IX A) the fractures radiate in a very imperfect way towards the margin. It is probable that most if not all of the mesh-fracturing developed during the consolidation of the lava and has no relationship to regional deformation.

Breccias. Breccias formed in the lavas during their extrusion (flow breccias) and breccias composed of ejected volcanic material (pyroclastic breccias) are both present in the district. By far the greater part of the breccias are of the flow type, however. It is difficult, especially in some isolated outcrops, to distinguish flow breccias from those of the pyroclastic type. Where the matrix of the breccia contains phenocrysts, amygdules, flow lamination, and other features characteristic of lava the rock is obviously flow breccia. On the other hand, where the breccia is interbedded with uniformly stratified tuff or is itself stratified in part it is almost certain that it is of pyroclastic origin. It was also noted that in the flow breccias the fragments are commonly spaced a considerable distance apart, whereas in the pyroclastic breccia they are usually closely compacted together.

Rhyolite flow breccia is especially abundant, forming a large part of many of the rhyolite belts. Except in a few localities where it occurs as a narrow zone along the tops of flows, it has an irregular distribution without relationships to the strike or dip of the lava flow of which it is a part. In most occurrences the fragments are angular to subangular (Plate X B) and equidimensional, but in places, notably in the dacitic flow along the eastern margin of the Vauze Creek rhyolite belt (*See* Figure 1), they are ribbon like in form. The flow breccias were presumably formed by the engulfing of fragments of lava crust either within the volcanic vent or while the lava was being extruded. The "ribbon" breccia shown in Plate IX B was almost certainly formed by the breaking up and crumpling of a thin crust of lava. In this case the side of a fragment originally in contact with the air, if not re-fused, would be more sharply defined than the margin originally in contact with the hot lava. This is illustrated by some of the fragments of the ribbon breccia.

The most extensive areas of pyroclastic rhyolite breccia are the two zones occurring within the wedge-shaped rock mass that lies between the Horne Creek and Andesite faults. The easterly of these zones trends in a northwesterly direction across the fault block adjacent to the No. 3 and No. 4 shafts of the Horne mine, and the westerly in a west-northwest direction adjacent to the north side of the Andesite fault from the Macamic highway to the Horne mine main workings. The fragments of this breccia range in size from grains one-sixteenth inch to fragments 1 foot or even 2 feet in diameter. In many zones, however, as in Plate X B, all the fragments are small. As the Noranda breccia is stratified in part and includes zones of stratified tuff, it is concluded that it was formed by the ejection of volcanic material into a standing body of water, presumably a lake.

The andesite breccias like the rhyolitic breccias are chiefly of the flow type, but there are a few occurrences that are probably of pyroclastic origin. The andesite flow breccia is mainly of the type shown in Plate VII B, consisting of well-rounded masses up to 2 feet or more in diameter enclosed in a fine or less brecciated andesitic matrix. The most extensive development of this breccia occurs in the eastern part of the Waite Hills andesite (*See* Figure 1). It is also common here and there in the Dune Creek-Rusty Ridge belt (*See* Figure 1). Much of the breccia that occurs at the top of flows is of this type. It is probably formed by the breaking up and engulfing of a thick crust and sufficient re-fusion of the margins of the fragments to give them a rounded outline. In the face of the rock cut on the west side of the railway at Rouyn station there is a succession of thin, east trending lava flows partly covered by glacial drift. The flows range in width from 10 to 40 feet. They consist almost wholly of dense, massive andesite with well-defined flow contacts. On the south side of the contacts the margin of each flow is marked by a zone of breccia 3 to 6 inches thick. On the north side, on the other hand, the margins consist of massive andesite with a well-defined edge against the breccia. The zones of breccia are composed of round, sausage-like to tabular-shaped fragments lying roughly parallel to the strike. This breccia is, no doubt, the broken top of the flow.

The most typical breccia of the ejected type in the area is that occurring in the Glenwood property, previously described. Another occurrence of breccia that may be of pyroclastic origin is that outcropping near the water-tank a few hundred feet southwest of the Amulet No. 4 shaft (Plate VIII A). This consists of closely compacted fragments of andesite from ½ inch to 6 inches in diameter, enclosed in a fine, fragmental matrix.

Flow Contacts within the Lava Belts. Flow contacts are numerous and conspicuous in the andesite, but are either uncommon or indiscernible in the rhyolite. The typical features that distinguish the flow contacts in andesite are: (1) a zone of breccia from 3 inches to 20 feet thick along the top of the flow; (2) a bed of laminated chert 3 feet or less thick lying along the contact; and (3) a zone of lamination up to 4 inches wide along the base of the flow above the contact. Individual flow contacts can be followed in successive outcrops for 2,000 feet or more. The line of contact is usually definite, but its trend, in detail, is irregular or sinuous.

Typical flow contacts in rhyolite were observed in only two localities, both in the Newbec rhyolite area (*See* Figure 1). One of these is exposed in the northeast slope of an outcrop on the west side of the Macamic highway about 2,000 feet north of Vauze Creek. In this locality the rock south of the contact is a dull grey variety consisting of fine, rod-like crystals of oligoclase altered in places to sericite, carbonate, or chlorite. Along the contact, which strikes northwesterly and dips northeasterly at an angle of about 40 degrees, there is a zone of breccia composed of fragments of rhyolite enclosed in and intersected by a dark grey, very fine-grained, flint-like rhyolite. Above the contact, there is grey weathering, finely laminated rhyolite. The other contact occurs in an outcrop of rhyolite intruded by diorite that adjoins the Canadian National Railways to the north of Vauze Creek. In this locality laminated rhyolite rests on a cavernous-weathering breccia. The contact for the most part is definite but very irregular. Its dip is to the northeast. The massive rhyolite is banded and laminated in a zone 1 to 3 inches wide adjacent to the contact at intervals up to 10 feet. The rock below the contact is a pale grey to greenish grey weathering rhyolite and rhyolite breccia.

Lava Belts. Owing to the weathered, bare condition of the rocks, there is little difficulty in distinguishing the successive lava belts, the rhyolite having in general a pale grey appearance in contrast with the grey-green weathering andesite. As the surface of lava flows is commonly more or less irregular, the dip and strike of the contacts between flows are less uniform in detail than those of the bedding of sediments. In general, however, the contacts of the lava belts trend sinuously from north to south and dip eastward in the northern part of the area, whereas in the southern part they strike approximately east and dip steeply to the north or are vertical. In the north the folds are broad and plunge easterly at angles of 25 to 35 degrees. In the south, on the other hand, the folds are vertical or nearly vertical and plunge steeply towards the east.

In detail the contacts of the belts of lava vary greatly in different localities. One of the best exposed and most irregular is that between the Bedford rhyolite and Rusty Ridge andesite (*See* Figure 1). This contact, which is well exposed in a high rock knob in the western part of Amulet map-area, is for the most part sharply defined. In one locality, however, fragments of rhyolite occur in the andesite for 3 feet from the contact, and at another point the two rocks are intermingled in a zone 6 feet wide. As indicated on the map, the trend of the contact is most irregular. On the top of the hill, at one point a mass of andesite 8 feet long and 4 feet wide projects into the rhyolite; at another point, the contact turns abruptly northward for 30 feet; and farther down the hill to the east, a tongue of andesite projects southward more than 100 feet into the rhyolite. East of this point a triangular-shaped mass of andesite appears to be included in the rhyolite. At the west end of the rock area some movement has evidently occurred along the contact, for the andesite is broken adjacent to the rhyolite in a zone 30 feet wide. The dip of the contact ranges from 25 degrees northeast to 85 degrees southwest, but is in the main vertical or nearly vertical.

In the northwestern part of Waite map-area there is a large outcrop, the western extremities of which belong to the Dune Creek andesite and the main eastern part to the Amulet rhyolite and rhyolite breccia belt (*See* Figure 1). Near the south end of this exposure there is a westerly curving extension, at the tip of which andesite forms a northeasterly trending zone 4 to 15 feet wide along the face of a scarp 25 feet high. The contact of the andesite with the rhyolite is more or less irregular and indefinite within a width of one inch. It has a vertical attitude at the top of the scarp, but bends southeasterly towards the bottom. The average dip is about 75 degrees. The andesite is amygdaloidal, rusty brown, cavernous weathering, and contains fragments of rhyolite up to 2 inches in diameter in a zone 6 inches wide adjacent to the contact. The rhyolite where it adjoins the contact is finely pitted on its weathered surface for a width of 6 inches to 1 foot.

In the group of outcrops at the southeast end of the Rusty Ridge andesite belt the contact of the andesite with the Amulet rhyolite (*See* Figure 1) is exposed for considerable lengths. Along the northeast margin of the belt the contact is well defined, and dips about 35 degrees northeastward. The rhyolite adjacent to the contact is laminated in zones 2 to 4 inches wide. On the top of the ridge to the southward, the andesite for 8 feet and the rhyolite for 4 feet from the contact is cut by veins of dark quartz, from a fraction of an inch to 1 foot wide, trending parallel the contact. From this point south along the contact, wherever it is exposed, zones of laminated chert interstratified with rhyolite breccia, probably of pyroclastic origin, occur. At the east end of the middle ridge of the group of outcrops the dip is about 30 degrees eastward. A similar interstratification of chert and rhyolite breccia occurs along the southeast margin of the belt, as shown in Plate XIII. In this place the dip is to the southeast, but in the next exposure to the southwest rhyolite breccia containing discontinuous zones of chert is in vertical contact with the andesite.

Along the trail that extends northwesterly from the Waite-Ackerman-Montgomery mine, at a point about 1,200 feet north of Duprat Creek, the contact of the Waite Hills andesite and the Waite Lake siliceous rhyolite area (*See* No. 7, Figure 1) is exposed in two places near the south tip of the rhyolite area. On the west side of the trail patches of rhyolite rest on the north and southeast slopes of an outcrop of andesite. On the north slope, owing to the irregularity of the contact, the rhyolite and andesite appear to be intermingled; on the southeast slope, on the other hand, the rhyolite occurs in a single sharply defined area. On the east side of the trail the rhyolite is exposed near or adjacent to the andesite in two rock areas. In the more southerly of these the rhyolite outcrops for a width of 40 feet beneath massive andesite. Dykes of rhyolite and andesite have been intruded along the contact except at one point where the rhyolite and andesite adjoin one another for 5 feet. The contact is sharply defined and dips at a low angle to the south. A zone of fine lamination 6 inches wide occurs in the rhyolite along its margin.

In the south face of an outcrop about 200 feet southwest of Waite Lake the contact of the western arm of the Waite Hills andesite and the Waite Lake rhyolite (No. 6, Figure 1) is exposed. In this exposure rhyolite flow breccia rests on andesite, the contact dipping 50 degrees to the east (Plate VIII B). The most important feature of this contact is the presence of lamination in the andesite parallel to the contact. The lamination is obviously associated with the original surface of the lava flow and indicates that no erosion occurred during the interval that elapsed between the extrusion of the andesite and the rhyolite flow breccia.

The volcanic rocks have been folded into four major anticlines with intervening major synclines. These with their names are shown in Figure 1. The Quebec-Copper anticline is best developed in the Quebec-Copper property in the northwestern part of Waite map-area. The actual contacts of the lava belts are not exposed along the axis of the fold, but at the point where it crosses the contact of the Amulet rhyolite and the Waite Hills andesite the rhyolite passes beneath the andesite at an angle of 30 degrees. On either side of the axis of the fold broad subsidiary anticlines occur, as shown by the eastward curvature of the contacts of the Amulet rhyolite with the Dune Creek andesite (No. 3, Figure 1) on the west and the Waite Hills andesite (No. 4, Figure 1) on the east. The axis of the Waite anticline lies about 1,500 feet south of the Waite-Ackerman-Montgomery mine and strikes east-west. The contact of the Amulet rhyolite and the Waite Hills andesite close to the axis dips 35 degrees east, but farther to the east and northeast flow contacts dip 25 degrees east and 30 degrees southeast, respectively. It is probable, therefore, that the average plunge of this anticline is not more than 30 degrees. The major axis of the Amulet anticline lies near the C or No. 4 shaft in the Amulet property and strikes a few degrees north of east. The axis of the Noranda anticline trends east-northeasterly and about parallel with the Horne Creek fault (Figure 1). The plunge at the Horne mine as determined from the dip of the contact of the

Noranda rhyolite and the Lake Trémoy andesite (No. 21, Figure 1) is about 55 degrees. Farther east on the anticline, in the Ville Marie property, stratified rhyolite tuff occurs striking north and dipping 80 degrees east. Crossbedding in the eastern part of this zone shows that the top is to the east.

The mapping of the lava belts affords evidence of the presence of numerous faults, the existence of most of which would otherwise be entirely unknown. Some of the most important of these are the Vauze Creek fault zone, the McDougall fault, the faults in the Powell and Pontiac Rouyn properties in the central part of Rouyn map-area, the Horne Creek fault, and the Bagamac fault.

THICKNESS

The lava belts are so irregular and have been so much faulted that it is not possible to determine their thickness accurately. An approximate estimate of the thickness of each belt has been attempted. In making these estimates it has been assumed that the several areas of siliceous rhyolite outcropping in Waite map-area were originally part of a single belt, and that the Waite Lake and Vauze Creek belts of rhyolite (*See* Figure 1), both of which underlie the Waite Lake siliceous rhyolite, are parts of a single belt. It has been further assumed that the Powell-Pontiac andesite is the southern continuation of the Amulet Hills andesite belt. The average thickness is assumed to be half the combined maximum and minimum thickness.

Some of the lava belts lying north of the Horne Creek fault apparently are repeated south of the fault, and for that reason not all the belts south of the fault are to be included in estimating the total thickness of lavas present. The Osisko Lake andesite is included in the estimate because, as explained later in this chapter, the rocks on the north side of the Horne Creek fault that are equivalent to this belt probably lie 2 miles east of the area studied. There is little probability that the Lake Trémoy andesite is represented anywhere in the area mapped north of the Horne Creek fault, and the same is probably true of the Noranda rhyolite. The South Bay andesite lying north of the fault and the Chadbourne andesite to the south of the fault resemble one another lithologically and may, therefore, be parts of one belt. If this is so, then the Osisko Lake rhyolite, which underlies the Chadbourne andesite, may be equivalent to the part of the Héré Creek rhyolite underlying the South Bay andesite. It is also possible that the areas of rhyolite and andesite (Glenwood andesite, Rouyn Station andesite, and Glenwood rhyolite) south of the Lake Trémoy rhyolite are stratigraphically the same as lavas farther north. For this reason the thicknesses of these have been omitted from the tabulation. Within the Noranda fault block there are two zones of rhyolite breccia and tuff, one of which extends in a northwesterly direction across the fault block where the ore deposits occur and the other along the north side of the Andesite fault from the Macamic highway eastward as far, at least, as the most westerly of the Horne mine buildings. If these two zones are not equivalent to one another then, presumably, there is a succession of rhyolite, rhyolite breccia, and tuff within the Noranda fault block having a total thickness of about 4,000 feet. The two belts of breccia and tuff are so much alike, however, that it is probable they are equivalent to one another, and that within the fault block there is an anticline a part of the south limb of which has been dragged westward along the Andesite fault. If this is so, 1,000 feet of breccia and tuff must be deducted because of duplication by folding. The thickness is, therefore, assumed to be 3,000 feet. The total thickness of the volcanic rocks included in the table is about 25,000 feet.

TABLE II

Thickness of Volcanic Rocks

Name of belt	Assumed average angle of dip	Thickness		
		Minimum	Maximum	Average
	Degrees	Feet	Feet	Feet
Northwest-Bedford rhyolite........	30	....	....	1,600
Dune Creek-Rusty Ridge andesite.	30	Nil	1,400	700
Amulet rhyolite..................	30	600	2,500	1,550
Waite Hills-Amulet Hills-Vauze Creek-Powell-Pontiac andesite..	30 (northern part)	800	11,000	5,900
Vauze Lake rhyolite..............	30	150	400	275
Vauze Creek-Waite Lake rhyolite..	30	Nil	750	375
Waite Lake siliceous rhyolite......	30	Nil	2,000	1,000
Andesite in northeast part Waite area.........................	30	80	120	100
Newbec-Héré Creek rhyolite.......	30	2,000	4,000	3,000
Newbec andesite.................	30	250	400	325
Area Creek andesite..............	45	200	200	200
South Bay andesite...............	90	Nil	800	400
Brownlee rhyolite................	60	....	....	4,000
Total..............	....	....	....	19,425

South of Horne Creek Fault

Noranda rhyolite.................	90	....	....	3,000
Lake Trémoy andesite............	90	....	....	1,000
Chadbourne andesite..............	90	2,000	2,000	2,000
Lake Trémoy rhyolite............	90	2,000	2,000	(2,000)
Glenwood andesite...............	90			
Rouyn Station andesite...........	90			
Glenwood rhyolite................	90			
Total..............	....	....	....	6,000

Summary

—	Rhyolite	Siliceous rhyolite	Andesite	Total
	Feet	Feet	Feet	Feet
North of Horne Creek fault.............	10,800	1,000	7,625	19,425
South of Horne Creek fault.............	3,000	....	3,000	6,000
Total.....................	13,800	1,000	10,625	25,425

QUARTZ DIORITE, DIORITE, GABBRO, DIORITE PORPHYRY, AND ALBITE GRANITE

The oldest intrusives that occur extensively in the district are quartz diorite and associated related rocks that have intruded the volcanic rocks in the form of dykes, sills, and irregular masses.

The dioritic intrusives are found in all parts of the area mapped. The largest occurrence is the wide, dyke-like belt that, except where it is interrupted by the Dufault Lake granodiorite stock, extends continuously from north to south for a distance of about 6 miles along the west boundary of Dufresnoy township. It has a width ranging from 1,000 to 4,800 feet. In the northern part of the Waite area offshoots of the mass cross the lava belts both to the east and west. The eastern offshoot connects with intrusions lying approximately parallel the strike of the lavas.

Lithological Character. The dioritic intrusives are predominantly quartz diorite, but in some of the dykes and smaller masses, or in places within the larger masses, diorite, gabbro, diorite porphyry, or albite granite are also present. The quartz diorite where it occurs in small masses, dykes, or sills is a uniform-textured, grey-green to rusty brown weathering rock, but throughout most of the large masses it is an exceedingly variegated rock both in texture and in the distribution of its minerals. Coarse- and fine-grained phases occur heterogeneously mixed, one phase fading into the other. In places white weathering zones or masses of feldspar are common, whereas at other points the ferromagnesian minerals form masses of amphibolite several feet in diameter. The most extensive area of the white feldspathic phase observed occurs in the Newbec map-area, adjacent to and east of the Canadian National Railway. In this locality, outcrops of the feldspathic phase are sufficiently free from amphibole to be almost anorthosite. In a few places the quartz diorite merges into graphic granite or pegmatite. In one occurrence of this rock adjacent to the road to the Waite-Ackerman-Montgomery mine near Duprat Creek a branching amphibole is present. This arborescent type of amphibole was observed in several localities in the Dufresnoy diorite mass. One of the most striking occurrences is that in the cliff northeast of Waite Lake where growths 2 feet or more long were noted. Throughout a large part of the quartz diorite, especially in the Dufresnoy mass, small dykes of aplite, ranging from an inch or less up to 1 foot in width, are common. In a very few localities banding was noted in the quartz diorite, light grey zones 1 to 2 inches wide in which ferromagnesian minerals are less abundant alternating with dark grey zones of normal composition 2 or more inches wide. In the southern part of the town of Rouyn and in the area adjoining Fourcet Creek these strike east-west and are vertical or dip steeply to the north. In the Dufresnoy mass they strike approximately north-south and are vertical or nearly vertical.

Examined microscopically the typical quartz diorite is found to consist chiefly of prism-shaped crystals of plagioclase, largely altered to epidote or zoisite, but where unaltered ranging in composition from acid to basic andesine, and an abundance of more or less fibrous, pale blue-green to yellow-green actinolite. The less abundant constituents are quartz, in part in micropegmatitic intergrowth with feldspar, apatite, and scattered, irregular grains of a black, opaque mineral, either ilmenite or magnetite or both. The quartz, which is intersected by minute cracks, in some sections forms 10 per cent more of the rock. In some places in the diorite, chlorite and, less commonly, brown mica are associated with the amphibole and are evidently alteration products from it.

In several localities a basic-looking phase of the dioritic intrusives, which contains augite, is present. This mineral was noted at the following localities: in a dyke outcropping about 1,200 feet south of Beaver Hill; in a wide area within the Dufresnoy dioritic belt to the southwest of the westerly bend in the Macamic highway near the outlet of Duprat Creek; on the south shore of Sergius (Moose) Bay, Dufault Lake, to the east of the Canadian National Railways, Taschereau branch; and in a rock cut on the Nipissing Central Railway north of Rouyn station. The rocks in all these occurrences are dark grey, all moderately coarse textured and contain rod-like to tabular crystals of plagioclase ranging from andesine of intermediate composition to acid labradorite. The augite is a light buff variety in various stages of alteration to fibrous, pale blue to yellow-green amphibole. The only other minerals commonly present are magnetite, in aggregates of grains and crystals, and epidote or zoisite. In the pyroxenic phase of the Dufresnoy dioritic mass some quartz is present. A few small aggregates of micropegmatite were also noted in the mass on the south shore of Sergius Bay. On the whole these occurrences in which pyroxene is present are more basic than the normal diorite. It is noteworthy, however, that the plagioclase where the pyroxene is present is in a remarkably fresh condition, and it is probable, as all the amphibole present in the rock is the same fibrous variety, that the diorite originally contained pyroxene everywhere.

In the north-facing slope of the ridge lying southwest of the Waite-Ackerman-Montgomery mine there is an east-west trending dyke of diorite. This is chiefly a moderately fine-grained, grey rock, but in one outcrop is largely composed of dykelets from ¼ to 1 inch wide that have been injected into the dyke rock parallel to its strike. This dyke intrudes dykes or sills of all the minor intrusives known to be older than the quartz diorite, but in the Duprat property, which adjoins the Waite-Ackerman-Montgomery on the west, a dyke of similar "ribboned" diorite is cut off by a dyke of quartz diorite. The "ribboned" diorite is probably, therefore, an early phase of the dioritic intrusives.

A phase of the diorite that contains phenocrysts of both amphibole and plagioclase occurs in the southern part of Rouyn map-area, notably in the area of diorite lying west of the Macamic road to the northwest of the Horne mine; in the outcrops west and south of the Youville hospital; in the northern part of the town of Rouyn; and in the rock cut on the Nipissing Central Railway north of Rouyn station. In two localities, one near the southeast corner of Pelletier and McQuaig Streets in Rouyn, and the other on the south margin of the group of outcrops to the south of the hospital, this porphyry is banded in zones 1 inch to 1 foot wide. These strike about east-west and are vertical or nearly vertical. In places the rock appears to be brecciated and consists of fragments of varying texture. At one point in the outcrops to the rear of the Youville hospital, the porphyry has a fine-grained edge against normal diorite, whereas in the rock cut on the Nipissing Central Railway a mass of similar rock is included in the gabbroic phase of the diorite. Under the microscope the dioritic porphyry contains phenocrysts of plagioclase almost completely replaced by epidote, and of amphibole having the crystal form of pyroxene. The matrix consists chiefly of small crystals of plagioclase and fibrous amphibole partly altered to epidote or chlorite.

The mass of quartz diorite that extends across the southern part of the town of Rouyn, in places, chiefly along its northern margin, passes transitionally within an interval of 50 feet or more into albite granite. This granite is moderately coarse, siliceous looking, and under the microscope is seen to have consisted originally almost wholly of quartz, albite, and a few scattered grains and crystals of magnetite. In most places, however, the rock has been considerably deformed and altered, as shown by the presence of zones of granulation along the contacts of the mineral grains and the abundance of carbonate and chlorite (penninite). In some thin sections micropegmatitic intergrowths of quartz and albite are present, and in one section constituted nearly the entire rock. Blue-green tourmaline was also noted in one occurrence of the rock.

On the north side of Fourcet Creek, in Duprat township, a mass of quartz diorite is adjoined on the north by a more acidic rock, which is shown on the map of the Amulet area as granodiorite. This rock is not seen in contact with the diorite, but its occurrence on the margin of the quartz diorite mass suggests that as in the case of the Rouyn albite granite it may be a marginal phase of the diorite. This granodiorite is a faintly pink-weathering, medium-grained, highly quartzose rock, which on its freshly broken surface, except that it contains a somewhat smaller proportion of ferromagnesian minerals and a correspondingly larger proportion of feldspar and quartz, resembles the quartz diorite. Microscopic examination shows it to consist of quartz, albite or albite-oligoclase largely replaced by sericite, epidote, and chlorite, and small amounts of amphibole altered for the most part to chlorite. Other constituents are magnetite, apatite, and pyrite.

Chemical Composition. The quartz diorite (older gabbro of some reports) is usually highly altered. The pyroxenic phase occurring in Dufresnoy township to the southwest of the outlet in Duprat Creek into Sergius Bay of Lake Dufault is the least altered of many occurrences of the dioritic group of intrusives examined microscopically. A chemical analysis of this pyroxene gabbro and its mineralogical composition, as determined by measurement in thin section, are included in Tables III and IV, respectively.

TABLE III

	Per cent
SiO_2	51·75
Al_2O_3	17·47
Fe_2O_3	2·96
FeO	9·16
CaO	9·40
MgO	5·20
Na_2O	1·37
K_2O	0·43
H_2O+	0·21
H_2O-	0·23
TiO_2	1·15
P_2O_5	0·34
MnO	Trace
BaO	....
CO_2	0·32
S	0·16
FeS_2	....
Total	100·15[1]

[1]Analysis by R. J. C. Fabry.

TABLE IV

	Per cent
Labradorite ($Ab_{45}An_{55}$)	50·3
Magnetite	1·0
Pyroxene / Amphibole	48·7
	100·0

Alteration. The changes that have occurred in the dioritic rocks may consist of alteration of individual minerals or of a more extreme transformation, in which the original texture of the rock has completely disappeared. The occurrence of augite partly transformed to fibrous amphibole in several localities suggests that the augite was originally the sole ferromagnesian mineral present and that the amphibole is a secondary product derived from the augite. This conclusion is supported also by the fibrous condition of the amphibole, a feature more characteristic of secondary than primary minerals. The amphibole, in its turn, in some sections of the rock is transformed in part to chlorite (penninite). The minerals that replace the plagioclase are chiefly epidote and sericite, less commonly carbonate, zoisite, or chlorite. In the highly feldspathic phase that occurs adjacent to and west of the line of the Canadian National Railway, in Newbec map-area, the plagioclase is almost completely replaced by zoisite. The albite of the albite granite associated with the Rouyn diorite mass is in some places replaced wholly by microlites of sericite, but in other places sericite, chlorite, and carbonate are present, partly associated with one another and partly in separate areas. Epidote was observed in only one thin section, from the albite granite west of Rouyn Railway station.

Where the alteration in the diorite has been extreme but without evidence of deformation, the rock may consist of indefinite aggregates of fibrous amphibole mingled with chlorite, and aggregates of epidote, carbonate, sericite, and, less commonly, zoisite. Where deformation has occurred, just as in the case of the rhyolite, the rock is traversed by zones of sericite, chlorite, and carbonate. A thin section from an outcrop of the albite granite phase that occurs in the Rouyn mass east of the Noranda north-south dyke showed the rock to be largely replaced by carbonate with some pyrite along zones of granulation. In the area northeast of the Bagamac shaft, zones of deformation in the rock are filled chiefly by sericite and chlorite (penninite) with carbonate present only in subordinate amounts. In many outcrops of the diorite, zones of epidote filling fractures up to 8 inches wide are common. These are especially common in the Rouyn dioritic mass.

Relations. The relationships between the various rock phases composing the dioritic group are of two kinds: (1) transitional; and (2) definitely intrusive. Most of the larger masses exhibit variations both in texture and composition, the different phases passing transitionally into one another. Examples of such variations are: the albite granite occurring on the north margin of the Rouyn diorite mass; the coarse, variegated and pegmatitic phase of the Dufresnoy mass; and the highly feldspathic phase of the Newbec diorite. In many places, but most extensively in the region south of the Horne Creek fault, sharply defined intrusive contacts occur at short intervals within the same outcrop of diorite. From the fine-grained margin of each intrusion towards its interior there is a gradual change in texture to that of normal diorite in an interval of 10 to 20 feet; and these relationships may recur at least twice in the same rock area, indicating three successive intrusions of diorite, each of the same composition. Multiple diorite intrusion of this type was noted in outcrops at the Horne mine, in the exposures to the south and west of the Youville hospital, and in many other localities. It can best be seen in the outcrops along the Kirkland Lake highway to the northwest of Noranda Lake. In most places the individual intrusions are too small to be differentiated on the maps accompanying this memoir. In the northwestern part of Waite map-area, however, there is a group of outcrops in which an intrusive contact has been indicated, the diorite to the northwest intruding that to the southeast.

The manner in which the dioritic intrusives cut across the folded structure of the volcanic rocks, and in some places lie along faults, shows that they were intruded not only after a considerable part of the folding but after much of the faulting was completed. These relationships are well illustrated by the Dufresnoy mass, the largest intrusion of dioritic rocks within the area mapped. This intrusion cuts across the Quebec-Copper, the Waite, and the Amulet anticlines (*See* Figure 1), and, where it crosses the Vauze Creek fault zone, offshoots extend along the fault zone both to the east and west. Another offshoot passing just south of Vauze Lake, in the north-central part of Waite map-area, extends east to connect with dioritic belts trending approximately parallel the strike of the adjacent siliceous rhyolite in the northeast corner of Waite map-area. This offshoot strikes obliquely across and offsets several belts of volcanic rocks, the parts to the north lying east of their continuation to the south.

An outstanding feature of the Dufresnoy diorite is the evidence it presents of having made room for itself by thrusting aside the volcanic belts traversed by it and not by stoping and assimilation or related processes in which displacement is not involved. Thus the manner in which the Vauze Creek andesite belt (Figure 1, number 9) is offset by the intrusion of the diorite lying south of Vauze Lake is proof of displacement, for if the diorite had replaced the andesite by assimilation or other processes the part of the belt north of the diorite would be in direct alinement with that on the south. Similarly, the way in which the Waite Lake siliceous rhyolite area (Figure 1, number 7) has been offset to the north with respect to siliceous rhyolite lying farther east by the intrusion of the main belt of Dufresnoy diorite is proof of displacement. The way in which the Dufresnoy main mass cuts across the folded structure of the volcanic rocks and the general vertical or nearly vertical attitude of its contacts despite the presence locally, as in the Lake Dufault property, of dips as low as 45 degrees or less to the east, is evidence that the mass is approximately vertical.

The contacts of the dioritic intrusives with the rocks they intrude are of three types: sharply defined; transitional; or marked by a zone of breccia. Where the contact is well defined the diorite has a fine-grained edge against the rock it intrudes. A good example of this type of contact is exposed along the western margin of the main Dufresnoy diorite mass near the top of the rock knob to the northeast of the camp buildings and mill on the Amulet property. Along the west border of the main diorite belt, at a distance of about 50 feet, there is a parallel band of diorite about 350 feet long and 10 to 30 feet wide that connects at its north end with the main mass. The diorite along its contact with the adjacent andesite, both in the main mass and in the parallel extension, has a fine-grained marginal zone from 6 inches to 2 feet wide. The change in texture from the fine-grained, basaltic looking border zone to the coarse diorite takes place in an interval of 2 inches, and the marginal zone at one point is cut by a dykelet of the coarse diorite. In the main mass of diorite, towards its interior, the rock becomes gradually coarser grained across a zone 50 to 100 feet wide. Beyond this the variegated phase occurs.

The second type of contact, the transitional, occurs in places where the diorite adjoins andesite. It is most strikingly exemplified in the eastern part of the southern area of andesite in the Newbec property. This andesite area, which is almost wholly enclosed in diorite, in places has the texture and mineralogical composition of diorite yet the presence of pillow structure proves that it is andesite recrystallized. Other localities where similar relationships were noted are along the west boundary of the Dufresnoy diorite belt to the north of Waite Lake and on its east border in an outcrop on the south side of the road to the Amulet mine a few hundred feet west of the Macamic road.

In places the contact of the diorite with adjacent volcanic rocks is marked by a zone of silicified breccia. This feature was observed on the margins of the two northeasterly trending dykes of diorite that cross the Amulet anticline in the Amulet property. Along the northwest contact of the southeasterly dyke and along the southeast contact of the northwesterly dyke a fragmental zone up to 4 feet wide occurs. In the first occurrence the fragments are up to 3 inches in diameter, are rounded, fine-grained, and siliceous looking. They are presumably silicified inclusions of andesite. In the second the inclusions range in size up to 10 inches in diameter, are coarse-grained, and consist chiefly of feldspar and amphibole. They are probably altered fragments of the rhyolite wall-rock.

Another contact zone of the breccia type was observed on the east margin of the Dufresnoy dioritic main belt southeast of Waite Lake. At this point there is an outcrop about 200 feet long, the northwest part of which is diorite and the southeast siliceous rhyolite. Along the contact of the diorite and rhyolite round fragments of rhyolite are included in the diorite in a zone 1 foot wide.

Other features characteristic of the volcanic rocks in the contact zone adjacent to the diorite are: the presence in the volcanic rocks of numerous dykes of the diorite; the occurrence in places of aplite dykelets similar to those in the diorite; an abundance of epidote in the lavas; and the pale grey, altered appearance of the andesite when it adjoins the diorite. Microscopic examination of the lavas adjacent to the contact shows the andesite to have for the most part the same constituents as in localities remote from the contact, but where recrystallization has occurred there is an unusual amount of granular quartz. In one thin section of andesite, epidote and zoisite form a large part of the rock. In most localities where rhyolite or rhyolite breccia is in contact with the diorite there has been so much faulting and deformation that it is not possible to determine the contact effects of the diorite. At the few points where there has been no deformation, no great changes in the rhyolite were noted.

GRANODIORITE

Granodiorite positively known to be later in age than the quartz diorite and related intrusives is confined to the Lake Dufault stock, and the small dykes in the contact zone along its border. This stock within the area mapped occupies some of the islands in Lake Dufault and the relatively low, flat, largely clay-covered area adjoining Lake Dufault on the west. It has a maximum width from north to south of about 3 miles and a length from west to east of 3½ miles within the area mapped, but J. W. Ambrose has found in the district to the eastward that the stock continues with diminishing width in that direction about 3 miles.

The Lake Dufault granodiorite is a moderately coarse, massive rock composed of glassy quartz, pale grey plagioclase feldspar, and aggregates of amphibole. Under the microscope the rock is seen to consist of abundant quartz in large, irregular grains, plagioclase largely or entirely replaced by sericite and epidote, buff to olive-green amphibole, scattered crystals of apatite, and a few, small, disseminated grains of magnetite. The plagioclase in a section in which it was least altered is acid andesine (Ab_{70} An_{30}). The amphibole in places is altered to green chlorite (penninite). In an outcrop on one of the islands of Lake Dufault biotite was noted. It was not seen in any of the thin sections examined.

In places within the granodiorite there are inclusions of quartz diorite. They are especially common in the rock cuts of the Canadian National Railways north of Sergius Bay, and along the border of the stock. The inclusions are usually finer grained than the granodiorite, rounded, and, in most occurrences, 8 inches or less in diameter. The boundaries are not sharp, but can be determined within a width of one-quarter inch.

The contact of the Lake Dufault granodiorite stock with adjacent rocks is, for the most part, covered by lacustrine post-Glacial clay. It is exposed, however, on the east side of the Macamic road to the south of the road to the Newbec shaft, about one-half mile to the southeast of the Waite mine, and in the country east of the Amulet mine. In the first locality the contact is well defined, but irregular on a minute scale. Offshoots 2 to 4 inches wide extend into the andesite for 2 to 4 feet. There is no noticeable change in texture in the granodiorite adjacent to the contact. The dykelets are also coarse grained. In the group of outcrops southeast of the Waite mine, the granodiorite is in contact with andesite and quartz diorite. Both the andesite and the diorite are cut by dykes of granodiorite up to 2½ feet wide. A specimen of the andesite taken from a prospect pit 5 feet from the contact was found on microscopic examination to consist chiefly of granular quartz, deep brown mica, and plagioclase occurring partly in large areas almost wholly replaced by epidote and sericite and partly in small, unaltered crystals. Less abundant constituents are pyrite and apatite.

Where the contact of the stock is exposed to the east of the Amulet mine numerous, sharply defined dykes of granodiorite up to 1 foot or more wide intersect the Dufresnoy diorite mass, as shown in Plate VII A. In this locality a vertical diamond drill hole was put down in claim R 28,359 by Lake Dufault Mines, Limited. This commenced in quartz diorite at a point 550 feet from the contact of the Lake Dufault granodiorite stock. It intersected diorite and granodiorite alternately to a depth of 627 feet, beyond which granodiorite occurred to the bottom of the hole at 951 feet. In the rock cut on the east side of the branch railway to the Amulet mill, a breccia composed of fragments of diorite in a granodiorite matrix is exposed. Dykes of granodiorite also intersect the diorite in places.

The Lake Dufault granodiorite, except for the larger proportion of quartz and feldspar that it contains, is very similar in mineralogical and, presumably, in chemical composition to the quartz diorite. It is possible, therefore, that the granodiorite has been derived from a dioritic magma, but if so the differentiation took place at depth before the granodiorite thrust its way in, for it definitely intrudes the quartz diorite.

ALBITE GRANITE (ALASKITE)

Granitic masses not associated with quartz diorite occur in two localities: (1) throughout an area about 2½ miles from east to west and 1 mile from north to south in the west-central part of Rouyn map-area; and (2) along the western margin of Amulet map-area from Lake Fourcet southward in a zone up to over ½ mile wide. The first of these masses is the Powell granite stock, and the second a part of the eastern margin of the Flavrian lake batholith, a complex of granitic rocks that has a diameter of about 5 miles.

Powell Granite

The Powell granite mass contains many inclusions of rhyolite and quartz diorite, and is intruded by small dykes of both acid and basic composition. Where it is unaltered, it is a medium-grained to moderately coarse, pale grey weathering rock consisting almost wholly of grey feldspar and glassy quartz. Throughout most of the mass, however, the rock is grey or green, due to the alteration of its feldspar. In its southern part, where it is intersected by east-west trending zones of schistosity parallel to the Horne Creek fault, chloritic alteration is so intense that the rock is dark green. Joints, in many of which seams of specularite are present, intersect the granite almost everywhere. These, however, do not follow well-developed systems. Specularite, alone or with quartz, also occurs in fractures up to one-half inch wide in many places.

Microscopic examination of the unaltered granite shows it to consist either of rectangular crystals of albite and large, irregular grains of quartz, or of tabular crystals of albite enclosed in micropegmatitic intergrowths of albite and quartz. Alteration varies greatly in its intensity. In incipiently altered specimens the plagioclase contains disseminated microlites of sericite, minute scattered areas of carbonate, a few aggregates of epidote, and areas of dark green chlorite (penninite). In more altered specimens sericite mingled with chlorite occurs in more or less granular zones interspersed between the original mineral constituents. In schistose phases of the granite, dark green chlorite intermingled with sericite occurs abundantly in zones and aggregates.

Flavrian Lake Granite

The eastern edge of this batholithic mass extends into the western part of Amulet map-area, from Lake Fourcet southward. In the area lying south of Lake Fourcet the granite is a variegated, siliceous-looking, grey rock that for the most part weathers pale grey and contains an abundance of spherulite-like forms up to one-eighth inch in diameter. In places the granite containing the spherulite-like forms exhibits small, irregular, green depressions from $\frac{1}{8}$ inch to 3 inches in diameter in its weathered surface. Under the microscope the spherulites are seen to consist of micropegmatitic, more or less radial, intergrowths of quartz and plagioclase in which scattered tabular crystals of albite are included. Areas of quartz also occur here and there. Other minerals present are apatite, epidote, and sericite. The epidote and sericite are chiefly associated with the plagioclase and are evidently alteration products. Most of the thin sections of the granite include at least one area of finely granular quartz and epidotized feldspar. These areas have the texture of rhyolite and are more altered than the other parts of the rock. They are, therefore, probably inclusions of lava. It is in these inclusions that the small, irregular depressions seen in the weathered surface of the granite are formed. The group of outcrops that lie close to the southeast shore of Lake Fourcet consist of grey, granular granite intermingled with rhyolite in an indefinite way. Some of the outcrops lying about 2,500 feet south from Lake Fourcet are of a dull grey-green weathering granite mingled with, and in places apparently cut across by dykes of, its spherulitic phase. This grey-green granite consists of quartz and feldspar almost completely altered to chlorite and sericite.

East-southeast of Lake Fourcet a separate or nearly separate elliptical-shaped mass of the Flavrian Lake granite is exposed in six outcrops. The rock in these is a moderately fine-grained, greenish grey type in which numerous grains of quartz are visible. Under the microscope it appears similar to the granite outcropping to the west, but the plagioclase has been almost completely altered to green chlorite (penninite) mingled with a small proportion of sericite, epidote, and carbonate.

The two easterly of the four outcrops in the southwest corner of Amulet map-area resemble the finer grained phase of the micropegmatitic granite in the area south of Lake Fourcet. The granite in the north-westerly outcrop appears to contain a large proportion of ferromagnesian minerals. Under the microscope, however, it is found that, although some pale blue to green, fibrous amphibole is present, a large part of the dark constituents is altered plagioclase, and that the rock originally consisted chiefly of micropegmatite and plagioclase with small amounts of amphibole, apatite, and magnetite. The granite of the outcrop on the Duprat-Beauchastel line, except for alteration products, consists almost wholly of quartz and plagioclase, mainly in micropegmatitic intergrowths. The plagioclase is altered chiefly to chlorite with subordinate amounts of sericite and carbonate.

Chemical Composition

A chemical analysis of a very slightly altered specimen of granite from the south edge of the large east-west trending ridge that stands up prominently in the west-central part of the Powell mass is given in column 1 of Table V. The analysis in column 2[1] of the table is that of a specimen from the Flavrian Lake mass at a point about 4 miles to the west of the exposures in Amulet map-area. The unusual feature of these analyses is the large content of soda and, in contrast with this, the low content of potash. It is possible that most or all of the potash present in the Powell granite is contained in the sericite, which occurs as microlites disseminated in the albite.

Table V

—	1	2
	Per cent	Per cent
SiO_2	74·89	73·79
Al_2O_3	13·27	11·83
Fe_2O_3	0·36	0·72
FeO	3·65	4·18
CaO	1·15	2·21
MgO	0·40	0·62
Na_2O	4·25	3·94
K_2O	0·37	0·85
H_2O+	1·22	0·90
H_2O-	0·03	0·40
TiO_2	0·22	0·39
P_2O_5	Trace	0·09
MnO	Trace	0·07
F	....	0·01[1]
CO_2	0·78	Nil
S	Trace	Trace
Total	100·59	100·00

[1] Determined by W. C. Gussow.

1. From Rouyn township, about 1,100 feet east of Rouyn-Beauchastel line and 2,000 feet north of Nipissing Central Railway. Analysis by R. J. C. Fabry.
2. From pit in Duprat township, range 2, lot 37. Analysis by W. H. Herdsman.

[1] Gussow, W. C.: Trans. Roy. Soc., Canada, sec. 4, 1937, p. 145.

Relationships

Both the Powell and the Flavrian Lake granite masses, for the most part, are enclosed in lavas, chiefly rhyolite. Along the eastern and northern margins of the Powell granite the contacts with rhyolite are transitional and difficult to fix. Both rocks have the same mineralogical compositions, so that their only distinguishing feature is their textures. The intrusion of the granite has recrystallized the rhyolite and it is possible that some rock has been mapped as granite that was originally rhyolite. Many of the small inclusions of rhyolite in the granite, on the other hand, have sharply defined contacts, and unlike the grey, coarse-textured, adjacent granite are fine-grained and cream-white weathering. The contact of the Powell granite with the Powell-Pontiac andesite was observed in only one locality. At this point, the two rocks are intermingled and in places the andesite is highly silicified and sericitized, possibly as a result of the intrusion of the granite. The rhyolite exposed along the eastern margin of the Flavrian Lake granite has the same relationships to the intrusive as the rhyolite adjacent to the Powell granite, and it is possible in this locality also that some of the rock mapped as granite is recrystallized rhyolite. Inclusions of quartz diorite occur within the Powell granite in places, and here and there are cut by dykes of the granite. The Powell and Flavrian Lake granite masses were not observed in contact with the granodiorite of the Lake Dufault mass and, therefore, the relationships of these intrusives to one another are not known.

In places within the volcanic rocks of the district, isolated blocks or groups of blocks of albite granite from a few inches up to 5 feet in diameter are present. These were observed in places near the Waite-Ackerman-Montgomery and Amulet mines and in many other localities, all remote from the extensive masses of albite granite of the area. The fragments are usually sharply defined but irregular in form, are completely isolated, and are not associated with fractures or other evidence of deformation. They are, possibly, broken fragments of dykes, although neither their form nor relationships affords any evidence in support of this hypothesis. Another possible explanation of their presence is that the lava before its extrusion passed through and engulfed fragments of albite granite older than the lavas.

SYENITE PORPHYRY

In the workings of the Horne mine and in other places within the southern part of Rouyn map-area there are dykes and masses of syenite porphyry. These, except for one small, isolated outcrop, all occur south of the Horne Creek fault. The dykes both at the surface and in the mine workings, in general, strike northeasterly, but have variable dips. The most extensive occurrence at the surface is the mass exposed in an area 900 feet long and up to 200 feet wide to the north of the Canadian National Railways station at Noranda. Numerous masses of syenite porphyry, most of them considerably broken, also occur in the long drift to the Chadbourne shaft on the 975-foot level of the Horne mine. These lie a few hundred feet northwest of the outcrop at Noranda station. Similar syenite porphyry is known to occur in numerous localities in western Quebec. It intrudes the quartz diorite of the Noranda district, but was not seen in contact with either the granodiorite or the granite. Recently, however, W. C. Gussow[1] has described the occurrence of a dyke of the syenite in lot 28, rge. 10, Beauchastel tp., intruding the granite of the Flavrian Lake batholith.

Lithologically the syenite porphyry varies considerably in its various occurrences. In the mass north of the Canadian National Railways station at Noranda it is a massive rock consisting of rectangular phenocrysts of wine-coloured feldspar up to one-half inch long by one-third inch wide in a speckled, pink to grey matrix. Under the microscope the phenocrysts are seen to consist of microperthitic intergrowths of plagioclase, chiefly albite, with orthoclase or microcline. Some are concentrically zoned. The matrix consists of grains of quartz, crystals and elongated areas of plagioclase with sutured edges, deep green to yellow aegerine-augite, titanite, and apatite. In the northeastern part of Noranda townsite a dyke of pink, fine-grained syenite porphyry intrudes the andesite that outcrops to the south of the east-west Noranda diabase dyke. This syenite dyke consists chiefly of phenocrysts of albite in a matrix of albite and quartz. In the thin section examined an area of exceedingly fresh albite and quartz coarser textured than the normal matrix was noted. This has presumably formed by recrystallization. Here and there in the rock small areas of carbonate and microlites of sericite are present. There are also areas of carbonate and sericite that have probably replaced a ferromagnesian mineral originally present.

MINOR INTRUSIVES

In addition to the intrusives already described, numerous dykes and sills of a great variety of rocks of various ages are present in the Noranda district. Only the larger of these, classified as acidic or basic, are shown on the maps. In places these intrusives are so abundant that they may be said to occur in "swarms." Some, although only a few feet wide, persist for one-half to three-fourths mile or more. They have some economic importance because, as in the case of the Waite-Ackerman-Montgomery mine, ore deposits may be associated with them, and some terminate abruptly at, or are offset along, linear drift filled depressions, thus showing the presence of unexposed faults, which would not otherwise be known to occur. Classified according to their relationships to the major intrusives, these dyke and sill rocks belong to four groups: (1) those older than the dioritic group of intrusives; (2) those younger than the dioritic intrusives, but not intrusive into the Lake Dufault granodiorite or the Powell granite; (3) those that intrude the Lake Dufault granodiorite; and (4) those that intrude the Powell granite.

MINOR INTRUSIVES OLDER THAN THE QUARTZ DIORITE

Andesite. In the vicinity of the Waite-Ackerman-Montgomery mine, five dykes or sills of andesite are intruded by dykes of another andesite with which intrusions of rhyolite (quartz-albite) porphyry are intimately

[1] Gussow, W. C.: Roy. Soc. Can., Trans., vol. 31, sec. 4, 1937, p. 160.

associated. The andesite that forms the five dykes or sills was not seen in direct contact with the quartz diabase minor intrusive next described, but it is inferred to be older than the quartz diabase because at one point a mass of the andesite appears to be cut off by an intrusion of the diabase. Although this early andesite intrusive was determined to be present only near the Waite-Ackerman-Montgomery mine it is probable that some of the other dykes and sills of andesite that occur so abundantly in the region are of the same age. The contacts of the five dykes or sills near the Waite-Ackerman-Montgomery mine for the most part are defined by a dense marginal zone from one-quarter to three-quarters inch wide, but in some localities the dense margins are difficult to follow and in places are absent.

This oldest andesite of the minor intrusives is a uniformly dark grey rock that weathers grey-green on exposed surfaces. It consists of pale blue to yellow-green actinolite, andesine in rod-like crystals largely altered to epidote, quartz here and there in small areas, and magnetite in scattered grains and aggregates of grains. The areas of quartz are partly irregular and partly sharply defined by the plagioclase crystals.

Quartz Diabase. Intrusions of an old quartz diabase that, so far as determined, is second in age among the minor intrusives, occur near the Amulet and Waite-Ackerman-Montgomery mines. On the lower part of the slope east of No. 4 shaft in the Amulet property, there are two irregular areas of this quartz diabase, each about 400 feet long and 50 feet wide. At the Waite-Ackerman-Montgomery mine it occurs most extensively in a zone 30 to 150 feet wide crossing the property in a north-northeasterly direction northwest of the ore-bodies and adjacent to No. 1 shaft. This dyke or dyke zone is now broken into disconnected areas by numerous transverse intrusions of andesite and rhyolite porphyry. Elsewhere near the Waite-Ackerman-Montgomery mine the old quartz diabase occurs in dykes or sills 8 to 40 feet wide, trending chiefly easterly to northeasterly parallel to the strike of the volcanic rocks they intrude. The contacts of the diabase are for the most part sharply defined, with a dense marginal zone from one-quarter to one inch wide merging into a zone of fine-grained texture 1 to 3 feet wide.

The quartz diabase is a medium- to moderately coarse-grained rock with a speckled, grey-green, shagreened to hackly appearance on its weathered surface. On freshly broken surfaces it is uniformly dark grey in its fine-grained, and speckled grey in its coarser grained, phases. Where least altered it consists mainly of lath-like crystals of labradorite and actinolite, partly in large bleached looking areas (uralite) and partly in mat-like areas of fine fibres. In some specimens irregular areas of granophyre or quartz are present. Other common constituents are epidote and magnetite. The epidote occurs in aggregates within the plagioclase; and the magnetite as small, irregular grains scattered through the actinolite. Both these are evidently products of alteration. The more highly altered phases of the diabase consist almost entirely of amphibole and epidote with chlorite and sericite in subordinate amounts. In some sections aggregates of brown mica were noted.

Amphibole Dacite (Quartz-feldspar) Porphyry. In a group of outcrops 100 to 200 feet north of the main camp buildings at the Amulet mine, there are areas of a dark grey, fine-grained rock containing phenocrysts of grey feldspar up to one-tenth inch in diameter and quartz in blebs about as large as the head of a pin. This rock was not seen elsewhere. Where it adjoins andesite it has a definite line of contact and a fine-grained marginal zone showing that it is intrusive; where it adjoins an andesite dyke, the andesite dyke rock has the fine-grained margin. This andesite, like the andesite next described, is associated with rhyolite porphyry.

Microscopic examination of the porphyry shows it to consist of phenocrysts of quartz and altered oligoclase, aggregates of fibrous pale yellow to blue-green amphibole, granular quartz, disseminated grains of magnetite, and some scattered aggregates of brown mica. The phenocrysts of feldspar are almost entirely replaced by epidote.

Andesite. Andesite younger in age than the quartz diabase previously described is one of the most abundant and widely distributed of the minor intrusives in the area. Its relationships are best displayed adjacent to the Amulet and Waite-Ackerman-Montgomery mines where it occurs in sills and dykes from a few inches to 40 feet thick. The trend of the sills and dykes is, for the most part, east or northeasterly parallel to the strike of the volcanic rocks. The angle of dip ranges from 25 degrees to vertical, but 30 to 35 degrees is most common. The dykes and sills are intruded by the rhyolite porphyry dykes and sills next described, but intrude the older diabase. The contacts of the andesite sills and dykes with the rocks they intrude are everywhere definite, with a dense, marginal zone from one-quarter to one inch wide.

The andesite is a fine- to moderately coarse-grained, massive rock, weathering greenish grey to rusty brown, and cut, in places, by numerous, small, intersecting fractures that outcrop in grid-like ridges. On freshly broken surfaces it is uniformly grey to dark grey, differing little in appearance from the massive phase of the volcanic andesite. It is amygdaloidal for a few inches to 2 feet along both margins of dykes and the upper margins of sills. It consists chiefly of pale blue to yellow-green, fibrous actinolite and rod-like crystals of plagioclase largely replaced by epidote or epidote and sericite. The plagioclase ranges from andesine to acid oligoclase. It was noted, however, that the acid oligoclase occurs in irregular areas and in the more highly altered phases of the rock. It is probable, therefore, that it is secondary. Other constituents of the rock are: magnetite, chiefly associated with the amphibole in small, irregular grains; quartz in irregular areas; and, in one thin section, brown mica in aggregates chiefly associated with the actinolite.

In many places this andesite occurs in three or more adjoining sills, most of which have intrusive contacts against the sill above them and are intruded by the sill below. In some places two sills of a group are separated by a zone of andesite lava a few inches or less wide, or the intervening andesite disappears and the fine-grained marginal zones of the two sills adjoin one another. All these features occur in succession along the contacts of some sills.

Rhyolite (Quartz-albite) Porphyry. Dykes, sills, and masses of rhyolite porphyry are widespread in the district. They are younger than the andesite sills and dykes just described, but are in some way related to them for in an area of one-fourth square mile adjacent to the Waite-Ackerman-Montgomery mine all but six of forty-seven occurrences of the rhyolite porphyry lie within or along the contacts of the andesite sills or dykes. The rhyolite weathers pale grey to cream-white and is usually porphyritic, the phenocrysts consisting of glassy quartz ranging in size from minute blebs scarcely discernible to the naked eye up to crystals one-quarter inch in diameter, and feldspar, in rectangular shaped individuals, ranging in size from small microlites up to crystals nearly one-half inch long and one-quarter inch wide. The matrix on freshly broken surfaces is dark grey and flint-like where fine grained and speckled grey in the coarser phases. In some occurrences spherulites are abundant. Lamination was noted in zones up to a foot or more wide along the margins of dykes and masses.

Microscopic examination shows the matrix to consist almost entirely of granular quartz, albite in more or less tabular grains, and radial, spherulitic intergrowths of quartz and feldspar. Actinolite in sheaf-like aggregates of pale blue-green fibres was noted in one thin section. Magnetite in scattered grains is present in some sections of the rock, but absent in others. The margins of both the quartz and albite phenocrysts in some sections are embayed. The quartz phenocrysts are cracked throughout, and in places are completely enclosed in a zone of radial micropegmatite.

For the most part, the rhyolite porphyry is not highly altered. Where alteration has occurred, the principal products of alteration are chlorite, epidote, and sericite. The chlorite occurs chiefly here and there in aggregates of deep green to yellow-green grains, and is probably in part derived from amphibole or some other ferromagnesian mineral and in part a replacement of the feldspar. The epidote is confined almost entirely to the albite phenocrysts of which it is evidently an alteration product. In one thin section, scattered microlites of sericite in the albite were noted. In some sections aggregates of small grains of a colourless, lamellar mineral resembling muscovite are present. These for the most part occur in association with the aggregates of chlorite in the interspaces between spherulites or replacing the albite. Carbonate occurs in irregular zones or filling fractures, but is not abundant.

The rhyolite porphyry found in the vicinity of the Amulet and Waite-Ackerman-Montgomery mines occurs chiefly in dykes and sills ranging from a few inches up to about 50 feet wide. These have been intruded mainly along the middle, less commonly along the margin, of dykes or sills of andesite. The zones of andesite bordering the rhyolite vary from a few inches to several feet in width and are in most cases rusty brown weathering. The contact of the rhyolite porphyry with the rock it intrudes, although definite in places, is for the most part indefinite, the transition taking place in an interval of less than 1 to 2 inches. In one locality, however, a transitional zone 6 inches wide was noted. In places dykelets of the rhyolite porphyry 1 inch to 1 foot wide extend for a foot or more into the adjacent sills or dykes of andesite. In many sills angular-to subangular, rusty brown weathering fragments of the associated andesite occur within the rhyolite porphyry. In some places the inclusions occur through the entire sill, but in most places they are confined to zones from 6 inches to 2 feet wide along the margin of the intrusive.

Andesite. In the area near the Amulet and Waite-Ackerman-Montgomery mines a considerable number of intrusions, chiefly dykes, of andesite cut the rhyolite porphyry or the older andesite with which the rhyolite porphyry is associated, or both. Some of these later dykes of andesite are intersected by dykes of quartz diorite, but a few intrude the quartz diorite thus indicating that some are older than, and others younger than, the quartz diorite.

The andesite younger than the rhyolite porphyry and older than the quartz diorite is a massive, moderately fine-grained rock, consisting, as seen in thin section, of pale blue-green to yellow-green actinolite, andesine in rod-like crystals, a few scattered areas of quartz filling triangular shaped interspaces between the plagioclase crystals, and magnetite in scattered grains or aggregates of grains. The actinolite fibres cut across and penetrate the feldspar and quartz. It is probable that this mineral is secondary, derived from another ferromagnesian mineral originally present in the rock. A few aggregates of brown mica, also probably an alteration product, occur here and there. The rod-like crystals of plagioclase, on the other hand, are almost certainly original. They have been more or less replaced by epidote.

Rusty Weathering, Epidotized Dyke Rock. In the vicinity of the Waite-Ackerman-Montgomery mine, east of Turcotte Lake in the Amulet property, and in a few other places in the district there are dykes of a highly epidotized rock that is commonly laminated parallel to the strike and dip of the dyke and rusty weathering due to the disseminated pyrite that it contains. All these dykes are small, ranging from a few inches or less up to a maximum of 3 feet in width, but some persist for long distances. In places a dyke breaks up into as many as four branches or pinches out along the strike to reappear a few feet to the right or left. One dyke occurring southwest of the Waite-Ackerman-Montgomery mine can be followed almost continuously for 600 feet to a fault where it is displaced about 600 feet to the eastward. Beyond the fault it is exposed at intervals for an additional 800 feet, so that it has a total length of at least 1,400 feet. The age relationships of these epidotized dykes have not been positively determined. They intersect the rhyolite porphyry and the andesite that intrudes the porphyry and are cut by a dyke of dacite porphyry. They were not observed to intrude the dioritic intrusives and are, therefore, probably older.

On freshly broken surfaces the epidotized dyke rock is seen to be a fine-grained, grey type in which pyrite is finely disseminated. Microscopic examination shows it to consist chiefly of epidote with small amounts of chlorite. Irregular areas of quartz occur here and there. In places the outlines of crystals of feldspar replaced by epidote can be observed. The pyrite occurs in small, scattered, irregular grains.

MINOR INTRUSIVES YOUNGER THAN THE QUARTZ DIORITE AND OLDER THAN THE LAKE DUFAULT GRANODIORITE

Dacite (Feldspar) Porphyry. Numerous dykes of dacite (feldspar) porphyry up to 6 feet wide, some of which can be followed almost continuously for distances ranging from 1,000 to 2,500 feet, occur within the district. One of the longest trends northeasterly across the Amulet property passing a few hundred feet northwest of the No. 4 (C) shaft. Another conspicuous dyke of the rock trends northwesterly across the east end of the high rock ridge to the southwest of the Waite-Ackerman-Montgormery shaft. This dyke cuts across a mass of quartz diorite. Its relationship to the andesite next described is not known. The dacite porphyry is a grey rock consisting of rounded phenocrysts of light grey feldspar up to one-eighth inch in diameter enclosed in a dark grey, fine-grained matrix. Microscopic examination shows the phenocrysts to consist of oligoclase largely altered to sericite or epidote, or both these minerals. The matrix is composed of minute prisms of plagioclase, quartz in irregular grains, chlorite, epidote, and a few, small, scattered grains of magnetite.

Andesite. The quartz diorite and related intrusives are cut by dykes of andesite ranging from a few inches up to 10 feet in width. The longest observed extends east-southeasterly for nearly 1 mile across diorite, andesite, and rhyolite at the eastern end of the Amulet Hills. The andesite of these dykes is a moderately fine- to very fine-grained, grey variety, the fine-grained phases of which contain minute, glistening, rod-like crystals of plagioclase. In thin section the rock is seen to consist of abundant blue to yellow-green amphibole, intermediate to basic andesine, epidote, magnetite, and, in some sections, carbonate.

MINOR INTRUSIVES YOUNGER THAN THE LAKE DUFAULT GRANODIORITE

Pyroxene Lamprophyre, Amphibole Lamprophyre. In several localities in the district there are dykes of pyroxene or amphibole lamprophyre. The pyroxene-bearing variety was observed in a dyke cutting the post-rhyolite porphyry andesite and the "ribboned" breccia southeast of the Waite-Ackerman-Montgomery mine, and in a dyke 2 to 3 feet wide cutting the quartz diorite at the southeast end of the high rock knob southeast of the Vauze Creek bridge on the Macamic road. The amphibole lamprophyre was seen in a dyke 3 to 4 feet wide, intruding the Brownlee rhyolite (*See* Figure 1) in the northern part of the Horne property, in a dyke intruding the Lake Dufault granodiorite in a rock cut on the Canadian National Railway about 1 mile south of the Waite-Amulet siding, and in a dyke 20 feet wide cutting granodiorite in the northeastern part of the southern of the two large islands in Lake Dufault shown in the northern part of Dufault area.

In the high rock ridge southeast of the Waite-Ackerman-Montgomery mine there are three dykes of moderately fine-grained, rusty brown weathering, pyroxene lamprophyre lying within 200 feet of, and trending parallel with, the dyke of quartz diorite that crosses the ridge in a northeasterly direction. The dykes range in width from 2 to 3 feet and in exposed length from 50 to 225 feet. The dips range from nearly vertical to 60 degrees to the southeast. On freshly broken surfaces this lamprophyre is moderately dark grey and displays glistening faces of crystals of a ferromagnesian mineral. Under the microscope the rock is seen to consist of numerous phenocrysts of augite partly altered to blue-green to yellow-green amphibole, acid labradorite, some epidote, chlorite, and scattered grains of pyrite. It has, therefore, the composition of camptonite. The pyroxene lamprophyre intruding the Newbec diorite near Vauze Creek is similar mineralogically, but the plagioclase occurs in phenocrysts and there are no phenocrysts of the pyroxene. The lamprophyre dyke rocks, except for the presence or absence of pyroxene, have the same mineralogical composition, and the amphibole associated with the pyroxene of the pyroxene lamprophyre is similar to that of the amphibole lamprophyre. It is probable, therefore, that all the lamprophyre dykes were originally pyroxene lamprophyre, were all intruded about the same time, and hence are all younger than the Lake Dufault granodiorite.

MINOR INTRUSIVES YOUNGER THAN THE POWELL GRANITE

Andesite and Rhyolite. Within the Powell granite there are small dykes of both andesite and rhyolite, most of them trending east-west. The andesite dykes are from 1 to 8 feet wide and up to 400 feet long. The rock composing the dykes for the most part is dark grey, fine grained, and massive, but in the Don Rouyn property about 1,000 feet north of the Horne Creek fault there is a dyke-like zone of chlorite schist exposed for 450 feet that is almost certainly a dyke of andesite transformed to schist by shearing. A thin section of the andesite from a dyke outcropping east of the Powell No. 2 shaft, consists of rod-like crystals of acid andesine enclosed in a matrix consisting chiefly of green chlorite, some rectangular areas of carbonate, and a few small grains of quartz. The plagioclase is partly altered to sericite.

The dykes of rhyolite range in width up to 20 feet and in exposed length up to 1,500 feet. The largest dyke seen outcrops about 500 feet northwest of the No. 2 shaft in the Powell-Rouyn property. It is from 5 to 20 feet wide and is exposed along the strike for about 800 feet. This rhyolite is a fine-grained, flinty, grey rock. Microscopic examination shows it to consist of phenocrysts of quartz and prismatic crystals of plagioclase in a matrix of granular quartz and plagioclase replaced in places by sericite, carbonate, and aggregates of green chlorite. The relationship of this rhyolite to the dykes of andesite intruding the Powell granite was not determined.

NEWBEC BRECCIA

On the Newbec property, northeast of the shaft, and in a triangular-shaped area about ½ mile long and 2,000 feet wide extending from the shaft westward to the Macamic highway and southward to the Lake Dufault granodiorite, there are outcrops of a breccia composed of angular to round fragments of rhyolite, andesite, and quartz diorite. The composition of the breccia and the size of the fragments vary greatly in different parts of these areas. In places in the group of outcrops northwest of the shaft, porphyritic rhyolite appears to form the matrix around fragments of diorite and andesite. At a few points, however, fragments of porphyritic rhyolite also were observed. The fragments for the most part are not more than 3 feet in diameter, but one of diorite 4 feet by 5 feet was noted. The breccia occurring in the ridge south of the shaft consists of large masses of andesite and diorite in a matrix composed of small fragments of porphyritic rhyolite up to 3 inches in diameter. The largest mass seen in this locality, one of diorite, was 40 by 50 feet. The proportion of matrix to fragments is small. In places the porphyry fragments of the matrix are enclosed in a fine-grained, dark, chloritic material. In some localities rusty weathering carbonate is present. In the eastern part of the group of outcrops adjoining the Macamic highway, there is a conglomerate-like rock composed of round fragments of porphyritic rhyolite up to 8 inches or more in diameter, in a rusty weathering matrix. At one point this also includes some angular fragments of andesite.

There is some uncertainty regarding the time at which the Newbec breccia was formed. It is certain that it is later in age than the dioritic intrusives, for it includes numerous fragments of the quartz diorite both in its fine-grained and variegated phases. At the extreme south end of the group of outcrops south of the Newbec shaft, the contact of the breccia with the Lake Dufault granodiorite was observed in two small rock exposures. For the most part the contact is definite or at least can be fixed within one-quarter inch, and in places the granodiorite appears to send irregular off-shoots into the breccia, but at a few points sharply defined, angular areas of the granodiorite occur in the breccia adjacent to the contact. The Newbec breccia is so much like the Chadbourne breccia that it is possible that the two rocks are similar in origin and, possibly, were formed about the same time. The Chadbourne breccia contains fragments of syenite porphyry and the syenite porphyry is probably younger than the granodiorite. This suggests that the Newbec breccia was formed after the granodiorite was intruded.

There are several possible ways in which the Newbec breccia may have been formed. The fact that porphyritic rhyolite forms the matrix of the breccia in places suggests that the breccia is an intrusion of rhyolite holding fragments of andesite rhyolite and quartz diorite. An objection to this hypothesis is that no porphyritic rhyolite intrusive into the quartz diorite has been found elsewhere in the area and the porphyritic rhyolite is similar to and almost continuous with rhyolitic lava adjoining the breccia. The tabular form of many of the fragments in the breccia, and the presence of quartz, pyrite, and carbonate in places in its matrix suggest that the rock is a fault breccia, but breccias formed by faults usually follow a definite line whereas the Newbec breccia occupies a roughly triangular area. In the Leadville mining district of Colorado four elliptical-shaped, pipe-like masses of breccia, ranging in size up to 2,700 feet long and 900 feet wide, extend vertically through granite, shale, and other rocks and contain numerous fragments of these rocks enclosed in a rhyolite matrix. The inclusions form up to 60 per cent of the whole[1]. In the Alleghany district of California, there is a breccia, like the Newbec occurrence, composed of fragments of andesite and other rocks in a basalt matrix. Ferguson and Gannett state that "the peculiar features of the intrusion are best explained

[1] Emmons, S. F., Irving, J. D., Loughlin, G. F.: U.S. Geol. Surv., Prof. Paper 148, 1927, pp. 55–59.

by supposing that the area occupied by basalt and mud was first the site of a steam explosion. . . Next came the intrusion of the basalt which worked its way upward through the loosely packed rubble"[1]. Both these occurrences of breccia in the United States are similar in many respects to the Newbec breccia and possibly, as is proposed for them, it is of volcanic, probably explosive, origin.

LATER DIABASE AND GABBRO

The youngest igneous intrusive in the Noranda district except for minor intrusions of aplite, is the rock known as the later diabase or gabbro. It forms four dykes. One of these extends north through the Powell-Rouyn property and is known as the Powell dyke; two others cross the Horne property in the vicinity of the ore deposits, one trending north and the other east; the fourth is a small dyke that strikes northwesterly across the McDougall property in the southern part of Dufresnoy township and may be called the McDougall dyke. All four dykes are vertical or nearly vertical, the lowest dip observed being 70 degrees.

The Powell dyke extends across the middle of Rouyn map-area, the southwest corner of Dufault map-area, and the eastern parts of Amulet and Waite map-areas, a total distance of over 10 miles. Its extent to the north and south beyond the area mapped has not been determined. It ranges in width from 50 to 90 feet. In places, as in Waite map-area, it divides into two dykes or is adjoined by small, parallel or branch dykes. East of the Amulet-Lake Dufault ore deposits, the dyke pinches out in a northerly direction, but recurs less than 100 feet to the west. Where crossed by the Horne Creek fault the dyke is dislocated horizontally almost 700 feet, the northern part having moved eastward relative to the southern.

The Noranda north-south dyke is well exposed in the southern part of Rouyn map-area as far north as the Horne mine. Underground intersection in the Horne and Quemont properties shows that it is dislocated horizontally on the Horne Creek fault about 700 feet, the northern part having moved westward relative to the southern. North of the fault the dyke or dyke zone is exposed in two small outcrops south of Lake Dufault, on a small island in Lake Dufault to the east of Sergius Bay, and in numerous exposures northwest of Lake Dufault. The width of the dyke for the most part where exposed ranges between 60 and 100 feet. According to a magnetic survey made recently by Hans Lunberg in the Joliet-Quebec property, the dyke proper terminates near the south shore of Lake Dufault to be replaced by a parallel dyke underlying a drift depression 1,600 feet to the west. The new dyke, as ascertained by Lunberg, continues northward passing beneath the drift of the large island at the entrance to the south bay of Lake Dufault. Theo Koulmonzine has determined by means of a magnetic survey on the ice of Lake Dufault that this second dyke terminates at a point about 350 feet east of the small island in Lake Dufault to the south-southeast of that east of Sergius Bay in which diabase is exposed, but 1,000 feet to the west it is replaced by a third parallel dyke continuous with that exposed in the island to the northward. This third

[1] U.S. Geol. Surv., Prof. Paper 172, 1932, pp. 17, 18.

dyke continues northward, passing southwest of the extreme southwest point of the next island to the north. The magnetic survey was not continued beyond this point.

The Noranda east-west dyke extends in a northeasterly direction across the southeast corner of Rouyn map-area. Southwest of Noranda it is well exposed. Its width ranges, for the most part, from 60 to 80 feet, but in the Noranda townsite and the Horne mine workings it tends to break up into small dykes offshooting to the northeast. East of the Noranda north-south dyke it has a more easterly strike and a width of 70 feet. Southwest of Noranda Lake, the Noranda east-west dyke is intersected by the Powell dyke, which has a definite, fine-grained margin on its northeast side against the Noranda dyke. The contact is exposed for only 2 feet, however. The Noranda east-west dyke and the Noranda north-south dyke are not seen in contact with one another at the surface, but in the roof of drive 3916 on the 975-foot level in the Horne mine the east-west dyke was observed to have a fine-grained edge against the north-south dyke.

The McDougall dyke trends in a southeasterly direction across the Dufresnoy quartz diorite in Amulet Hills and the adjacent andesite to the southeast. It ranges in width from 2 to 12 feet and outcrops at intervals for over 1 mile. In places it divides into two dykes up to 30 feet apart, and in one locality into three dykes from 100 to 200 feet apart.

All of the later diabase dykes are more or less brown coloured owing to the weathering of small, scattered grains or crystals of pyrite. On freshly broken surfaces the diabase is a uniform, medium-grained, dark grey rock with a faintly speckled appearance. It consists chiefly of elongated to rectangular crystals of acid labradorite, augite filling the interspaces between the labradorite crystals, and magnetite. In some thin sections, quartz, chiefly in micropegmatitic intergrowths with a feldspar of much lower refractive index, is present. In others quartz is entirely absent. The less common constituents are apatite, green amphibole, sericite, and epidote, the amphibole being an alteration product from the augite and the epidote and sericite from the feldspar.

The Powell dyke where exposed near the northwest side of the branch railway to the Waite-Amulet mill, is cut by dykes of pink aplite up to 8 inches wide and 60 feet long. These consist chiefly of micropegmatite, albite, and quartz. The less common constituents are microcline, apatite, titanite, tourmaline, epidote, chlorite, and calcite. A dyke of similar aplite, 4 inches wide, lies along the margin of an east branch from the Powell dyke in Waite Hills, southeast of Beaver Hill.

The contacts of the dykes of later diabase and gabbro with the rocks they intrude are sharply defined and for the most part straight, but in places they are irregular or sharply angular. Offshoots from the main dykes are common, and in some localities the dykes include angular fragments of the wall-rock along their margins. In most places from the wall of the dyke inward, there is a dense, black weathering zone from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches wide, followed by a fine-grained, porphyritic phase up to 4 feet wide. In the Newbec property, in the outcrop where the Noranda north-south dyke cuts quartz diorite, the dense phase of the diabase at one point lies within the dyke and is absent along the dyke wall. Along the west border of the

Powell dyke in Waite Hills, the diabase in one place has a fine-grained zone against diabase 2 feet from the margin of the dyke. In some places small dykes of dense diabase up to 6 inches wide intrude the main dyke. An example of this was observed in the Powell dyke at a point about one-third mile north of the road to the Waite-Ackerman-Montgomery mine.

The rock adjacent to the dykes, so far as can be observed, has not been altered by them. Alteration within the dykes consists chiefly of the transformation of the augite to amphibole and the plagioclase to epidote and sericite, but fractures filled with epidote or epidote and quartz are common, especially in the part of the area south of the Horne Creek fault.

The later diabase dykes, except for small intrusions of aplite, intrude all the other rocks in the area and, except for their dislocation on the Horne Creek fault and some fracturing on the Andesite fault and within the Noranda fault block, have suffered no deformation. It is evident, therefore, that they came in after all batholithic intrusion in the district was completed. As, with the possible exception of the diabase, no rocks known to belong to the Proterozoic are present within the area mapped it is not possible to determine the age of these dykes by direct relationships. Several dykes of similar rock, however, are now known to intrude the Cobalt series of the Kekeko Hills southwest of Noranda. According to a report of the Committee on the Measurement of Geologic Time, the age of the Noranda diabase determined by the helium ratio method is between 465,000,000 and 505,000,000 years and approximately the same as that of Keweenawan lava flows of the Lake Superior region[1]. Recently, however, the accuracy of this method of age determination has been questioned[2]. In any case, it seems probable that the later diabase and gabbro of Noranda district are of late Proterozoic age.

GLACIAL

Deposits of glacial origin are not extensive in Noranda district. Above an elevation of about 1,200 feet above sea-level the glacial material consists chiefly of scattered boulders. Below 1,070 feet the glacial material has been largely buried beneath lacustrine clay, but about 1 mile west of Rouyn, at an elevation of 990 feet, stratified gravel, now largely removed, was observed in a gravel pit, and about 500 feet southeast of Rouyn station, at an elevation of 950 feet, 12 feet of fluvioglacial, crossbedded sand is exposed in a sand pit. These glacial stream deposits lie below the level of the highest lacustrine clay, but have not been completely covered by it.

Above the elevation of 1,070 feet, up to which post-Glacial stratified clay occurs, glacial material was noted in several localities. In the northwestern part of Waite map-area there are sand dunes ranging from 1,070 to 1,120 feet in elevation that have probably been formed from glacial sand deposited extensively in this locality. At still higher elevations, up to 1,200 feet, on the slopes of the rocky ridges both in Waite and Amulet map-areas there are areas of small, glacial boulders from which the finer material at one time associated with it appears to have been washed away.

[1] National Research Council, Washington, D.C., 1936, p. 37.
[2] Keevil, N. B.: Trans. Roy. Soc., Canada, sec. 4, 1938, pp. 123-150.

Near the point where the trail to the Bedford property crosses the contact between the Amulet rhyolite and rhyolite breccia and the Rusty Ridge andesite (*See* Figure 1), there is a low ridge of gravel at an elevation of 1,170 feet. No opening has been made in this, but it is probably of glacial origin. About one-half mile north of the Waite-Ackerman-Montgomery mine a northeasterly trending ridge of gravel at an elevation of 1,190 feet forms a divide within a west-northwest trending valley. In the faces of a gravel pit that has been excavated in the ridge about 15 feet of cross-bedded gravel dipping both to the north and south is exposed. This ridge is probably an esker. In the elevated area ranging from 1,150 to 1,300 feet above sea-level to the south of Beaver Hill, there are considerable areas of bouldery glacial drift. These have probably survived because of their protected position between the knobs. The largest mass of glacial drift seen in the area is that exposed in a cut made for the new road to the Amulet mine north of the "A" ore deposits. For 400 feet or more south from the point where the new road joins the old, a face of unstratified glacial drift up to 15 feet high and containing boulders up to 4 feet in diameter is exposed on the east side of the road. This occurs between elevations of 1,150 and 1,170 feet.

POST-GLACIAL

Throughout the lower parts of the district from an elevation of 947 feet, that of the surface of Lake Trémoy, up to 1,070 feet post-glacial, lasustrine, stratified clay has been deposited. This clay, which forms a part of the "clay-belt" of northern Ontario and Quebec, was laid down from a large lake known as Ojibway-Barlow, formed in front of the great Labradorean ice-sheet as it melted away. The time of deposition at Noranda was too short for more than the minor irregularities of the drift-covered bedrock surface to be filled in. For this reason the clay flats vary in elevation in different parts of the area. Thus, in the southern part of Rouyn map-area the surface of the clay has an average elevation of 960 to 970 feet above sea-level, whereas in the southwestern part of Amulet map-area the elevation is about 1,010 feet, and near the Waite-Ackerman-Montgomery mine in Waite map-area, 1,050 feet. Where clay flats adjoin rocky ridges clay has been deposited irregularly for 20 feet or more above the flats. The stratified clay was seen in sections up to 5 feet thick in recent excavations along the highways. It occurs in alternating light and dark grey beds (varves) from one-quarter inch to one-half inch thick. The maximum total thickness of clay reported to the writer was 85 feet in a diamond drill hole on the Glenwood property. It is probable that the maximum thickness of clay in any locality does not exceed 100 feet. The possible reason why glacial drift is almost entirely absent from the higher rock areas is that it was swept away by the wave action of Lake Ojibway-Barlow. In that case the maximum elevation of the lake surface was higher than the crests of the higher hills and ledges, and these range from 1,300 to 1,400 feet in elevation. No definite beach ridges or other shore features were noted, but the absence of fine material in much of the bouldery drift in exposed slopes below an elevation of 1,200 feet suggests that it has been removed by wave action. Presumably the water of Lake Ojibway-Barlow was drained away too rapidly at levels below 1,200 feet for beaches to be formed.

FOLDING

Owing to the great variations in the thickness of the individual lava belts and the complications brought about by faulting, the structure of the rocks resulting from folding is not so evident in this district. That the volcanic rocks in the northern part of the area dip in a general easterly direction is evident from the gentle eastward dip of the rock ridges and their steep, westerly facing scarps. The angles of dip of the flows, also, show that the folding increases in intensity from north to south. There are four major anticlines in the area (*See* Figure 1). These named in succession from north to south are the Quebec-Copper, the Waite, the Amulet, and the Noranda, and between the anticlines, named in the same order, lie the Duprat Creek, the Fourcet Creek, and the Héré Creek synclines.

Quebec-Copper Anticline. In the northwestern part of Waite map-area, a southeastward striking anticlinal axis with minor folds on either side is clearly indicated by the trend of the contacts of the Amulet rhyolite belt. The contact of the rhyolite and the overlying andesite is not exposed on the axis of the fold, but the rhyolite is known to dip under the andesite at an angle of about 30 degrees. It is inferred from this and the dip of the pillows in the andesite that the anticline plunges southeastward at about this angle. The Quebec-Copper anticline is interrupted to the eastward by the Dufresnoy belt of dioritic rocks. East of the diorite belt and north of the Vauze Creek fault zone (*See* Figure 1) the lavas strike northwesterly and dip to the northeast. They have, therefore, the same attitude as the strata of the north limb of the Quebec-Copper anticline and may be the eastward continuation of the north limb of that fold. South of the Vauze Creek fault zone to the Lake Dufault intrusion of granodiorite, the lava flows strike about north and dip eastward. The Waite Hills andesite, which underlies the greater part of this territory, rests on siliceous rhyolite that has been disconnected from the Waite Lake siliceous rhyolite by the intrusion of the diorite. Farther to the northeast there is a third area of siliceous rhyolite that has almost certainly been separated from the Waite Lake area by a fault, which before the intrusion of the diorite extended across the area by way of Waite Lake and the lower Vauze Creek Valley. Along the south slope of Waite Hills east of the Dufresnoy dioritic belt, there is an area where the flow contacts bend westerly forming a minor syncline. This lies almost directly east of the Duprat Creek syncline (*See* Figure 1) and may be its eastward continuation. In that case, the Duprat Creek syncline fades out to the eastward.

Waite Anticline. In the rock ridge southwest of the Waite-Ackerman-Montgomery mine the eastward dipping Amulet rhyolite belt extends to the east about 1 mile. An anticline is, therefore, present in this locality. On the axis of the fold the rhyolite dips beneath the overlying andesite at an angle of 35 degrees. The approximate average eastward plunge of the anticline is estimated to be about 30 degrees. To the north the anticline appears to be cut off, south of the Waite-Ackerman-Montgomery mine, by an east trending fault, for north of this fault adjacent to the mine the dips are southward. To the east the Waite anticline terminates against the Lake Dufault granodiorite. To the south the exposed rock is chiefly diorite, but the occurrence of andesite in an area south of Fourcet Creek indicates that a syncline is present in this valley.

Amulet Anticline. At the Amulet mine the Amulet rhyolite and rhyolite breccia with the overlying Amulet Hills andesite have been folded into five minor anticlines, all part of the larger Amulet anticline. Diamond drill holes through the andesite to the rhyolite breccia show the minor anticlines to have a plunge to the eastward of 20 to 25 degrees and dips on their limbs up to 45 degrees. To the north the major anticline passes into the Fourcet Creek syncline; to the south it continues into the McDougall property where the Amulet rhyolitic belt terminates abruptly at the McDougall fault. West of the Amulet mine, the Rusty Ridge andesite belt, which lies on the north limb of the major anticline, does not appear to have been folded into the minor anticlines continuous with those near the Amulet mine. The south end of the Rusty Ridge andesite lies close to the axis of the Amulet anticline. To the eastward beyond the Dufresnoy diorite belt, the Amulet Hills andesite recurs in an elongated area followed to the southeast by the overlying Héré Creek rhyolite. To the south this rhyolitic belt lies on the south limb of the Amulet anticline or the north limb of the Héré Creek syncline. That the flows dip and have their tops to the southeast in this locality is indicated by the dip of the rhyolite-andesite contact, by the attitude of pillows in the Area Creek andesite mass (*See* Figure 1, number 14), and by the southeasterly inclination of columnar jointing in the rhyolite. The amount of the dip cannot be accurately determined, but it probably ranges from 30 degrees in the western part to possibly as much as 60 degrees in the eastern.

Noranda Anticline. From the Héré Creek syncline southward to the Horne Creek fault, the attitudes of flow contacts, and stratified tuff, show the strike to be northwesterly and the dip to the northeast at angles of 60 degrees to vertical. The pillows show that the tops of the flows face to the northeast. The volcanic rocks in this part of the area, therefore, form the north limb of an anticline. The Noranda wedge-shaped rock mass that lies between the Horne Creek and Andesite faults is composed of andesite in the east and rhyolite, rhyolite breccia, and tuff in the west. The contact between rhyolite and andesite as determined from one intersection on the 975-foot level in the Horne mine, dips eastward at an agle of about 50 degrees. The rhyolitic rocks probably form an eastward facing anticline, a part of the south limb of which has been dragged westward along the Andesite fault. South of the Andesite and Horne Creek faults the flow contacts trend east and are vertical or nearly vertical. Pillows in the andesite areas and brecciated flow tops in the Rouyn Station andesite (*See* Figure 1) show that the tops of the flows face to the north. It is concluded, therefore, that the volcanic rocks of this area form part of the north limb of an anticline. These various parts of anticlinal folds, that north of the Horne Creek fault, that lying between the Horne Creek and Andesite faults, and the part lying south of the faults, are thought to be faulted parts of one anticline, the Noranda anticline. The evidence for this conclusion is given in the immediately following section.

FAULTING

The rocks in the district are intersected by almost innumerable faults, some of the most important of which are indicated on the accompanying maps. Beneath the drift cover, however, there are, no doubt, numerous faults that in the absence of positive evidence of their presence have not been indicated. The faults associated with the ore deposits of the Waite-Ackerman-Montgomery, the Amulet, Newbec, McDougall, Pontiac Rouyn, Powell Rouyn, and Horne mines are described elsewhere in this report. Descriptions here will, therefore, be confined to the Vauze Creek fault zone, and the Waite Hills, Horne Creek, and Bagamac faults.

Vauze Creek-Waite Lake Fault Zone. In the northern part of the district a depression largely filled with clay extends across Waite and Newbec map-areas by way of Waite Lake and the lower part of the valley of Vauze Creek. North of this depression, to the east of the Dufresnoy diorite belt, siliceous rhyolite, underlain to the west by alternating belts of rhyolite and andesite, is present. All of these lavas strike northwesterly and dip northeast. Directly opposite, on the south side of the depression, a wide area of Waite Hills andesite overlain by the Newbec rhyolite to the east and underlain on its northwest border adjacent to the Dufresnoy diorite belt by siliceous rhyolite occurs. These lavas strike north to northeast and dip east to northeast. West of the Dufresnoy belt of diorite the Waite Lake rhyolite and siliceous rhyolite areas (Figure 1, numbers 6 and 7) on the south side of the depression lie opposite andesite to the north. Still farther west a large area of Amulet rhyolite south of the depression lies at least 1,600 feet east of the nearest rhyolite (presumably its continuation) to the north. This abrupt interruption of lavas having almost the same strike and dip is proof that a fault or zone of faults is present in this valley.

If, as seems certain, the siliceous rhyolite north of the fault zone was originally a part of the same area as that occurring south of the fault, then the rocks on the north side have been dislocated at least 4,000 feet to the east with respect to those on the south. Close to the siliceous rhyolite in the northwest corner of Newbec map-area, there is an isolated outcrop of andesite composed of small, pale grey-green weathering pillows having a north strike and easterly dip. The andesite in this isolated outcrop is evidently separated from the adjacent siliceous rhyolite to the north by a fault, but the andesite of the isolated outcrop is an unusual type and is similar in every respect to andesite occurring on the south side of Vauze Creek Valley 3,000 feet to the west. It is obvious, therefore, that another fault must also be present to the south of the isolated outcrop.

The presence of extensions of Dufresnoy diorite both to the east and west along the Waite Lake-Vauze Creek fault zone indicates that the faulting in the main occurred before the diorite was intruded, but in other parts of the district it has been ascertained that faulting recurred on the major faults after the diorite was intruded. Along the southern edge of the group of outcrops of diorite close to the western border of Waite map-area, directly west of Waite Lake, is a well-developed zone of shearing. Other zones of shearing were not observed in the diorite along the fault zone, but outcrops of diorite are not numerous and it is possible that the zone of post-diorite shearing continues across the area but is not exposed.

Waite Hills Fault. Northeast of Beaver Hill, a well-defined depression extends northwesterly across Waite Hills. There are no rock outcrops in this valley in which a fault can be observed, but where andesite occurs on the opposite sides, that to the east is pillowed and includes parts of two flows separated by a well-defined flow contact, whereas that to the west is massive and exhibits neither the pillows nor the flow contact. Southeast of the area of andesite, the boundary of an intrusion of diorite turns sharply southeast for 800 feet along the valley and to the northwest the boundaries of areas of siliceous rhyolite and diorite terminate in a similar manner. All these features are evidence that a fault underlies this valley and that the rocks on the east side of the fault have moved southeast with respect to those on the west.

Horne Creek Fault. A wide, clay-filled depression extends west-southwest across the southern part of Rouyn map-area through the valley of Horne Creek, Tailings Lake, and along the Kirkland Lake highway. There are no outcrops in this valley, but it is known that it follows a fault partly by the manner in which the rocks are interrupted along its course and partly from intersections of the fault in the workings of the Quemont and Horne properties.

The workings of the Quemont property have been filled with water since 1930, but according to the mine plans the fault zone was crossed on the 215-, 500-, and 905-foot levels, on each of which the width of broken rock is over 150 feet. The Noranda north-south later diabase dyke is intersected in the workings and on the north side of the fault lies 700 feet west of its position on the south side. In the Horne mine, the Horne Creek fault is crossed in drive 3917, on the 975-foot level, at a point over 1,000 feet west of the most westerly intersection in the Quemont workings. At this locality there is about 500 feet of broken rock in which intensely sheared zones up to 6 feet wide occur in places.

In the western part of Rouyn map-area the Horne Creek fault, except in two localities where small areas of granite lie south of the fault, cuts off the Powell albite granite mass on the south for its entire length of 2½ miles. Westward beyond the Rouyn map-area the location of the fault has not been determined. According to the regional map[1] the granite continues to the southwest about one-half mile. If the fault continues directly westward without deviation a third outcrop of granite would lie south of the fault in this direction. On the other hand, if the fault bends southward a few degrees the entire western continuation of the stock lies north of the fault, as shown in the map of Rouyn-Bell River area.[2] In any case the straight southern boundary of the granite mass along the fault, and the numerous zones of shearing in the granite trending parallel to the fault, are proof that considerable movement occurred along the Horne Creek fault after the Powell granite was intruded. The wide extent of granite north of the fault and its restricted occurrence to the south also indicates that the rocks to the south lie above the roof of the granite stock and that the south side has moved down vertically with respect to the north. The evidence thus favours the conclusion that there has been a large vertical movement along the Horne Creek fault subsequent to the intrusion of the Powell granite and that the downthrust side is to the south.

[1] Opasatika Sheet, Geol. Surv., Canada, Map 240A, 1930.
[2] Geol. Surv., Canada, Map 328A, 1936.

The Powell diabase dyke on the north side of the Horne Creek fault is displaced about 700 feet to the east with respect to its continuation to the south. The Noranda north-south dyke, on the other hand, is displaced on the fault about 700 feet to the west. The Powell dyke where it outcrops adjacent to the fault is close to vertical. Its attitude at depth is unknown. The Noranda dyke in the Quemont workings dips 85 degrees east north of the fault, and 87 degrees east south of the fault. In the Horne mine workings east of the No. 3 shaft, the dyke is practically vertical to a depth of 1,200 feet, below which it dips about 83 degrees east. The dip of the dyke adjacent to the fault is not known beyond a depth of 905 feet.

The writer examined the rocks along the eastward continuation of the Horne Creek fault and found that the South Bay andesite belt (*See* Figure 1) extends beyond Rouyn map-area east-southeast for about 1¼ miles to where it terminates at a well-defined, southwesterly trending valley continuous to Lake Trémoy. East of the valley outcrops of rhyolite occur. It is probable, therefore, that a fault underlies this valley. North and northeast of Lake Trémoy, rhyolite and rhyolite flow breccia outcrop almost continuously along the hydro-electric transmission line at least as far as the Ville Marie property, lying almost 2 miles east of the east boundary of the Rouyn map-area. Within the rhyolite on the Ville Marie claims there is a north trending band of stratified tuff dipping 80 degrees to the east. The eastern part of this band is crossbedded and the tops of the beds face east. The rhyolitic rocks are exposed in numerous outcrops south as far as an east-west trending linear depression that extends eastward from the north end of Lake Trémoy. This depression is almost certainly underlain by the continuation of the Horne Creek fault. The rock is not exposed in the depression, but on its north margin there is rhyolite more or less sheared and to the south andesite in which the pillows trend northwesterly and dip northeast. The fact that the South Bay andesite continues along an east-southeasterly course for 1¼ miles to the southwesterly striking fault indicates that the north limb of the Noranda anticline north of the Horne Creek fault continues eastward at least as far as the southwesterly striking fault.[1]

A comparison of the rocks adjacent to the south side of the Horne Creek fault in Rouyn area with those north of the fault to the east of the area shows that there are some points of similarity. The stratified tuff within the rhyolitic rocks in the Ville Marie property is similar to the stratified tuff cut off abruptly by the Horne Creek fault at the Horne mine. Furthermore, there is no other known occurrence of stratified tuff north of the fault as far east at least as the Ville Marie occurrence. This suggests an eastward horizontal displacement along the Horne Creek fault of more than 2 miles. The South Bay andesite is lithologically similar to the Chadbourne andesite to the south of the fault and both andesites are alike in that zones of rhyolite breccia occur along the flow contacts in them. If the South Bay and the Chadbourne andesites are parts of the same belt, their present distribution also suggests a large horizontal displacement of the north side of the fault eastward with respect to the south.

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[1] J. W. Ambrose, who has recently mapped the rocks of this area, confirms the writer's observations and has found additional evidence that the Noranda anticline somewhat distorted by faulting continues eastward beyond Rouyn map-area.

Bagamac Fault. Near the southeastern margin of Rouyn map-area an east trending zone of schistosity and fracturing outcrops at intervals for nearly 2 miles, from the Nipissing Central Railway on the west to the eastern outskirts of Rouyn townsite on the east. The amount of displacement on this fault has not been determined, but the width of the zone of schistosity and the difference in the rocks on opposite sides of the fault indicate that the movement was considerable.

In the outcrops of the fault to the west of the Noranda north-south diabase dyke two zones of schistosity and fracturing converge eastward towards one another and a subsidiary branch fault extends to the northeast. These zones are in both rhyolite and quartz diorite and range in width from 5 to 25 feet. The presence of subsidiary shear zones extending northeastward and the drag-folds along the fault zone suggest that the north side of the fault has moved eastward with respect to the south. The main fault zone is exposed for a width of about 10 feet on the south side of Cardinal Begin Street at a point about 800 feet west of the diabase dyke. At this point the rock is a dark green schist that under the microscope was found to be highly chloritized rhyolite.

At the southeast corner of Cardinal Begin and Main Streets in Rouyn a zone of schist 25 feet wide outcrops on the continuation of the main fault. This zone consists of sheared rhyolite interbanded with a green, cavernous weathering rock, which is almost certainly altered quartz diorite. The rock south of the zone is rhyolite, that to the north quartz dorite. About 600 feet west of this outcrop three shear zones are exposed. The southerly of these zones, which is exposed for a width of about 3 feet in a prospect opening on the south edge of the rock area, is in alinement with the main fault. In this locality, as farther east, the rock is quartz diorite on the north and rhyolite to the south. From the outcrop just described westward for 1,800 feet the main fault lies south of the rock outcrops. Its presence is proved in the Bagamac shaft, which has been sunk on the shear zone. North of the main zone in this locality two other shear zones, up to 10 feet wide, in the diorite diverge towards the northwest.

South of Rouyn Railway station the fault zone is exposed at a point about 300 feet east of the railway in an outcrop 12 feet long by 6 feet wide. The entire outcrop is vertical rhyolitic schist striking north 83 degrees west. In the face of the rock cut at the railway and in the rock area to the west the outcrop of the fault is a vertical zone of schist 10 to 15 feet wide, with diorite to the north and andesite to the south. In the andesite there are pillows having their tops to the north and thin flows with brecciated tops to the north.

In the territory south and southwest of Noranda Lake the fault zone is exposed in several outcrops. Except for later diabase dykes, the rock to the south of the fault is entirely massive andesite and to the north chiefly rhyolite intruded by diorite. In an outcrop south of the west end of Noranda Lake there are branches in the fault zone in which the rhyolite and andesite interfinger or are intermingled. The rocks along the fault in this area are sheared and broken for a width of 50 feet or more, but the zones of schistosity are discontinuous and variable in width. In the outcrops farther west, the fault is marked by a zone of broken and schistose rock up to 50 feet wide. The Powell dyke crosses and completely cuts off the fault in one of these exposures.

In the clay-covered territory east of Rouyn diamond drill holes in the Dasserat Rouyn group of claims along the eastward continuation of the Bagamac fault intersected zones of chloritized schistose rhyolite impregnated with pyrite and cut by veinlets of quartz and carbonate. The fault, therefore, probably continues eastward to the south of Lake Trémoy.

Age and Type of Faulting. It is noted elsewhere in this report: (1) that intrusions of diorite follow some of the major faults of the area; (2) that in the workings of the Horne mine the zones of shearing that occur along faults are much more intense in the volcanic rocks than in the diorite; and (3) that the major faults, at least, appear to be of the thrust type related to the folding of the volcanic rocks. These observations show that faulting in Noranda district began before the dioritic group of rocks were intruded. On the other hand, the occurrence of shear zones in the dioritic intrusives along the same zone as the earlier faulting proves that faulting recurred after the diorite was intruded. Similarly, the large displacement of the Powell granite and the smaller displacement of the dykes of later diabase along the Horne Creek fault show that faulting occurred after each of these rocks were intruded. It is concluded, therefore, that movement recurred along the major fault zones at intervals from early Archæan to Proterozoic time.

The evidence previously cited suggesting that an apparent horizontal displacement of at least 2 miles has occurred along the Horne Creek fault, the large amount of shearing along the fault, and the huge amount of vertical displacement necessary to effect such an apparent horizontal displacement of lavas pitching steeply eastward by normal faulting, make it almost certain that the early movement along the fault was a thrust of the north limb of the Noranda anticline eastward as an accompaniment of the mountain building to which the volcanic rocks were early subjected. Within the Noranda fault block there is included a fragment of the north limb of an anticline with a small part of the south limb apparently dragged westward along the north side of the Andesite fault, relationships also pointing to eastward thrusting. South of the Horne Creek and Andesite faults, the belts of volcanic rocks strike east and face north. This condition could be brought about by a repetition of the north limb of the Noranda anticline by faulting. The northeasterly trending, subsidiary shear zones along the Bagamac fault that merge into it suggest, as in the case of the Horne Creek fault, that the movement was a thrust of the north side to the east with respect to the south. The structural relations within Rouyn map-area from the Noranda anticline southward are, therefore, similar to those of successive overthrust folds standing on edge. It is probable also that the faulting of the Vauze Creek zone, and in fact all or most of the early faulting in the area, was of this thrust type related to the mountain building folding to which the volcanic rocks were subjected before the intrusion of the dioritic intrusives. On the other hand, the faulting that occurred subsequent to the intrusion of the Powell granite and the dykes of later diabase, as shown by the relationships along the Horne Creek fault, was almost certainly of the normal type.

FORM AND RELATIONSHIPS OF INTRUSIVES

The major intrusives of the district, the quartz diorite and related rocks, the Dufault Lake granodiorite mass, and the Powell and Flavrian Lake masses of albite granite, differ from one another, in some respect at least, in their manner of emplacement. The diorite and quartz diorite in places, as in the northwest part of Waite map-area and in the region southwest of Lake Dufault, occur in linear masses trending approximately parallel to the strike of the volcanic rocks, and in these localities are almost certainly sills. In other parts of the district, as along the Vauze Creek fault zone, they obviously have been intruded along faults. The Dufresnoy mass, on the other hand, in part at least cuts abruptly across the folded structure of the lavas. Certain structural features suggest that the dioritic intrusives have thrust aside the volcanic rocks to make place for themselves. In the northeastern part of Waite map-area, for example, where the belts of lava are cut across diagonally by the northwestward trending tongue of diorite, the lava belts are offset to the eastward on the north side the exact distance that would have resulted if the two walls had been thrust apart for the width of the diorite body. It is noteworthy also that the diorite, unlike the granodiorite, contains few inclusions of the intruded rocks.

The Lake Dufault granodiorite within the territory mapped occupies an almost circular area 3 to 3½ miles in diameter. Its contact on the whole is not well exposed. Where it can be observed the adjacent rocks are cut by numerous intersecting dykes of the granodiorite. The approximate dip of the contact, determined from a diamond drill hole commencing in diorite on the Lake Dufault property about 800 feet north of the andesite-diorite contact and 550 feet south of the granodiorite boundary, is about 50 degrees. The occurrence of numerous more or less recrystallized inclusions of the adjacent rock gives support to the hypothesis that the granodiorite made place for itself, in part at least, by assimilation of the intruded rock. On its western margin it cuts abruptly across the Waite anticline, the Fourcet syncline, and the northern part of the Amulet anticline. Its eastern extension, according to J. W. Ambrose, beyond Newbec and Lake Dufault map-areas, lies, however, on an anticline that fades out to the eastward.

The albite granite of the Flavrian Lake and Powell masses, unlike the granodiorite, does not appear to cut the adjacent rocks in dykes to any great extent and its boundaries are very indefinite. The Flavrian Lake granite occurring in the area is only a small, marginal part of a larger mass lying outside the area to the westward. It lies about on the westward continuation of the Amulet anticline. The outcrop of the Powell granite mass lies almost wholly within the Noranda anticline. The western part of the mass lies beyond the area mapped.

RELATIONS OF IGNEOUS ROCKS

All the rocks occurring in Noranda district are either igneous or closely related to igneous activity in origin and, except for the dykes of later diabase and gabbro, all belong to the Archæan basal complex. The outstanding characteristic common to nearly all the rocks of the complex, both intrusive and extrusive with the exception of the syenite porphyry, is a relatively high content of soda in contrast with a low content of potash. They belong in chemical composition, therefore, to a sodic province.

VOLCANIC ROCKS

The lavas consist of siliceous rhyolite, normal rhyolite, rhyolite flow breccia, and andesite, all of which have been poured out in successive alternating belts ranging from a few hundred feet up to about 11,000 feet in thickness. Several flow belts terminate within the district, but, with the exception of some very small lava streams, all continue at least in one direction beyond its confines. The greatest length of flow belt within the district, that of the Waite Hills-Powell-Pontiac andesite, is about 6 miles. The presence of original lamination and breccia at the tops of both flow belts and lava flows within the belts shows that neither the individual flows nor flow belts underwent erosion following their extrusion. The lava flows, therefore, followed one another without any great lapse of time.

Nowhere in the district were the volcanic rocks observed to have the structure of a typical volcanic crater. The presence of pyroclastic breccia and stratified tuff in the southern part of the district suggests that craters were originally present somewhere in the region. The presence of fragments up to 2 feet in diameter in the Noranda pyroclastic breccia also indicates that the vent from which they came could not have been very far distant. Northwest of Waite Lake, a triangular-shaped mass of "ribbon" breccia about 800 feet in diameter lies on the east margin, and hence on the upper side of the Amulet rhyolite and rhyolite breccia. The ribbon-like inclusions of this breccia have the characteristics of engulfed fragments of lava crust such as commonly form in volcanic vents. The objections to the hypothesis that this is a lava cone are that, so far as observed, it is not connected with a dyke or other intrusion of rhyolite through which the rhyolite could make its ascent, and, at the top of the Vauze Creek rhyolite belt in the northeast part of Waite map-area a lava flow is composed of similar ribbon breccia. It is possible, therefore, that the triangular mass is merely a local variation in the Amulet rhyolitic belt.

The almost entire absence of pyroclastic rocks or of structures suggesting craters throughout most of the district and the abundance of dykes of both rhyolite and andesite cutting the lavas suggest that some of these intrusions occupy channels along which the lavas made their ascent. Although no dyke was observed to connect with a lava flow, in the northwestern part of Amulet map-area south of Duprat Lake, two dykes of rhyolite up to 50 feet wide cut across the Rusty Ridge andesite in an east-west direction and very probably join the overlying Amulet rhyolitic belt to the eastward. The data on which this conclusion is based are as follows: (1) The northerly of the two dykes outcrops up to the west side of a drift-filled depression 25 feet wide on the rhyolite-andesite contact and does not occur in the rhyolite beyond the contact. Its absence in the rhyolite suggests that it either abruptly stops at the rhyolite-andesite contact or that it merges into the rhyolite beneath the drift cover. (2) Both dykes are finely and uniformly laminated parallel to their margins, a feature that suggests that the rhyolite was moving at the time of its consolidation. (3) Both dykes are highly spherulitic. The presence of this structure more characteristic of lava than of dyke rock may indicate close proximity to the surface. (4) Where the southern of the two dykes meets the Amulet rhyolite belt there are no outcrops either at this point or to the eastward, but in the most easterly outcrop of the dyke, which probably lies only a few feet west of the margin of the Amulet belt, the lamination in the dyke is highly crumpled. This also suggests that the lava in the dyke was moving at the time of its consolidation.

INTRUSIVES

A resemblance exists between most of the intrusives of Noranda district and the equivalent phases of the volcanic rocks. Thus, the diorite and quartz diorite differ little in composition from the andesite lavas, and the albite granite of the Flavrian Lake and Powell masses, except for their textural difference, are practically the same rocks as the rhyolite lavas. These relationships hold for all the intrusives of the Archæan complex, with the exception of the syenite porphyry, which as shown by the analysis contains almost as much potash as soda.[1] These observations suggest that, with the possible exception of the syenite porphyry, all the igneous rocks of the Archæan were derived from a magma or magmas of related composition, which in some manner differentiated into acid and basic phases.

The variations within the intrusions of quartz diorite may afford some information regarding the process by which the various phases were formed. The quartz diorite body in the southern part of the town of Rouyn, for example, in places, chiefly along its northern margin, passes into albite granite. There is no intrusive contact and it is almost certain that the albite granite formed locally from the diorite by differentiation. Similarly, within the large Dufresnoy mass, there are numerous areas, some of them of considerable extent, in which the rock is highly variegated and the feldspar abnormally abundant. In contrast with this there are also extensive areas, notably in the region west of Sergius (Moose) Bay, of basic diorite to acid gabbro. Areas of graphic pegmatite, and in some localities masses in which amphibole forms almost the entire rock are present. In the northeastern part of the Newbec area of diorite there are numerous outcrops of a highly feldspathic phase in which ferromagnesian minerals are sparingly present. The presence of all these variations in the dioritic intrusives shows that the diorite had a marked tendency to differentiate into acid and basic phases, and various stages in this process are displayed in its numerous occurrences in the district. These relations suggest that the magma from which the lavas and intrusives of the Archæan were derived may have been of dioritic composition and was transformed by differentiation, in a manner somewhat similar to that observed at the present surface, into acid and basic phases. According to this hypothesis, the diorite, granodiorite, and albite granite may all be differentiates of a single magma.

[1] Hawley, J. E.: Que. Bur. Mines, Ann. Rept. 1931, pt. B, p. 23.

CHAPTER IV

ORE DEPOSITS

The ore deposits of Noranda district belong to two main classes: (1) sulphide replacement deposits; and (2) gold-bearing quartz veins. The deposits of the first class are by far the most important. The most typical examples of the second class are the Powell Rouyn veins.

SULPHIDE REPLACEMENT DEPOSITS

The sulphide replacement deposits known to be extensive are those of the Noranda, Amulet, Lake Dufault, and Waite-Ackerman-Montgomery properties. Other important sulphides ore deposits occurring outside the district, in western Quebec, are those of the Aldermac and the Normetal (formerly Abana) mines. Brief references to the latter are included in this report for comparison of their rock alteration and the relationship of their ore to the later diabase. Sulphide occurrences in Noranda district from which small shipments of ore have been made or on which considerable development work by diamond drilling or in other ways has been done are those in the Newbec, the northern part of Powell Rouyn, the eastern part of Pontiac Rouyn, Joliet Quebec, and Bedford properties.

GENERAL CHARACTER

The sulphide ore deposits of western Quebec, most of which lie within Noranda district, resemble one another in their character, relationships to structure, and associated wall-rock alteration, but there are wide differences in the proportions of the different minerals present, not only in different properties but in some cases within the ore masses of the same property.

The irregular and gradational boundaries of the ore deposits; the preservation in the ore of the original banding of the stratified rhyolite breccia and tuff; the association of the ore in every case with breccias of various kinds, or with tuff, rocks that are easily permeable; the presence of fragments completely or partly replaced by ore in the breccia; and the dissemination of the sulphides through the matrix of breccia (Plate XIVA), and along or adjacent to fractures, are all features indicating that the ores have been deposited by replacement. The association of most of the sulphide ores of western Quebec with rhyolitic rocks suggests that the acid lavas were possibly more easily replaced than basic, but, in places, as at the Waite-Ackerman-Montgomery mine and the Upper A group of deposits of the Amulet, the ore occurs in, and evidently replaced, andesite. In places the sulphide replaces intrusives, as at the Horne mine where ore replaces both quartz diorite and syenite porphyry.

At the Aldermac, where a mass of syenite porphyry bordered by a network of dykes adjoins the ore, both the dykes and the larger mass are chloritized, are penetrated along fractures by ore, and, in places, include masses of ore that have obviously replaced the syenite. It is probable, as suggested by E. L. Bruce, that the syenite served as a barrier to the movement of the ore-bearing emanations, and thus promoted the deposition of the ore at this point.[1]

STRUCTURE

The most important structural features with which the sulphide ore deposits of Noranda district are associated are: (1) faults that were almost certainly the channels of ascent for the emanations from which the ore was deposited; (2) the permeable structure of the volcanic rocks due chiefly (a) to the original open texture of flow breccia, pyroclastic breccia, or tuff, or less commonly (b) to the brecciated condition of the lavas resulting from deformation; (3) the presence of impermeable rocks either extrusive or intrusive above the deposits in relationships that suggest that they served as barriers to the further ascent of the ore-bearing solutions; and (4) in some occurrences the presence of anticlinal folds. Of these structures controlling ore deposition, Nos. 1 to 3 played an important rôle in the deposition of all the sulphide ore deposits of western Quebec. No. 4, on the other hand, although important at the Amulet and to some degree at the Horne mine, was probably not a major factor in the development of the ore masses elsewhere. In addition to the structural associations mentioned, in places in the area, pyrite, pyrrhotite, and chalcopyrite occur along flow contacts in the andesitic lavas. Although these deposits are nowhere extensive, their presence indicates that the ore-bearing solutions were able to penetrate along flow contacts. So far as observation has gone, however, flow contacts are only of secondary structural importance as channelways of ascent for mineral solutions.

Faulting. The ore deposits of the Horne mine occur within a wedge-shaped fault block of volcanic rocks having its apex to the west and forming a part of the eastward plunging Noranda anticline. This wedge-shaped mass is delimited on the north by the Horne Creek fault, which down to the lowest point to which it has been intersected has a vertical or nearly vertical attitude; and on the south by the Andesite fault, which between the surface and the 3,975-foot level has an average dip to the north of about 82 degrees. The ore deposits lie on or adjacent to zones of faulting and shearing, most of which strike southwest and dip southeast towards the Andesite fault (Figures 2 and 3). Where these zones have been followed in the mine drives they merge into the Andesite fault. It is concluded, therefore, that they are subsidiary to the Andesite fault and that the ore-bearing emanations made their ascent by way of the Andesite fault and its subsidiaries. The Andesite fault, if it maintains its dip of 82 degrees to the north, in its turn merges into or intersects the Horne Creek fault at a depth of about 15,000 feet.

[1] Arntfield-Aldermac Mines Area; Quebec Bur. of Mines, 1923–33, pt. C, p. 57.

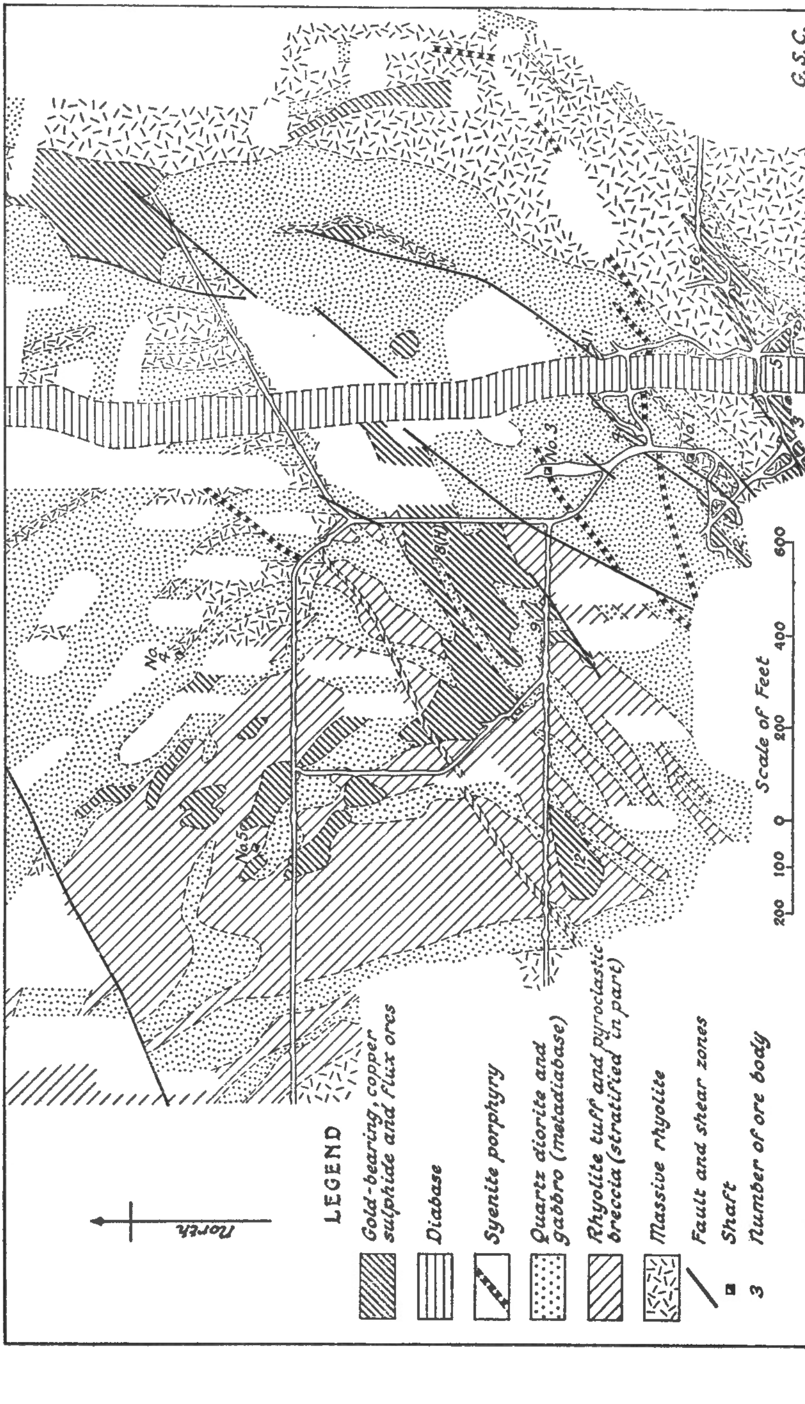

Figure 2. Plan of 200-foot level, Horne mine.

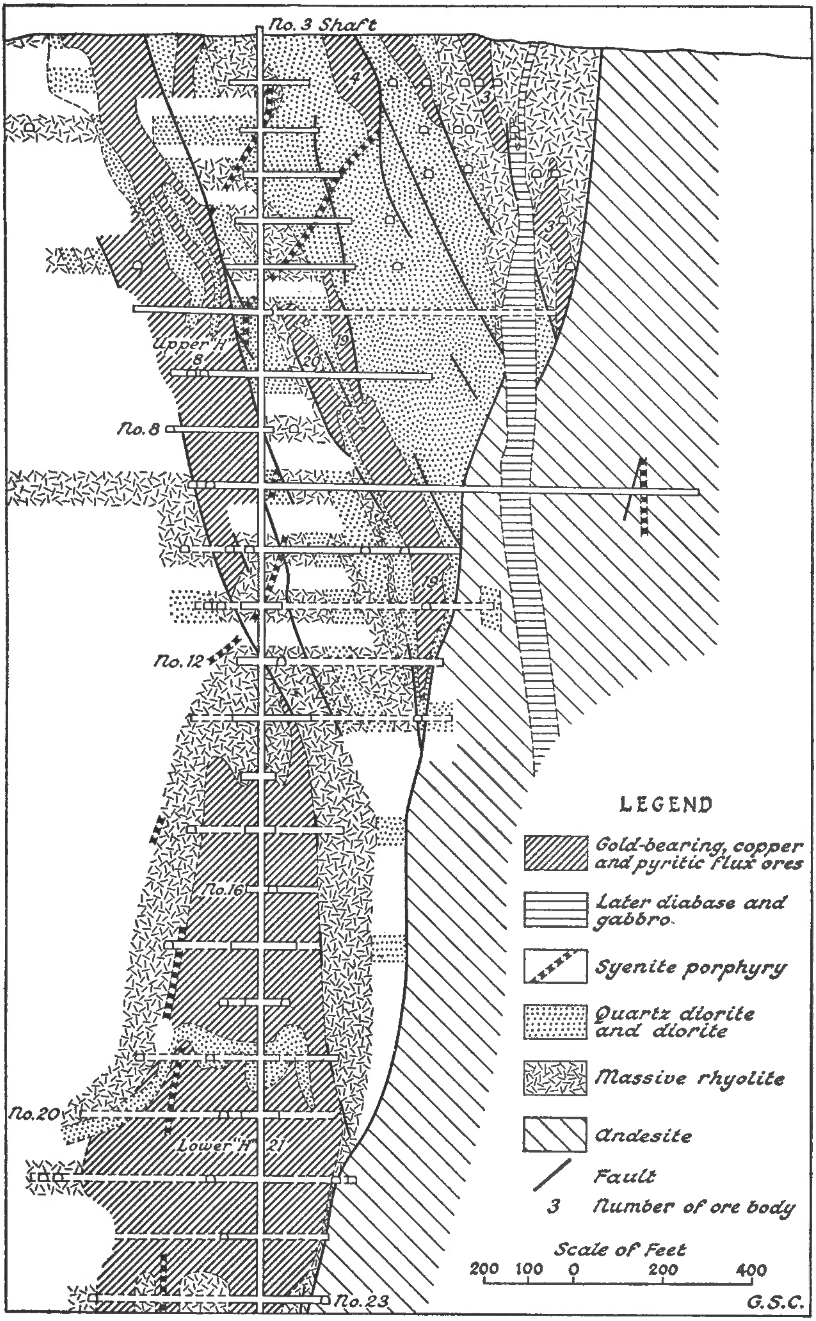

Figure 3. North-south section through No. 3 shaft, Horne mine.

The three main ore groups in the Amulet property, known as A (2), C (4), and F (5), are all associated with faults, but only in the case of the C group has development proceeded far enough to fully disclose the relationships. At this locality the ore occurs in four masses known as B, C, D, and E, adjacent to a northeasterly trending fault along which the contact of the rhyolite breccia and andesite has apparently been displaced 80 feet downward on the south side so that the B and C deposits, which lie on the north side of the fault, occur at a higher elevation than D and E, on the south. The ore deposits extend for 280 feet to the south and about 400 feet to the north of the fault, and longitudinally along the fault for about 800 feet. The deposits of F or (5) group are associated with numerous small faults, which have apparently served as channels of access for the ore-bearing solutions. Intersections of zones of deformation in diamond drill holes also show that larger faults are probably present below and to the southeast of the ore deposits, but these have not been crossed in the mine workings. The deposits of the A or (2) group are known only from the outcrops of the Upper A zone at the surface and from diamond drill intersections. An east trending, drift-filled valley along which zones of breccia appear to have been displaced lies along the south margin of the group, but whether this is the major fault associated with the ore deposit is not known. A wide north trending valley also crosses the deposit along its eastern margin. Diamond drill holes in the eastern part of the Lake Dufault property have intersected eastward dipping faults, and it may be possible that a fault parallel to these lies in the valley, although north trending faults are relatively uncommon in Noranda district.

The ore deposits of the Waite-Ackerman-Montgomery mine are associated with numerous faults, part of which are steeply inclined and part low-angle thrust faults dipping 30 to 45 degrees to the south. The orebodies all lie close to or adjoin the No. 1 fault, which trends north-northeasterly and dips steeply to the north. It was, on this account, at first thought that the No. 1 fault was the channel along which the ore-bearing solutions made their ascent, but the ore-bodies also lie above south-dipping faults, which must either intersect or merge into the large No. 4 fault (*See* Map 455A, Waite area), which lies about 1,000 feet to the south. It is also possible, therefore, that the ore made its ascent from depth by way of the No. 4 fault and from it followed the south-dipping faults to the places of deposition. In any case, although the precise route followed by the ore-bearing emanations is not known, from the close association of the ore with faults and the absence of any other probable channelway, it is concluded that the ore made its ascent by way of faults.

At the Normetal (formerly Abana) mine the ore occurs in a highly schistose and broken fault zone that trends northwesterly and dips steeply towards the northeast parallel to the strike and dip of the stratified rhyolitic breccia and tuff in which the deposit occurs. Cutting across the zone is an almost vertical dyke of later diabase about 180 feet wide. Within the dyke near its eastern margin is a fault zone of broken and slickensided diabase from 7 to 20 feet wide. On the east side of the dyke, presumably, because of displacement along the fault in the dyke, the ore zone lies about 160 feet to the north. There is some doubt regarding the age relationships of the last fault to the ore, but it is at least evident that the ore not only occurs in a fault but made its ascent from depth by way of a fault or faults.

Breccia, Tuff, and Brecciation. All of the sulphide ore deposits of Noranda district occur in rocks that were originally breccia or tuff or have been transformed into breccia by deformation. In the Horne mine, the ore of the Lower and Upper H deposits, which are by far the largest ore masses in the property, occur in the Noranda pyroclastic rhyolite breccia (Plate XIVA). In places the ore masses are elongated to the northwest following the trend of the breccia, and where stratification is present can be seen to have replaced individual beds. These features indicate that the breccia, presumably because of its permeable texture, was easily replaced by ore. The smaller ore masses and the gold-bearing flux deposits in the southeastern and eastern part of the property occur in massive rhyolite that has been broken by deformation along faults. The gold-bearing ore of the Chadbourne property also occurs in a deformation breccia, which includes fragments of all the Archæan rocks present in the property, including the syenite porphyry (Plate XIV B). In the Amulet property, the ore, except for the relatively small ore masses of the Upper A group, which are in rounded, andesite flow breccia, occurs in the upper, scoriaceous, easily permeable top of the rhyolite flow breccia phase of the Amulet rhyolitic belt. The ore so far discovered in the Waite-Ackerman-Montgomery property occurs mainly in zones of brecciated and silicified andesite. It is possible that this breccia is in part original flow breccia, but the highly fractured and broken condition of the rocks indicates that it has also been subjected to intense deformation. At the Normetal mine the ore occurs in stratified rhyolite tuff along a zone broken and sheared by faulting. Both the permeable texture and the broken character of the tuff were obviously favourable structural conditions for ore deposition. The ore at the Aldermac mine occurs mainly in stratified tuff and breccia. These relationships all show that an easily permeable rock was one of the essential conditions for the deposition of the sulphide ore.

ROCK ALTERATION

The changes effected in the wall-rock by the ore-bearing solutions consisted chiefly in the addition of large amounts of magnesia, iron, alumina, and water, and a reduction in the content of lime and soda. The relative amounts of these elements introduced in different localities, however, may have varied, for the minerals formed in different properties were not all the same.

Horne Mine. In the Horne mine, the outstanding alteration that accompanied the deposition of the ore was the formation of chlorite, but the related mineral ottrelite was also noted in one thin section of the rhyolite breccia examined. It is possible, as suggested by Price[1], that

[1] The Geology and Ore Deposits of the Horne Mine; Trans. Can. Inst. Min. and Met., vol. 37, 1934, p. 119.

some silicification and sericitization accompanied the mineralization. That the chloritization and the deposition of the ottrelite were effected by the emanations from which the ore was deposited is proved by the following observations.

(1) Throughout a large part of the mine workings, notably near the H deposits, the rhyolite and rhyolite breccia are highly chloritized adjacent to the ore, and especially, as noted by Price[1], where some of the highest grade gold ore occurs.

(2) In places where massive rhyolite adjoins the ore-bodies, as on the fifth level in drive 3518 on the east side of the Noranda north-south diabase dyke, dark chlorite with some associated sulphides, chiefly pyrite, occurs in a network of fractures through light grey, sericitized rhyolite. At some points this chloritization has extended from the fractures various distances to leave unaltered areas that give the rock a breccia-like appearance. The chloritization and deposition of sulphides occur along fractures that are the continuation of those along which the ore penetrated the rhyolite. Where beds of the rhyolite breccia are chloritized, the alteration with the ore minerals extends along individual, presumably more easily permeable beds. In some localities the chloritization in massive rhyolite occurs in scattered spots. This is probably due to some original difference in the rock at the point where the spots occur.

(3) In several thin sections of rhyolite, examined microscopically, the rock was seen to be traversed by zones of granular quartz, chlorite, and pyrite or pyrite and chalcopyrite. In some of these chlorite is concentrated along the margins of the pyrite crystals or grains. The occurrence of the chlorite in these zones suggests that the elements composing it entered the rhyolite with the ore-bearing solutions. Much of the chlorite in zones of this type occurs in rosettes.

(4) In a thin section of a specimen of rhyolite breccia collected from the extremity of the drive extending northwesterly from No. 5 shaft on the 700-foot level, a zone of granular quartz was seen to contain chlorite, pyrite, and ottrelite.

Although some wall-rock silification accompanied the deposition of the ore at the Horne mine, it was not a general alteration effect. The pyritic phases of the Horne ore, on microscopic examination, are seen to contain quartz in radial growths on pyrite cubes, showing that some quartz was deposited with the ore. The analysis of rhyolite, in column 2, Table I, indicates, however, that the rhyolite and rhyolite breccia in which the Horne sulphide ore occurs probably contains about 75 per cent of silica, so that it was not possible for it to undergo silicification to any great degree. Furthermore, microscopic examination of the wall-rock does not suggest that there has been an addition of quartz in any considerable amounts. The

[1] The Geology and Ore Deposits of the Horne Mine; Trans. Can. Inst. Min. and Met., vol. 37, 1934, p. 130.

following is a partial analysis of the average of a large tonnge of flux ore from the Horne mine supplied the writer by H. M. Butterfield, formerly of the Noranda geological staff.

TABLE VI

	Per cent
SiO_2	56·0
Al_2O_3	10·3
Fe	12·6
Cu	0·5
CaO	1·7
S	9·5
MgO	1·0
Na_2O	0·8
K_2O	1·9
Total (calculating Fe as FeO)	97·9

If pyrite and chalcopyrite be eliminated from this analysis and the content of the remaining constituents recalculated to a total of 100, it is found that the silicia is about 76 per cent, or that of normal rhyolite. It is probable, therefore, that in the formation of the flux ore no silica was added. On the other hand, the replacement of rhyolite by large masses of sulphide ore necessitated the removal of a considerable amount of silica. It is possible, therefore, that part, at least, of the numerous quartz veins seen in the mine workings, notably in the diorite, have been derived from this source. Most of the quartz veins do not carry gold, but the relationships of the gold to the sulphide in the ore show that the gold was deposited after the sulphides so that gold would not be present in quartz veins derived from the rhyolite by replacement, unless introduced into them at the time of the gold mineralization. Price points out that some small dykes of quartz diorite in the ore are highly silicified[1]. The inclusions of andesite in the Chadbourne breccia are also considerably silicified where the brecciation is most intense. This mineralized breccia consists of tabular fragments of andesite, rhyolite, and, in the long drive from the Horne No. 3 shaft, diorite and syenite porphyry in a matrix of quartz, with some pyrite, and ankerite and a very little specularite and chalcopyrite (Plate XIV B).

The rhyolite and rhyolite breccia contain considerable sericite and the analysis of flux ore shows that it contains less soda and much more potash than normal rhyolite, a change represented in the rock mainly by the replacement of albite by sericite. It is uncertain, however, that this sericitization was all an accompaniment of the sulphide mineralization, for sericite occurs everywhere in the rhyolite wherever it has undergone deformation and the amount of sericite present appears to be proportional to its degree of schistosity. In one thin section of rhyolite examined sericite was observed to occur in a zone surrounding a pyrite crystal as if deposited on it, but there is no evidence of extreme sericitization adjacent to the ore masses. In the Horne mine, therefore, the alteration associated with the sulphide mineralization was in the main chloritization.

[1] Geology of the Horne Mine, Noranda, Quebec. Thesis submitted in partial fulfilment for the degree of Doctor of Philosophy, McGill University, 1933, pp. 145–6.

Amulet and Lake Dufault. The most unusual alteration rock in Noranda district is the cordierite-bearing dalmatianite associated with the ore deposits of the Amulet and Lake Dufault properties. This rock, named dalmatianite by prospectors because the spotted appearance of its weathered surface suggests the spots of a coach or Dalmatian dog, occurs chiefly with and beneath the ore masses. Where, however, two separate groups of deposits are present in the same locality but one beneath the other as in the case of the Upper and Lower A deposits, the dalmatianite below the upper deposit is above the lower. In addition to the occurrences in association with the known ore deposits there are extensive areas underlain by dalmatianite in the Amulet rhyolite and rhyolite breccia belt in the western part of the Amulet property. These occurrences lie structurally below the rhyolite breccia-andesite contact and hence almost certainly below ore deposits that have been removed by erosion. So far as observed up to the present, the dalmatianite is confined wholly to the Amulet anticlinorium and hence to the Amulet property and the adjacent territory to the west and east.

On its freshly broken surface the dalmatianite is a fine-grained, dark grey, brownish, or greenish grey rock, the colour varying according to the mineral predominating in its different phases. The cordierite in some phases is indistinguishable, whereas in others it has a glossy apearance strikingly different from the dull-looking matrix. In some specimens, small rosettes of gedrite, the aluminous variety of anthophyllite, and in others small black octahedra, which proved under the microscope to be green spinel, are common. Another common phase of the rock is the brown variety in which pale yellow to deep brown mica, occurring in aggregates or in large areas of small crystals of approximately uniform size, is the predominant mineral present. The dalmatianite also generally contains varying proportions of the common ore minerals, pyrite, pyrrhotite, sphalerite, and chalcopyrite.

On its weathered surface, the dalmatianite is characterized by numerous small protuberances. This wart-like appearance of the rock arises from the resistance to weathering of round to bean-shaped, less commonly rect-angular-shaped, crystals of cordierite (Plate XI B). In some places the weathered surface also exhibits small, round, pea-like protuberances of granular quartz, which, as T. L. Walker suggests, are probably amygdules[1]. On the surface of diamond drill cores, the dalmatianite as a rule also presents a variegated appearance, and many original structures of the lavas, amygdules, breccia, and flow lamination, can be observed. Under the microscope the dalmatianite is seen to consist chiefly of two or more of the following minerals: cordierite, mica, gedrite, quartz, spinel, chlorite, magnetite; and one or more of the ore minerals, pyrite, pyrrhotite, sphalerite, and chalcopyrite.

The quartz of the dalmatianite is all finely granular. It occurs partly in sharply defined, round, elliptical, or elongated areas similar in every respect to the amygdules of the unaltered volcanics, and partly in irregular zones and aggregates. Some border phases of the dalmatianite include scattered grains and aggregates of quartz (in some cases associated with feldspar), which is obviously the original quartz of the rhyolite from which

[1] Walker, T. L.: Dalmatianite, the Spotted Greenstone from the Amulet Mine, Noranda, Quebec; Univ. of Toronto Studies, Geol. Ser. 29, 1930.

the dalmatianite was formed. The proportion of granular quartz in the dalmatianite is exceedingly variable. In many sections it is entirely absent, in others it forms at least 75 per cent of the rock.

The chlorite of the dalmatianite is pale green and lamellar and occurs in irregular zones traversing the cordierite, its relationships indicating that it is an alteration product of the cordierite. In many thin sections of the dalmatianite, octahedral grains, skeletal areas, and parallel, rod-like aggregates of a black mineral that is at least in part magnetite, occur abundantly. The fact that titanium is shown by analysis to be present in the rock, however, suggests that some ilmenite or titaniferous magnetite is also present. In a few thin sections of the dalmatianite associated with the andesite, rod-like areas of partly altered plagioclase enclosed in a matrix of fine brown mica are present. This plagioclase is similar to that of the andesite and is almost certainly a remnant of the original rock.

The contact relationships of the various minerals composing the dalmatianite, as seen under the microscope, present some interesting features. The spinel crystals were not seen in contact with the magnetite, but they maintain their form with respect to all the other minerals except that in places the gedrite fibres indent their margins. Where the gedrite rosettes meet the magnetite they are for the most part cut off, only a few imperfect fibres penetrating into or continuing across the magnetite. With respect to all the other minerals, however, the gedrite maintains the perfect stellar orientation of its fibres, the cordierite, mica, quartz, and chlorite occupying the interspaces between them.

The mineralogical composition of the dalmatianite shows that in general it is composed of minerals containing large proportions of iron, magnesia, alumina, or silica, the predominance of which in the rock is confirmed by analyses I, II, and III, in the following table.[1]

TABLE VII

—	I	II	III	IV
	Per cent	Per cent	Per cent	Per cent
SiO_2	30·00	60·52	67·94	44·46
TiO_2	0·42	1·00	0·45	0·64
Al_2O_3	21·41	15·68	12·02	25·76
Fe_2O_3	7·06	0·32	......	8·40
FeO	21·22	6·26	6·72	8·24
CaO	......	1·38	1·88	0·62
MgO	11·54	7·34	1·74	7·42
MnO_2	0·22	0·14	0·25	0·47
NaO	0·58	3·14	1·72	0·74
K_2O	0·68	2·24	2·46	0·68
H_2O	6·84	1·93	2·16	2·73
CO_2	0·13	0·04	0·08	......
P_2O_5	0·15	0·17	0·16	......
S	0·56	......	1·34	......
Zn	......	......	1·61	......
Totals	100·81	100·16	100·53	100·16
O equiv. of S	0·28	......	0·67	......
	100·53	100·16	99·86	......
Sp. gr.	3·04	2·81	2·87	......

[1] Walker, T. L.: Dalmatianite, the Spotted Greenstone from the Amulet Mine, Noranda, Quebec; Univ. of Toronto Studies. Geol. Ser. 29, University of Toronto Press, 1930, p. 10.

A sample of the cordierite separated from the dalmatianite was also analysed and found to have the composition of column IV. Of the above analyses, only I is typical dalmatianite, II and III are probably rhyolite, partly transformed to dalmatianite of the micaceous type.

A comparison of the chemical composition of the rhyolite and andesite in Table I with that of the most typical dalmatianite shows that in the formation of the dalmatianite there are considerable additions of iron, alumina, magnesia, and water, and a reduction in the content of silica and soda. In the micaceous phase there is probably an addition of potash.

The chemical analysis of the dalmatianite shows that in composition it differs from the volcanic rocks or the rocks that intrude the volcanics. It replaces not only the rhyolite, rhyolite breccia, and andesite, but dykes of andesite and diorite. The cordierite, in places, fills fractures and, therefore, has been introduced into the rock (Plate XI B). The amydaloidal, brecciated, scoriaceous, and other original structures of the lavas preserved in the dalmatianite prove conclusively that it is a product of rock alteration. Furthermore, its close association with the ore deposits indicates that it was formed by the solutions from which the ore was deposited.

Waite-Ackerman-Montgomery Mine. The alteration in the andesite exposed at the surface at a distance from the No. 1 ore mass in the Waite-Ackerman-Montgomery property consists mainly of the conversion of the ferromagnesian mineral originally present into fibrous amphibole and the transformation of the plagioclase to epidote, or in some cases to epidote and sericite. It is probable, however, that this alteration is largely regional and has little if any relationship to the ore deposits. A further stage in alteration more closely related to the mineralization is the development of aggregates of brown mica and the chloritization of the amphibole adjacent to the ore. Where alteration has been more complete the rock has been transformed almost entirely to chlorite. On the 700-foot level in the wall-rock adjoining the ore recently found to the north of the No. 1 fault, pyrite was observed to occur in circular zones surrounding green, lamellar chlorite. In the long crosscut to the south on the 700-foot level there is a zone of fragmental rock mapped as rhyolite breccia on the mine plans that has been followed in drives both to the east and west. This rock is composed of angular to subangular fragments from 2 to 3 inches in diameter, on the margins of which there is a light grey, siliceous zone up to one-quarter inch wide. Many of these zones make a complete ring, so that the rock may be described as a "ringed" breccia. The writer's examination of this breccia was not sufficiently complete to ascertain whether the original rock present at this point was rhyolite or andesite, but it is certain that the rock has undergone both deformation and intense silicification. The matrix of the breccia contains considerable pyrite in places. On the 1,000-foot level in the crosscut to the No. 2 shaft a similar breccia in rhyolite was observed. It is noteworthy that the rings of pyrite in chloritized wall-rock seen adjacent to the ore on the 700-foot level are similar to the rings of the breccia, as if the original rock in this locality had the same fragmental structure. From these observations it is concluded that there are zones of silicified breccia associated with the ore deposits of the Waite-Ackerman-Montgomery property, the silicification of which may have been effected by the ore-bearing solutions. However, the alteration most closely associated with the ore, as at the Horne mine, is chloritization. The replacement even of andesite by ore would set free considerable silica, and it could be possible that this was the source of the silica by which the "ringed" type of breccia was silicified.

Normetal Mine. The ore at the Normetal mine occurs in a zone of shearing and faulting that strikes northwesterly and dips about 80 degrees to the northeast, parallel to the strike and dip of the stratified tuff and fine pyroclastic breccia in which the deposit occurs. Throughout a large part of the mine workings this tuff and breccia contains an abundance of small green crystals of ottrelite. Microscopic examination of this ottrelite schist shows the rock to consist predominantly of granular quartz, carbonate, some sericite, and green, finely twinned ottrelite that has developed in the schist in prismatic individual or in radial aggregates of crystals. In only one thin section was chlorite present. In this section the foliation in the rock bends around the crystals of ottrelite. This relationship could result either from pressure exerted by the crystal as it grew or by deformation after the crystal was formed. In the latter case, however, the ottrelite crystals would show some effect of the deformation. As they do not, crystal growth seems the most probable explanation of this phenomenon. In the east drive along the ore zone on the 675-foot level a schist was observed containing abundant prismatic grey crystals of cyanite[1] up to 1 inch long. The remainder of the rock consists mainly of granular quartz, sericite, and pyrite. The cyanite is in part fibrous.

MINERALOGY

The greater part of the minerals composing the sulphide ore deposits of Noranda district and the associated minerals genetically related to them are varieties believed to be formed predominantly under conditions of high temperature. There are also possibly a few minerals associated with the deposits that were either present before the ore was deposited or were introduced later. These, in that case, are only accidentally a part of the ore deposits. The minerals so far known to be present in the deposits are the following:

Apatite, $(CaF)Ca_4(PO_4)_3$. Apatite was observed in abundant hexagonal crystals in a thin section of altered wall-rock enclosed in a mass of chalcopyrite collected from the ore bin at the Waite-Ackerman-Montgomery mine. The associated minerals were actinolite, chlorite, and a small amount of epidote.

Amphibole, mountain leather. Mountain leather was observed in a zone in the ore of Lower H ore-body, in drive 1705 on the seventeenth level of the Horne mine. A specimen obtained from the Andesite fault near the bottom of the 19 ore-body was also sent the writer by G. G. Suffel of the Noranda geological staff. Suffel suggests that the mountain leather seen in the workings of the Horne mine was present before the ore was deposited and resisted replacement. It is possible that this is so, for it is improbable that a metamorphic mineral of this type would be formed in fractures in the ore that was deposited after regional deformation had largely ceased.

[1] Microscopic identification confirmed chemically by E. Poitevin of Mineralogical Section, Geological Survey.

Ankerite, $(CaMgFe)CO_3$. Ankerite is a common mineral in the district. It was observed in veins in shear zones in the Horne workings and in the matrix of the Chadbourne breccia with quartz. It was also observed in vein zones of the Pontiac Rouyn and Farrell-Rouyn groups of claims.

Arsenopyrite, FeS_2FeAs_2. Arsenopyrite enclosed in galena was observed by M. H. Haycock[1] in a polished specimen of Amulet ore collected by the writer.

Barite, $BaSO_4$. A specimen consisting of white crystals of barite from the 2,475-foot level of the Horne mine, sent to the writer by G. G. Suffel, was submitted to H. V. Ellsworth of the Mineralogical Division of the Geological Survey. Ellsworth confirmed Dr. Suffel's identification of the barite and found that it was associated with pink, corroded crystals of albite.

Biotite, $(HK)_2$ $(MgFe)_2$ $Al_2(SiO_4)_3$. This variety of mica occurs abundantly as an alteration mineral in some phases of the dalmatianite that occurs so extensively in the Amulet anticlinorium. It is also present as an alteration product in places in the wall-rock adjacent to the ore deposits of the Waite-Ackerman-Montgomery mine.

Calcite, $CaCO_3$. Calcite is a common, although not an abundant, mineral in veins in association with the ore deposits of the Horne mine. These cut all the rocks present in the property, including the later diabase. It was also seen to fill the interspaces between cubes and areas of pyrite and sphalerite in core from diamond drill hole 96 at the Amulet.

Chalcopyrite, $Cu_2SFe_2S_3$. Chalcopyrite is by far the chief source of copper in the sulphide ores of western Quebec. It occurs in some of the ore deposits, notably at the Horne mine, in masses many feet in diameter, either interbanded with pyrrhotite or almost solid. It also occurs in veins, alone or mingled with other ore minerals, intersecting chloritized rhyolite, rhyolitic flux ore, quartz diorite, and the marginal parts at least of the dykes of later diabase. Price[2] notes that where other ore minerals are present in veins, the chalcopyrite in many places is the only mineral present at the termination of the vein, relationships suggesting that it penetrated farther than the other minerals. Microscopic examination of polished specimens of ore shows the chalcopyrite to occur in irregular areas within other ore minerals, or gangue, or in veins cutting pyrite, magnetite, and sphalerite. It also occurs in parallel rows of rod- or bead-like areas following the octahedral structure of the sphalerite. The relationships of the chalcopyrite show that it was deposited later than the pyrite, magnetite, and sphalerite, but closely following the latter.

Chlorite, $4H_2O5MgO.Al_2O_3.3SiO_2$. Chlorite is the predominant mineral formed by wall-rock alteration at the Horne, the Waite-Ackerman-Montgomery, and Aldermac mines. At the Amulet it replaces the cordierite where this mineral has undergone alteration. At the Normetal it was

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[1] Mineragrapher, Bur. of Mines, Dept. of Mines and Resources.

[2] Geology of the Horne Mine, Noranda, Quebec. Thesis submitted to the Department of Geology, McGill University, in partial fulfilment of the requirements for the degree of Doctor of Philosophy, p. 222.

observed in only one thin section examined. The place of chlorite at both the Amulet and the Normetal mines is largely taken by ottrelite or cordierite or other minerals having a higher iron content.

Cosalite, $PbS.Bi_2S_3$. Cosalite was observed by Rodgers Peale[1] and M. H. Haycock in polished specimens of ore from the Waite-Ackerman-Montgomery mine. It replaces the pyrrhotite and the chalcopyrite.

Cordierite, H_2O 4(MgFeO) $4Al_2O_3$, $10SiO_2$. Cordierite occurs, so far as known, in Noranda district only in the dalmatianite of the Amulet anticlinorium. It is colourless, closely resembling quartz in sections where it is unaltered. It contains so many inclusions, however, and is so commonly partly altered to a lamellar phase or to chlorite that large continuous areas of the fresh mineral are uncommon. The transformation to the lamellar phase takes place, as a rule, along irregular fractures through the mineral, the fresh cordierite remaining as cores or islands within the altered phase. In many sections the cordierite is twinned in alternate, irregular zones or areas. In one area of cordierite showing zoned twinning the zones were observed to have a triangular form. The six sector (pseudohexagonal) twinning characertistic of cordierite was noted in only one section. A sample of the cordierite from the dalmatianite separated for analysis (Table VII) was sent by T. L. Walker to H. E. Merwin of the Geophysical Laboratory at Washington for optical examination. The determinations made by Dr. Merwin were as follows: Refractive index: 1.540 to 1.550, birefringence: 010, 2 V large, optically negative. A. N. Winchell of the University of Wisconsin found the optical properties of another specimen of the cordierite submitted to him by H. C. Cooke to be as follows: 2V, 84°-85°; Ng=1·5582 (in sodium light); Mn=1·5524; Np=1·5458.[2]

Cyanite, Al_2O_3 SiO_2. Cyanite occurs in grey, prismatic crystals up to an inch or more long in a zone of schist adjoining the ore in the east drive on the 675-foot level at the Normetal mine.

Epidote, $H_2O4CaO.3(AlFe)_2O_36SiO_2$, and *Zoisite* $HCa_2Al_2(SiO_4)_3$. Epidote and zoisite are among the most abundant alteration minerals in Noranda district. They are most common in the andesite and the dioritic rocks, but also occur in places in the rhyolite and rhyolite breccia. It is improbable, however, that most of this alteration has any connection with the ore deposits. In a specimen of rhyolite from the workings of the Horne mine, however, both epidote and zoisite were observed in zones of granular quartz with chalcopyrite. This epidote and zoisite, therefore, may have been deposited by the ore-bearing solutions.

Galena, PbS_2. Galena was observed by the writer in the ore of all the mines of the Noranda type in the district, including the Aldermac and the Normetal. It is not abundant. At the Horne mine it is associated with sphalerite in the gouge of one of the fracture zones or minor faults that lie within and parallel to the margin of the north-south dyke of later diabase at the end of drive 1204 on the second level. At the Amulet it is seen in polished specimens of the ore. At the Waite-Ackerman-Montgomery mine it occurs in the west face of the west glory hole and was

[1] Geology of the Waite-Ackerman-Montgomery Deposit; Trans. Can. Inst. Min. and Met., vol. 34, 1931, p. 209.

[2] Cooke, H. C., James, W. F., and Mawdsley, J. B.: Geol. Surv., Canada, Mem. 166, 1931, p. 215.

seen under the miscroscope by Haycock in specimens of ore collected by the writer from the ore bin. At the Aldermac and the Normetal mines it was observed in the dump, at the former on the face of a fracture cutting rhyolite, and at the latter in zones up to 1 inch wide in grey sericite schist, probably from the wall of the deposit.

Gold. Native gold is stated by Price to occur at the Horne mine: (1) in irregular areas, as isolated dots, and in veinlets alone or with other minerals in pyrite, also on the surface of pyrite crystals; (2) with tellurides in irregular areas in magnetite; (3) with tellurides in pyrrhotite; (4) in chalcopyrite, usually alone, in aggregates or short veins; (5) in chloritized rhyolite or in chloritic inclusions in massive sulphides; (6) in aggregates of granular quartz in high-grade, chloritic gold ore; and (7) in veinlets intersecting the quartz diorite, syenite porphyry, and the later diabase. At the other mines of the district the gold content is much lower than at the Horne, and native gold has so far not been observed in their ore.

Hisingerite. Specimens of a black, glistening mineral found in zones along faults in the workings of the Horne mine, given the writer by G. G. Suffel, were examined by H. V. Ellsworth of the Mineralogical Section of the Geological Survey, and found to be hisingerite, a hydrated ferric silicate of uncertain composition.

Magnetite, $FeO.Fe_2O_3$. Magnetite is an abundant ore mineral at the Horne mine. It was observed in solid masses up to 5 feet in diameter and intimately associated with sulphide minerals in polished specimens of the ore. Price notes its occurrence as areas and in veins in pyrite, as skeletal crystals in chloritized wall-rock, and as veins in the H and No. 21 ore-bodies. In many thin sections of the dalmatianite at the Amulet mine an opaque mineral occurs abundantly, partly in octahedral grains, partly in skeletal areas, and partly in parallel, rod-like aggregates, which are at least in part magnetite. The presence of titanium in the analysis of rock suggests, however, that the magnetite is titaniferous or some ilmenite is also present.

Molybdenite, MoS_2. Molybdenite was observed on the face of a fragment of Powell granite in the dump adjacent to the Don Rouyn shaft. The mineral in this specimen obviously occurs as a vein filling a fracture. The molybdenite extends irregularly into the granite for over half an inch from the vein. The Don Rouyn shaft was full of water at the time the property was examined and the writer has, therefore, no information regarding the relationship of this occurrence of molybdenite to that of the chalcopyrite, for the development of which the shaft was sunk. Molybdenite was also noted on the face of a boulder of granodiorite similar to that of the Lake Dufault mass lying on the north side of the Flavrian Lake road in the northwestern part of Rouyn township, along the margin of a mass of diorite in the Newbec breccia west of the Newbec shaft, and in specimens collected from the dump adjacent to the Newbec shaft.

Ottrelite or Chloritoid, $H_2(FeMg)Al_2SiO_{71}$. Ottrelite occurs abundantly as green spots in the altered, stratified, rhyolite tuff and breccia in which the ore of the Normetal mine occurs. Microscopic examination of this schist shows the ottrelite to be present in twinned, prismatic crystals, developed in many cases diagonally across the schistosity. It was also observed with granular quartz, pyrite, and chlorite in a thin section of massive rhyolite collected from the extremity of the drive northwest from the No. 5 shaft on the 700-foot level at the Horne mine.[1]

Pyrite, FeS_2. Pyrite is one of the most common minerals of the sulphide ore deposits. It occurs in solid masses to individual grains or crystals, cubes or pyritohedrons within the ore minerals. These are especially abundant in the pyrrhotite of Upper H ore mass at the Horne mine. In some polished specimens of the Amulet ore the pyrite has a branching form or occurs in cross-like areas in sphalerite, relationships that suggest the pyrite may be later than the sphalerite, although in the main the sphalerite penetrates and replaces the pyrite. It is more probable, however, that these are unreplaced remnants of pyrite crystal. Remnants of crystals are also present, as noted by Price, in the ore of the Horne mine. Adjacent to the north-south dyke of later diabase in drive 3516, in the southeastern part of the fifth level in the Horne mine workings, there are masses of cavernous pyrite, the interspaces of which are filled with hematite. The relationships of this pyrite suggest that it has been formed secondarily by surface water percolating along the dyke wall. At one point on the stripped surface of the No. 1 ore mass at the Waite-Ackerman-Montgomery mine, nodules of pyrite about three-fourths inch in diameter occur in a layer about 1 inch thick on the surface of the ore. This pyrite is obviously a superficial secondary development.

Pyrrhotite, $Fe_{11}S_{12}$. Pyrrhotite is a common ore mineral in all the sulphide ore deposits within Noranda area. It is especially abundant at the Horne mine, where it is the predominant mineral in the Upper H and the upper part of the Lower H ore masses, occurring in solid masses enclosing cubes of pyrite or interbanded with chalcopyrite. Microscopic examination shows the pyrrhotite to occur alone or associated with chalcopyrite in veinlets intersecting the pyrite or in irregular areas having corroded margins within the chalcopyrite and sphalerite. Its relationships indicate that it was deposited in the main after the pyrite and before the sphalerite, but minute veinlets of pyrrhotite have been noted in the chalcopyrite of the Waite-Ackerman-Montgomery, Amulet, and Horne mines. J. S. Stevenson, who assisted the writer during the field season of 1931, suggests that this pyrrhotite, which appears to be later than the chalcopyrite, has been deposited by exsolution.[2]

Quartz, SiO_2. Quartz is a common mineral in some phases of the ore and is abundant in the mine workings adjacent to the deposits, but it is probable that much of this quartz was deposited before the ore minerals and has no genetic connection with them. In the description of the Powell Rouyn gold-bearing veins it is pointed out that the greater abundance of chalcopyrite, specularite, and gold in association with the faults that cut transversely across the veins suggests that all the mineralization came in by way of the later faults, and in that case, the quartz of the main vein was

[1] G. F. Flaherty informs the writer that the presence of ottrelite at the Normetal mine was first noted by the late R. J. Colony of Columbia University.

[2] Stevenson, J. S.: Vein-like Masses of Pyrrhotite in Chalcopyrite, from Waite-Ackerman-Montgomery Mine, Quebec; Am. Mineralogist, vol. 18, 1933, pp. 445–9.

deposited a considerable time before the gold. In the Noranda workings quartz veins are very common, and are especially abundant in the diorite. Wherever these veins were observed in contact with the dykes of later diabase they are cut off by them. If the ore deposits are later in age than the diabase, then these quartz veins must be much older than the ore deposits and have no genetic connection with them. The sulphide ores in most cases replaced rhyolite, rhyolite breccia, or tuff, rocks containing 70 per cent or more of silica. It is probable that some of this replaced silica would be deposited in quartz veins. The most definite evidence regarding the age of the quartz was observed in the workings of the Normetal mine. In the crosscuts from the No. 2 shaft to the ore zone quartz in veins and irregular masses is exceedingly abundant. Cutting abruptly across these veins and the schistosity of the rhyolite tuff and breccia are dykes of massive rhyolite, which in turn are cut across and replaced by the ore. In this case, therefore, the intrusion of the rhyolite intervened between the deposition of the quartz and the ore. It also proves that folding and mountain building had ceased before the ore was introduced.

That the quartz is not all of the same age is shown, however, by the following observations. (1) In some cases, as in the Powell Rouyn property, the quartz of the main vein is not only composed of quartz veined by quartz, but is crossed by quartz veins deposited along the transverse faults. (2) In places, as in the No. 1 ore mass in the Waite-Ackerman-Montgomery property and in some phases of the Amulet ore, quartz occurs as matrix enclosing crystals of pyrite. (3) Microscopic examination of the ore shows quartz to occur in radial growths on cubic crystals of pyrite, and in this case the quartz is obviously later in age than the pyrite. (4) In the outcrop of the Waite-Ackerman-Montgomery No. 1 ore-body veins of quartz cut across the ore. It must be concluded, therefore, that the quartz associated with the sulphide ore masses of western Quebec is in part older than the ore and has no relation to it, part is of approximately the same age as and genetically a part of the ore, and in one case at least it is of later age than the ore.

Selenium. Analyses of the copper anodes from the Horne smelter show that selenium is one of the most abundant of the minor constituents of the ore. Because of its chemical similarity to tellurium it is most probable that the selenium occurs as a selenide associated with the telluride ore minerals.

Silver. Native silver was observed by M. H. Haycock in galena collected by the writer from the west wall of the pit at the Waite-Ackerman-Montgomery mine.

Sphalerite, ZnS. Sphalerite is a constituent of all the sulphide ore deposits of western Quebec, and is the predominant mineral at the Normetal mine and in the upper A, C, and F groups of deposits at the Amulet mine. It is also an abundant mineral in places in the ore deposits of the Waite-Ackerman-Montgomery property. Microscopic examination shows it to intersect and replace the pyrite and pyrrhotite and to be intersected and replaced by chalcopyrite. M. H. Haycock found from spectroscopic analyses that the sphalerite of the Amulet ore contains cadmium.

Spinel, MgO. Al_2O. Spinel is a common and abundant mineral in the dalmatianite of the Amulet anticlinorium, occurring in over half the thin sections examined. It has a moderately deep green colour, well-developed cleavage, and occurs in well-formed crystals, chiefly octahedra.

Tetrahedrite, $4Cu_2S.Sb_2S_2$. Tetrahedrite is an uncommon constituent of the sulphide ores. It has been found in a quartz vein 3 inches wide in drive 3915 on the ninth level of the Horne mine by Suffel, and was observed enclosed in galena and lying along the contact of areas of chalcopyrite and sphalerite by Haycock, in polished specimens of Amulet ore collected by the writer.

Tellurides. Seven telluride minerals have been identified by Price in polished specimens of the ore of the Horne property. They are: hessite, Ag_2Te; petzite, $(Ag.Au)_2Te$; sylvanite, $(Au.Ag)Te_2$; krennerite, $(Au.Ag)Te_2$; calaverite, $(Au.Ag)Te_2$; tetradymite, $2Bi_2Te_3.Bi_2S_3$; and altaite, AgTe. They occur in veinlets and areas within pyrite, along the margins of pyrite crystals, in areas replacing pyrrhotite and chalcopyrite, in chloritized rhyolite and diorite, in quartz aggregates in chloritic, gold-bearing ores, and in irregular-shaped areas enclosing gold particles in syenite porphyry. Recently R. C. McMurchy, geologist of Powell Rouyn Mines, Limited, submitted to the Geological Survey from that mine a specimen of a silvery grey mineral that E. Poitevin, Chief of the Minerological Section, identified as tetradymite. This occurs in association with free gold and pyrite and was obtained in a stope on the 800-foot level. J. C. Rogers, consulting geologist, also states that sylvanite occurs at the east end of the main crosscut on the same level.

Zircon, $ZrO_2Fe_2O_3SiO_2$. Zircon is obtained in minute crystals in the blankets of the mill at the Horne mine. It has not been observed in the ore.

RELATIONSHIP OF ORE TO DYKES OF LATER DIABASE

The age of the sulphide ore deposits of western Quebec is the most difficult and at the same time the most important problem in the geology of the region, for it involves not only the age of the deposits themselves, but, as noted by Suffel[1], has probably a bearing on the age and source of the gold ores of the surrounding region. It is also important because of its relationship to prospecting, for the ore deposits, if older than the diabase dykes, are presumably related in origin to the very latest intrusive of the Archæan basal complex, and should show some association in their distribution with these masses. If, on the other hand, they are later in age than the diabase, the only known Late Precambian intrusive in the region, they possibly had as their source the diabase magma, which the widespread distribution of dykes shows probably underlay a large part of the region. As the diabasic magma was so widespread, ore derived from it could occur anywhere in the region where conditions favourable for deposition are present.

The evidence bearing on the relationships of the sulphide ore deposits of western Quebec to the later diabase may be classified in three groups: (1) relations exposed in the workings of the Horne mine; (2) relations exposed in the workings of the Normetal mine; and (3) regional relations.

[1] Ec. Geol., vol. 30, 1935, p. 905.

Horne Mine. The Noranda north-south, later diabase dyke is displaced along the Horne Creek fault about 700 feet to the eastward, on the south side with respect to the north. Where the north-south dyke is crossed by the Andesite fault there is a zone of broken rock 3 feet wide in the dyke, but so far as known there is little if any displacement. The amount of deformation in the dyke is about one-fourth as much as that in the lavas outside the dyke. Throughout the workings of the Horne mine the dykes of later diabase are traversed, in most cases between 2 and 10 feet from their margins, by a zone of fractured rock up to 3 feet wide, within which there is usually a zone of gouge up to 6 inches wide. In these fracture zones are veinlets of sulphides, chiefly chalcopyrite and pyrite.

In 1929 L. C. Graton made an examination of the Horne mine, and in an unpublished report presented evidence from which he concluded that the ore was deposited after the later diabase dykes were intruded. In 1934 Price[1] pointed out that the greater part of the evidence is inconclusive, but decided that "the most logical interpretation is that the ore bodies are post-later diabase in age." In 1935 Suffel[2], who possibly has studied the workings of the Horne mine more than any other geologist, directed attention to relationships exposed at the dyke contact on the 17th level and concluded that the "diabase preceded the entire mineralization at the Horne, resisting replacement in the same manner as the metadiabase (quartz diorite) and syenite porphyry but to a much greater degree."

Price states that the hypothesis that the ore-bodies are earlier than the later diabase receives support from the following data: (1) the mine plans show that the ore-bodies occur on opposite sides of the diabase dykes as if they had been intersected and thrust apart by the diabase; (2) the dykes, for the most part, terminate abruptly with a fine-grained margin against the ore; (3) no large ore-bodies replace either of the diabase dykes; (4) the diabase is comparatively unaltered compared with the other intrusives, even where in direct contact with an ore-body; (5) the sulphide deposition in the dykes is possibly a secondary mineralization induced by the intrusion of the diabase.

Evidence from which Price and Suffel conclude that the ore-bodies are later in age than the diabase is as follows: (1) the abrupt termination of the ore against the dykes is of no significance because the fine-grained margin of the dyke was a barrier to replacement; (2) veinlets of sulphides penetrate the margins of the dykes in some places and at some points the fine-grained margin appears to be fretted by the sulphide; (3) in at least three localities tongues of ore 18 inches to 3 feet wide have been observed to extend into the dyke without interruption for distances ranging from 4 to 8 feet, and in some of these localities the ore is in contact with coarse diabase; (4) on the third level ore cuts completely across an offshoot of the east-west dyke 18 inches wide in No. 3 (C) ore-body; (5) if one tries to match the ore masses occurring on opposite sides of the dykes horizontally and vertically it is found that the "pairing" is imperfect, and this suggests that they were not originally parts of single ore deposits.

Some relationships of the ore in the Horne mine to which attention has not been directed were noted by the writer. In drive 3614 on the 6th level at the northeast extremity of H ore mass the contact of the ore with the

[1] Price, Peter: Trans. Can. Inst. Min. and Met., vol. 37, 1934, p. 140.
[2] Suffel, G. G.: Ec. Geol., vol. 30, 1935, pp. 906–907.

north-south diabase dyke is exposed. A fracture zone 6 inches wide, in which lenticular masses of ore are included, occurs within the dyke along and parallel to its margin. Gouge and broken rock separate the ore inclusions in the dyke from the main ore mass, and some of the fracturing extends into the inclusions. In drive 3713 on the seventh level wedge-shaped masses of ore up to 12 feet long and 2 feet wide occur in the Andesite fault zone mingled with gouge and broken rock. Zones of gouge appear to intersect the ore, and the ore masses are considerably fractured. These observations show that part at least of the fracturing in the diabase dyke and some movement along the Andesite fault occurred after the ore masses were deposited.

At the end of a short drive to the north contact of the east-west diabase dyke opposite the south end of drive 1212 on the 200-foot level a minor fault with a slickensided surface crosses the contact of the diabase and No. 3 ore mass. A veinlet of quartz and chalcopyrite about one-eighth inch wide has been deposited in the fault. In this case, therefore, chalcopyrite presumably derived from the ore has been deposited in a small way both in the ore and in the dyke, as those who postulate secondary deposition suggest.

In a number of places along the borders of the dykes small offshoots of diabase apparently penetrate the ore. On the north contact of the east-west dyke at the end of drive 1228 on the 200-foot level a small tongue of diabase about 3 inches long and up to one-quarter inch wide extends into a mass of pyrite, an outlying part of No. 3 ore deposit. The contact of the projection examined under the microscope is seen to be irregular and not very sharply defined. Zoisite occurs in the diabase adjacent to the contact, and the phenocrysts of plagioclase have been completely replaced by sericite and zoisite. The relationships at this point may be explained in two ways. According to the pre-dyke hypothesis the diabase offshoot penetrated ore and a certain amount of interaction between the ore and the diabase resulted in an irregular contact. According to the post-dyke hypothesis, the sulphide replaced the diabase margin sufficiently to make the margin of the diabase irregular. Although for the most part the contact of the diabase with ore is definite, fretted contacts such as that just described can be seen in many places. Except for the zoisite alteration in the diabase, which may be contact effect of the ore on the dyke, either explanation of the relationships at this point seems equally possible.

Normetal Mine. At the Normetal mine the ore zone occurs on either side of a north-south trending dyke of later diabase, but lies about 160 feet farther north on the east side than on the west. This displacement of the ore zone probably took place along a north-south trending vertical fault that occurs in the eastern part of the dyke. J. B. Mawdsley, who examined the property in 1928, noted the occurrence of veinlets of pyrite in the dyke wall and concluded this pyrite had been obtained by the dyke as it cut through the ore zone. He also states that small offshoots of diabase cut the sulphides, and that on the 300-foot level, where the ore zone adjoins the dyke, the fine-grained margin is much wider than against the adjacent wall-rock. From these observations he concluded that the dyke was later in age than the ore.

The writer examined the contacts of the ore and later diabase wherever they are exposed in the Normetal workings and found little to add to Mawdsley's description. Except for the large fault that lies wholly within the dyke there has been little deformation in the diabase and almost none at the contact, and on that account there is much less deposition of sulphides in the dyke than at Noranda. It was observed, however, that the contact of the ore and the fine-grained margin of the dyke on a minute scale are irregular and indefinite. This is especially evident on the 675-foot level. Either the magma of the dyke has attacked the ore or the ore has replaced the fine-grained margin. Of these alternatives possibly the latter is the more probable. The abnormally wide marginal zone of the dyke adjacent to the ore on the 300-foot level, mentioned by Mawdsley, is probably of no significance, for it occurs for only a few feet and was not observed elsewhere at the Normetal or Horne mines. A few very small veinlets of the ore project into the dyke wall, as pointed out by Mawdsley, and disseminated pyrite was also noted by the writer in the marginal zone of the dyke at one point. The most important evidence of the age of the ore observed in the workings at the Normetal is the manner in which the ore cuts across and replaces a massive unmetamorphosed dyke of rhyolite, which in its turn cuts abruptly across the vertically folded and schistose rhyolite tuff and breccia. This shows, at least, that the ore deposition occurred after folding and mountain building were entirely completed.

Regional Relations. Dykes of the later diabase occur at intervals of 2 to 10 miles or less throughout the whole of western Quebec, showing that at the time they were intruded diabasic magma underlay a large part of the region. If the sulphide ore deposits are later in age than, but related to, the diabase dykes then they almost certainly came from this widespread magma, for it would be impossible for ore masses as extensive as those at Noranda to be derived from the dyke of diabase only 80 feet wide. It is probable that the upper surface of the magma would be higher where the dykes occur than elsewhere, and, for this reason and because of the deformation that accompanied the intrusion of the diabase, the territory adjacent to the dykes would be a somewhat more favourable locality for ore deposition. It is noteworthy in this connection that of the five properties in western Quebec where important sulphide ore deposits are present, at two, the Noranda and Normetal, the deposits adjoin dykes of diabase, that the huge lower A deposit, in the Amulet and Lake Dufault properties, lies only 200 feet from the Powell dyke of later diabase, and that all of the sulphide ore masses lie within 1 mile or less of a dyke. It may be suggested that dykes are so common in the region that this association is accidental. This is, of course, possible, nevertheless, the deposits are more closely associated with the dykes than would be the case if the distribution were normal, and this is, therefore, to a degree at least, evidence favourable to the later age of the ore.

Discussion. It is apparent that the evidence bearing on the age of the sulphide ore deposits of Noranda district just presented, is conflicting, for most of the relationships observed might result from either the intrusion of the dykes into the ore or the deposition of the ore adjacent to the dykes. Thus, the sharply defined, fine-grained edge of the dykes against the ore would normally be positive evidence of their later age, but in many of the ore deposits, as at the Waite-Ackerman-Montgomery mine, numerous fine-grained dykes of andesite down to an inch or less wide occur in the ore and the only evidence of their older age is the presence of the transverse veinlets of sulphide minerals that cross them in places.

Similarly, most of the relationships of the ore with the fracturing and faulting that occur in the dykes can be explained in either way. If the ore was deposited after the faulting then the deformation opened the dykes and permitted deposition in them. On the other hand, if the diabase was intruded into the ore, fragments would almost certainly occur in the zones of faulting and, in places at least, blocks of ore do occur in this relationship. It has been suggested that the almost entire absence of deformation in the ore adjacent to the dyke, in contrast with that in the dyke, is proof of the later age of the ore, but the absence of fracturing and faulting in the rhyolite adjacent to the dyke as well as in the ore is proof that the deformation was confined almost wholly to the dykes, and this, therefore, affords no evidence regarding the age of the ore. It has been pointed out that a considerable amount of deformation occurred in the ore masses and that some of the fracturing in the diabase extends into small masses of ore occurring in the zones of faulting in the dykes. It is probable, however, that the deformation in the ore is less than should be present if the faulting in the dykes all occurred while the ore was present.

The occurrence of ore deposits on both sides of the diabase dykes on the same zone of shearing and faulting is evidence favourable to the pre-dyke age of the ore, for, except possibly along the Andesite fault, there has not been sufficient deformation in the dykes for the ore-bearing emanations to pass transversely across them. It must be assumed, therefore, if the ore is later in age than the dyke, that the emanations made their ascent independently from the magmatic source on opposite sides of the dyke. This is a less probable explanation than the hypothesis that ore masses on opposite side of the dykes were originally parts of single ore deposits and have been split apart by the intrusion of the dykes.

Conclusions. In the preceding description of the relationships of the sulphide ore deposits of Noranda district to the dykes of later diabase the known data has been presented as objectively as possible, but these are so conflicting that a conclusion on the problem can be obtained only by a careful balancing of one observation against another. It is also probable that as investigation continues other important information bearing on the age of the ore will be obtained.

The presence of veins and veinlets of ore in the dykes is positive proof that at least some sulphide deposits occurred after the dykes were intruded. It is possible, however, if the ore deposits are older than the dykes, that hot solutions made their ascent along the faults in the dykes, and, in that case, some solution and redeposition of the chalcopyrite and other ore minerals would almost certainly occur, but the writer knows of no way in which uninterrupted offshoots of ore up to 3 feet wide and 8 feet long could extend transversely into the coarser textured interior part of the dykes and be of pre-dyke age. At the contact of the Horne lower H ore-body with the north-south diabase dyke, on the south wall of drive 1712 on the 17th level, as noted by Suffel, a tongue of ore 20 inches wide extends 4 feet into the dyke as part of a vein of quartz and calcite continuing for 15 feet. Except for some very minor fracturing crossing the extension of ore at the margin of the dyke, it is continuous with the main ore-body. The irregular, indefinite contact of the ore with the fine-grained margin of the dykes in places both at the Horne and Normetal mines is also a feature that is more probably the result of the replacement of the dyke by the ore than the action of the diabase magma upon the ore. For these reasons, it is concluded that the evidence, although conflicting, is more favourable to the hypothesis that the ore was deposited after the diabase was intruded.

GOLD-BEARING QUARTZ VEINS

Veins of quartz, some of which are gold-bearing, occur in numerous localities in Noranda district. The most important are those occurring in the Powell Rouyn and Pontiac Rouyn properties. There are also numerous east to northeast trending veins intersecting the Amulet Hills andesite in the northwestern corner of Rouyn township and the adjacent parts of Dufresnoy and Duprat townships. Some of these contain gold up to 1 ounce a ton across an average width of 1 foot.

The most important veins of the Powell Rouyn and Pontiac Rouyn properties range in average width from 3 to nearly 12 feet and in grade from 0·092 to 0·233 ounce a ton. They all trend northwesterly and dip northeasterly, and with the exception of the Pontiac-Rouyn main vein, which has probably been displaced 1,000 feet to the northeast by faulting, are in alinement with one another. They, therefore, probably belong to a single zone of deformation about 6,000 feet long. The known maximum length of individual vein zones determined in underground workings is about 2,000 feet. The vein zones are dislocated various distances up to 40 feet by numerous, transverse, east trending faults, along which transverse veins of quartz and calcite have been deposited. The minerals in the veins include pyrite, marcasite, chalcopyrite, specularite, tetradymite, sylvanite, calcite, ankerite, and quartz. The veins of quartz carrying gold in the northwestern part of Rouyn township also contain aggregates of chalcopyrite; those in the McDougall property in southeastern Dufresnoy township contain considerable chalcopyrite, but, so far as known, little gold. It is noteworthy that, in the Powell Rouyn and Pontiac-Rouyn vein zones, the gold values are higher adjacent to the transverse faults, and that chalcopyrite and specularite are more abundant in the transverse than in the main veins.

CHAPTER V

DESCRIPTIONS OF PROPERTIES

NORANDA

Previous Descriptions:

Cooke, H. C., James, W. F., and Mawdsley, J. B.: Geol. Surv., Canada, Mem. 166, 1931, pp. 183-206.

Price, Peter: The Geology and Ore Deposits of the Horne Mine, Noranda, Quebec; Trans. Can. Inst. Min. and Met., vol. 37, 1934, pp. 108-140.

Hall, Oliver: Mining at Noranda; Trans. Can. Inst. Min. and Met., vol. 40, 1937, pp. 141-164.

The original property of Noranda Mines, Limited, at Noranda includes the Horne and Chadbourne groups of claims. The Horne group, consisting of six claims, Bl. 13 to 17, 25, and 26, with the exception of a small area belonging to the Quemont property, takes in all the territory between the Horne Creek fault and the north limit of the town of Rouyn and from Lake Trémoy westward about to the Canadian National Railways. The Chadbourne group of eight claims, Bl. 1 to 3, 53, and 62 to 65, lies west of the Horne group. It extends south as far as Noranda Lake and northward to the Powell Rouyn property.

The description of the geology of the Noranda ore deposits that follows is based largely on the detailed mine plans prepared by the geological staff of the company. In the limited time at the writer's disposal, it was scarcely possible to do more than verify the plans in critical localities. Attention was especially directed to the faults, and to the relationships of the ore to the later diabase dykes. In this work the writer was assisted by Dr. Suffel. He is also indebted to Dr. Price, chief geologist of Noranda Mines, Limited, for information in a report on the Noranda, contributed as a thesis for a Ph.D. degree at McGill University, a copy of which was kindly given the library of the Geological Survey by Dr. Price. Thanks are due, moreover, to the entire geological staff of the company, including H. M. Butterfield, former chief geologist, the late A. L. Dempster, and W. L. Bancroft, for information and assistance freely given.

HISTORY AND DEVELOPMENT

During the years 1911 to 1920, Edmond Horne made several prospecting trips into western Quebec, and noted the presence of rusty weathering rock at the present site of the Horne mine, but the amount of mineralization observed at this time was scarcely sufficient to warrant staking claims. Finally in September 1920, he staked claim Bl. 25, in which most of the ore of the Horne mine occurs, on behalf of the Trémoy Lake Prospecting Syndicate. The remaining claims of the group were staked for the syndicate in 1921 and 1922. Up to this time only scattered assays carrying gold had been obtained and the presence of copper ore was unknown. In February

1922 a syndicate was formed by S. C. Thomson and H. W. Chadbourne for the purpose of acquiring mining prospects in northern Ontario and Quebec, and in May of the same year a company to be known as Noranda (Northern Canada) Mines, Limited, was incorporated to carry on the development of properties acquired by the syndicate. Late in 1922 the Thomson-Chadbourne Syndicate acquired the Chadbourne group of claims and an option on the Powell property, in which the gold-bearing vein of quartz now being mined had been discovered. In January 1923 an option was obtained on the Horne group, but work was not undertaken until August of that year when a diamond drill that had been in operation on the Chadbourne property was transferred to the Horne claims. In the second diamond drill hole, put down at an angle of 35 degrees beneath sulphide-bearing rock exposed in a trench, 131 feet of ore averaging $4.36 in gold and 8·23 per cent copper was intersected. Following this discovery other ore masses were encountered, first by diamond drilling and later in underground workings. At the present time (May 1940) twenty-four separate ore-bodies have been outlined in the mine above a depth of 2,975 feet. Of these, the No. 8 or Upper H, and Lower H or No. 21 are by far the largest, together extending from the surface almost continuously to a depth of 2,900 feet (*See* Figure 3). The smelter, construction of which was undertaken in 1925, commenced operation in December 1927. Mining, until recent years, has been carried on from the No. 3 and No. 4 shafts, the depths of which (May 1940) are, respectively, 2,754 and 2,975 feet. In 1935 work was begun on No. 5 shaft. From this, levels at 3,475, 3,725, and 3,975 feet have been extended. It has now a depth of 4,094 feet. In 1939, sinking of No. 6 shaft was undertaken. It commences at the 2,975-foot level and will be carried immediately to a depth of 5,000 feet.

PRODUCTION AND ORE RESERVES

The production of copper, gold, and silver from the Horne mine since operation began is tabulated in the following statement.

TABLE VIII

Year	Tons of ore hoisted	Fine copper Pounds	Gold Ounces	Silver Ounces
1927	10,740	552,345	767	2,644
1928	265,970	33,065,261	52,949	186,277
1929	323,316	51,223,115	68,732	334,279
1930	849,303	75,509,373	117,393	691,920
1931	1,012,005	62,859,355	253,363	558,801
1932	1,218,795	63,013,485	341,350	619,597
1933	1,541,524	65,008,731	284,675	510,739
1934	1,777,021	70,175,512	248,615	552,809
1935	1,906,661	74,478,436	268,333	544,559
1936	2,011,730	62,750,342	342,495	543,250
1937	2,024,468	87,060,237	280,806	705,494
1938	1,996,485	96,966,169	337,024	975,623
1939	1,926,902	105,363,477	318,599	967,943

The total amount of dividends paid up to December 1939 was $53,982,425.63.

The estimated ore reserves above the 2,975-foot level on January 1, 1940, according to the general manager's report, were as follows:

TABLE IX

——	Tons	Copper Per cent	Gold, per ton, oz.
Sulphide ore over 4 per cent copper.....	6,948,000	6·96	0·153
Sulphide ore under 4 per cent copper...	8,886,000	0·81	0·190
Siliceous fluxing ore..................	3,679,000	1·31	0·136

ROCK TYPES

Volcanic Rocks. The oldest superficial rocks in the Noranda property, as elsewhere in the district, are lavas and pyroclastic sediments. They include the Noranda rhyolite, rhyolite breccia, and tuff, occurring in a westward pointing, wedge-shaped mass lying between the Horne Creek and Andesite faults, the Lake Trémoy andesite that occupies the point projecting into Lake Trémoy to the east of the mine workings, the Chadbourne andesite, best exposed in the Chadbourne property, but extending eastward across the southern part of the Horne group of claims, the Lake Trémoy rhyolite belt in the southern part of the property, and north of the Horne Creek fault a part of the Brownlee rhyolite and rhyolite breccia.

The Noranda rhyolite, rhyolite breccia, and tuff include three groups of rock: (1) pyroclastic breccia and tuff, stratified in part; (2) massive rhyolite; and (3) rhyolite flow breccia. The rocks of class (1) occur in two areas or belts, one striking in a northwesterly direction across the wedge-shaped fault block in the territory adjacent to and southwest of the No. 3 and No. 4 shafts, and the other in outcrops lying between the Horne mine and the Macamic highway. The first occurrence at its northwest end terminates against the Horne Creek fault. At its southeast end it is cut off by diorite, so that its termination cannot be fixed definitely. At least in the upper levels it does not continue to the Andesite fault. Its width is 900 to 1,000 feet and its length about 1,600 feet. It consists of rounded to angular inclusions of rhyolite in a fragmental, more or less altered, rhyolite matrix. The inclusions, on the whole, are abundant and closely spaced. They range in size up to 2 feet in diameter, but for the most part are small. In places in the breccia, notably along its northeastern margin, there are uniformly stratified zones of fine rhyolite breccia or tuff consisting of alternating light and dark grey bands from $\frac{1}{16}$ inch to 2 inches wide. In some bands there is a suggestion of still finer lamination. Outcrops of the banded phase of the breccia were observed in two localities, in an outcrop about 300 feet east of No. 4 shaft and in rhoylite exposed on the Noranda-Quemont line 150 feet south of the bridge over Horne Creek. In the first locality the strike is north 52 degrees west and the dip vertical; in the second, the rock is chiefly massive, fine-grained rhyolite, but on the southeast slope of the outcrop almost covered by slag there is breccia composed of fragments from one-quarter to one-half inch in diameter. This continues down the slope in a zone 2 feet wide. One foot east of the breccia zone is a parallel zone of banded tuff 3 inches wide. The strike of these zones is north 28 degrees west and the dip 65 degrees southwest. In the mine workings the banded breccia and tuff of the northeastern belt can be seen as far down as development through the zone has been carried (3,975 feet). The most easterly occurrence noted is 400 feet east of No. 3 shaft on the 2,475-foot level; the most southerly south of H or 8 ore-body on the 300-foot level; the most westerly beyond the No. 5 shaft on the 700-foot level; and the most northerly on the 975-foot level, at a point about 300 feet southwest of the outcrop seen on the Noranda-Quemont line at the surface. The strike is everywhere northwesterly except on the 2,475-foot level in drive 2122, east of the north-south diabase dyke, where the strike bends locally from northwesterly to west. The dip ranges from 60 degrees to the southwest to 55 degrees northeast, but for the most part is vertical or very steep to the southwest.

The second band of rhyolite breccia and tuff in the Noranda fault block outcrops at the Canadian National Railways to the north of the Andesite fault and extends eastward to the mine buildings and westward as far at least as the Macmic highway where it is exposed by excavations recently made for a new pipe-line to Tailings Lake. In a stripped area and rock cuts adjacent to the railway, alternating bands of rhyolite and rhyolite breccia are exposed across a width of 400 feet. The strike of the breccia zones is north 73 degrees west and the dip 80 degrees to the north. To the east of the railway about 410 feet, there is an east trending ridge of rock consisting of massive rhyolite with flow lamination at its west end and rhyolite breccia at the east. This breccia is composed for the most part of small fragments closely compacted together and is probably of pyroclastic origin. About midway between the outcrop just described and the transformer station of the Northern Quebec Power Company, there is a group of outcrops in which west to northwest trending zones of stratified tuff, up to 5 feet wide, occur at intervals up to 40 feet in pyroclastic rhyolite breccia. The total width of the zone exposed is about 250 feet. Banded tuff, striking approximately west, was also observed on the south edge of a mass of rhyolite breccia exposed beneath the transformer northwest of the office building of the Horne mine. In the long drift to the Chadbourne shaft on the 975-foot level, which passes beneath the outcrops just described, banding trending about north 83 degrees west is crossed. This occurs about 130 feet north of the Andesite fault and is intersected diagonally in the drift across a width of about 200 feet. It is noteworthy that this banded zone lies directly beneath breccia and tuff exposed at the surface. On the eastward continuation of this banded zone rough banding is recorded on the mine plans in several localities in drive 3911 on the 975-foot level in the territory north of the Andesite fault and south and southeast of the mine office. The occurrence of banded tuff at the surface and in the mine workings, as just described, shows that there is a continuous westerly trending belt of rhyolite tuff and pyroclastic breccia extending from the Macamic highway as far east, at least, as the mine office building, and indicates the possibility that this belt and the northwesterly trending zone with which a large part of the ore in the mine is associated were originally parts of a single belt.

Throughout the mine workings and in surface exposures, outside the belts of rhyolite breccia and tuff and in places apparently interbedded with these pyroclastic sediments, the rock is typical, fine-grained, massive rhyolite. It is porphyritic in places, spherulitic, exhibits flow lamination, contains disseminated pyrite, and, for the most part, has the pale grey to cream-grey colour characteristic of the rhyolite wherever it has been sericitized. In some parts of the mine workings, chiefly adjacent to the ore deposits, the rhyolite has been highly chloritized, either throughout the entire rock or in various stages along fractures. In places where this transformation is partly completed a pseudobreccia results that in places resembles either flow or pyroclastic breccia.

In the northwestern part of the Noranda fault block, adjacent to the hydro-electric transmission line and the Canadian National Railways, there are outcrops of rhyolite breccia, the matrix of which has the characteristic features of lava, and is, therefore, flow breccia. There are few rock outcrops in this part of the area, but it is probable that the northern part of the fault block at its western end is composed largely or wholly of rhyolite flow breccia.

The scattered outcrops or groups of outcrops that occur in the triangular-shaped, eastern part of the Noranda property that projects into Lake Trémoy consists mainly of massive Lake Trémoy andesite intruded in places by diorite. On the lake shore near the extremity of the point pillow structure not well exposed was noted. The contact of the Lake Trémoy andesite and the Noranda rhyolite is not exposed at the surface. Its approximate position, as determined from the diamond drill records, is as shown on the Rouyn map (No. 453A). In the mine workings the contact has been intersected near the extremity of drive 3912 on the 975-foot level. This intersection lies a few hundred feet south of the south shore of the west bay of Lake Trémoy and about 300 feet west of the Adsit shaft, which lies about 500 feet from the extremity of the point. The dip of the contact projected from its approximate position at the surface is about 50 degrees east.

The Chadbourne andesite is most typically developed and best exposed in the central part of the Chadbourne property. It consists of successive, east trending, vertical flows of andesite separated by thin zones of rhyolite breccia, rhyolite, or andesite breccia. Well-developed pillows with their tops to the north occur at the base of most of the flows. Projected eastward this area of andesite is continuous with, and presumably is the same belt as, that occurring in the northern part of Noranda townsite south of the Andesite fault. This andesite is too poorly exposed for its character to be fully determined. It contains areas or zones of rhyolite in places and in two localities, at the west end of the townsite near the Nipissing Central Railway and at its east end on the shore of Lake Trémoy east of the tennis court and north of the filtration plant, pillows were observed with their tops to the north. In these respects it resembles the andesite of the typical Chadbourne area, and in the absence of any known important faults by which it could be displaced it seems reasonably certain that the andesite of the two areas are parts of a single belt. In the mine workings the Chadbourne andesite has been penetrated on numerous levels in drives south across the Andesite fault down to a depth of 2,975 feet. The long drive westward to the Chadbourne shaft crosses the Andesite fault about 400 feet west of the Canadian National Railways, and from this point southward, except where intrusives are intersected, continues in andesite to a point about 200 feet east of the shaft where the Lake Trémoy rhyolite is encountered. The andesite again occurs on the northwest side of a northeasterly trending fracture crossing the northwest corner of the shaft.

The Lake Trémoy rhyolite, which extends across the southern part of the Horne and Chadbourne properties, and the Brownlee rhyolite breccia, occurring in the northern part of the Chadbourne, are described in Chapter III.

Intrusives. The intrusive rocks occurring in the Horne and Chadbourne properties include quartz diorite, diorite, and other rocks of the dioritic group, syenite porphyry, small basic intrusions seen in the Horne workings, known as " D " dykes, and the Noranda north-south and east-west dykes of later diabase.

The rocks of the dioritic group are largely fine-grained phases that have made way for themselves by successive intrusions, for both at the surface and as noted by Price and Suffel in the mine workings, diorite is intruded by diorite that is itself in turn intruded by diorite. Microscopic examination shows the rock to be the normal diorite or quartz diorite seen elsewhere in the district, but for the most part highly altered to actinolite, epidote, chlorite, and magnetite or ilmenite.

Within the Noranda fault block the diorite and quartz diorite, known at the mine as meta-diabase, have been intruded in a most complex manner as innumerable dykes or sills into the rhyolite, rhyolite breccia, and tuff. So variable are the strikes and dips and the thickness of the individual intrusions that it is difficult to make definite generalizations regarding them. As can be seen on the generalized plan of the 200-foot level (Figure 2) prepared from the detailed mine plans by Price, the predominant strike of the intrusions in a very general way is northeasterly in the southeastern part of the block, north in the eastern part, and north to northwesterly in its central part. It may also be observed that the ore deposits are intimately associated with the diorite, that an almost solid northeasterly trending mass of diorite about 600 feet wide occurs adjacent to the No. 3 shaft, and that this extends with increasing width more or less continuously northward into the Quemont property and westward to the northeast of shaft No. 4, forming a large, roughly U-shaped intrusion. The dips of the smaller intrusions are variable without evident uniformity, but in the mine plans from the 200-foot down to the 975-foot level the large, U-shaped mass just described moves progressively eastward and hence dips to the east. Below 975 feet the workings on most levels have not been extended much beyond the ore deposits. There are a considerable number of small intrusions of diorite southeast of shaft No. 3 and westward along the Andesite fault down to the 17th level (1,975 feet), and on the 1,225-foot level there is a mass of diorite 150 feet wide to the northwest of shaft No. 3, but, on the whole, the proportion of diorite in the lower workings is small. In the long drift to the Chadbourne shaft on the 975-foot level large masses of diorite occur within the Chadbourne andesite south of the Andesite fault, beneath the clay-covered area to the west of the Canadian National Railways.

Throughout Noranda district most of the small intrusions of diorite either lie in faults or shear zones as dykes, or follow the structure of the lavas and pyroclastic as sills. Within the Noranda fault block, notably in its southeastern part, some of the dioritic intrusions lie parallel to zones of shearing, on the other hand, in the central part of the block some intrusions at least lie parallel to the bedding of the stratified breccia and tuff, and the large, U-shaped mass plunging eastward also lies in part, at least, about parallel to the flows of lava. It is probable, therefore, that the distribution of the diorite within the fault block is controlled in part by zones of shearing in the volcanics and in part by their structure.

Syenite porphyry in dykes or small, more or less irregular masses occurs here and there within the Horne and Chadbourne groups of claims, both at the surface and in the mine workings. The largest occurrence exposed at the surface is the northeasterly trending mass 200 feet wide exposed at the crossing of the Canadian National Railways and the Macamic highway. Occurrences of the syenite underground have been found mainly in the southeastern part of the mine workings. These consist for the most part of northeasterly to easterly trending dykes or dyke zones up to a total width of 20 feet. The most extensive dyke or dyke zone is that occurring at or near the No. 3 shaft. This has been followed vertically from the 100-foot to the 2,975-foot level and horizontally on the 975-foot level in drives and diamond drill intersections for about 3,000 feet. Above the 11th level this dyke or dyke zone lies at or near No. 3 shaft; below the 11th level, owing to a northwesterly dip between the 11th and 13th levels, it lies from 100 to 250 feet northwest of the shaft. About 450 feet southeast of No. 3 shaft, on the 200-foot level, a branch of the dyke zone just described extends easterly to northeasterly across the mine workings. It has been intersected at intervals for about 1,500 feet. At its east end it bends to the north parallel to the strike of the rhyolite-andesite contact. It is probable that a mass or masses of syenite porphyry larger than those exposed at the surface occur to the east and southeast of the mine workings at depth, for, on the ninth level, a diamond drill hole at a point about 1,300 feet east of No. 3 shaft penetrated southeasterly for 220 feet into syenite and at the eastern extremity of the workings, on the 21st level, a diamond drill hole commencing about 2,350 feet east of No. 3 shaft penetrated easterly into syenite for over 325 feet. No information regarding the extent of the syenite between these levels is as yet available. In the long drive to the Chadbourne shaft masses and dykes of syenite, most of them much broken, were cut beneath the swamp-covered area to the west of the Canadian National Railways.

All of the rocks of the Archæan complex in the Horne and Chadbourne groups of claims so far described are cut across sharply by the north-south and east-west dykes of later diabase. The north-south dyke crosses the Noranda fault block at the surface about 175 feet east of No. 3 shaft. To the south of this point, beyond the railway that circles the mine, the dyke splits into two branches. To the north it continues across the Quemont property as far as the Horne Creek fault where, as explained more fully in Chapter III, it is offset to the west about 700 feet. In the mine workings the dyke has been followed to a depth of 3,975 feet. The width ranges from 60 to 90 feet in this distance. The dip of the dyke east of No. 3 shaft in the upper levels is nearly vertical, below the 11th level it dips steeply to the east. The average angle of dip from the surface to the 25th level is 86 degrees east and from the 11th level to the 25th 83 degrees east. It is noteworthy, however, that in the Quemont property the dyke bends east near the Horne Creek fault, and that on the 17th level, where the dyke has been intersected northeast of No. 3 shaft, it bends sharply west, so that it is possible that adjacent to the Horne Creek fault at depth the dip of the dyke is to the west.

The Noranda east-west later diabase dyke extends diagonally in a northeasterly direction across the southeastern part of the Chadbourne property, and in a northeasterly to easterly direction across the central part of the Horne property. At the surface the dyke lies about 600 feet south of No. 3 shaft. It has been intersected in drives and by diamond drill holes down to a depth of 3,975 feet, and in this interval is vertical or nearly vertical. In the upper workings it lies in the rhyolite north of the Andesite fault, but owing to the northerly dip of the fault at the seventh level it crosses into the andesite south of the fault and from this point occurs farther south in the Andesite with depth (*See* Figure 3). At the surface and down to the fourth level west of the north-south dyke it divides into two, or in places three, narrow branches, all but one of which pinch out as the north-south dyke is approached. At and below the fifth level it is a single dyke having a normal width of 50 to 60 feet.

There are certain structural features of the Noranda later diabase dykes within the Horne property observed nowhere else in the district. These are: (1) the unusual number of branch diabase dykes in the faulted and sheared territory in which the ore deposits occur; (2) the presence of zones of fracturing and faulting along the margins of both the north-south and east-west dykes adjacent to the ore deposits; and (3) the apparent displacement of the north-south dyke 700 feet to the westward on the north side of the Horne Creek fault and the considerable amount of deformation in this dyke where it is crossed by the Andesite fault. All of these features are important because they afford information bearing on both structural history and the age of the ore deposits.

In the western part of the mine workings, within H ore deposit in part, small, northeasterly trending, basic dykes up to 7 feet wide, known as " D " dykes, are present. The most extensive of these by far lies about 475 feet northwest of No. 3 shaft and has been followed vertically to the 975-foot level. This dyke is offset to the north or south in places various distances up to about 20 feet. This condition could be brought about either by the pinching out of the dyke and its recurrence to the right or left or by faulting. So far, the dyke has not been observed to pinch out. Price states that in one of the stopes in H ore-body the dyke ends "bluntly against sulphides and the latter show no sign of faulting or movement." It is noteworthy that the changes in position of the dyke all occur within or near the ore deposit where faults are most common. Although the evidence is not conclusive, it is more probable, therefore, that the apparent displacement of the dyke, as suggested by Price, is the result of faulting rather than by the termination and recurrence of the intrusive. The rock composing the "D" dykes is a dense, dark grey, porphyritic variety. It was not examined microscopically by the writer, but Price states that it consists of phenocrysts of common hornblende and highly altered feldspar in a groundmass of alteration products, chiefly epidote and chlorite with small crystals of pyrite and magnetite. The "D" dykes have a fine-grained edge against, and, as can be seen on the plan of the 200-foot level, cut abruptly across, the diorite.

STRUCTURAL FEATURES

Structurally the rocks occurring in the Horne and Chadbourne properties, as previously explained, form a part of a large eastward pitching anticline, the north limb of which has been repeated along successive, approximately east-west trending, vertical or nearly vertical faults. Within the two groups of claims there are two of these main faults converging at an acute angle to the westward to form the Noranda fault block. The chief structural features associated with the ore deposits of the Horne Creek group of claims are those of this rock mass. In the Chadbourne the structural feature of special interest is the peculiar breccia in which the Chadbourne gold-bearing flux ore occurs.

Noranda Fault Block

The Horne Creek fault is intersected in the Horne workings at only one locality, near the northwest end of drive 3917 on the 975-foot level. This intersection lies about 1,30C feet northwest of No. 4 shaft and 400 feet west of the bridge to the Quemont property over Horne Creek. The deformation on this fault is not as intense as might be assumed for a break of such importance. On the other hand, the zone of deformation is unusually wide. The end of the drive is in massive, fine-grained rhyolite porphyry, presumably lava. Southeastward from a point 40 feet from the end of the drive for over 500 feet the rock is broken, with, here and there, a zone of shearing up to 6 feet wide. Some gash veins filled with carbonate and a little quartz were noted at one point in the zone.

The Andesite fault, which forms the south boundary of the Noranda fault block, has been intersected in drives and diamond drill holes from the 300- to the 2,975-foot level, and horizontally from the region southeast of No. 3 shaft westward to within 400 feet of the Canadian National Railways, a total distance of over 3,600 feet. South of the fault the rock is everywhere andesite, whereas to the north it is rhyolite, rhyolite breccia, or tuff. The average dip of the fault for the vertical distance through which it has been followed is 82 degrees to the north. The width of the zone of shearing at the andesite-rhyolite contact, which marks the main line of faulting, ranges from a few feet up to 40 feet or more. This variability in width is probably explained by the numerous subsidiary shear zones along which movement has occurred in places. Another striking feature of the fault is the bend to the southeastward that takes place directly south of No. 3 shaft. This is present on every level where development along the fault in this part of the workings has been sufficient to determine the strike of the fault, but is sharpest on the 21st level. On the 9th level zones of shearing extend into the andesite, but these are almost certainly part of the Andesite fault system.

Within the Noranda fault block the chief structural features related to ore deposition are: (1) the structure of the volcanic rocks composing the block; (2) the distribution of the dioritic intrusive; (3) the faults and shear zones cutting the volcanic rocks and dioritic intrusives; and (4) the presence of easily permeable pyroclastic breccia and tuff.

Folding of the Volcanic Rocks of the Fault Block

The eastern part of the fault block is occupied by andesite and the western by rhyolite, and rhyolite flow breccia in which two zones of pyroclastic breccia and tuff are included. The dip of the rhyolite-andesite contact between the surface and one intersection on the 9th level is about 50 degrees. One of the zones of pyroclastic breccia and tuff extends northwesterly across the fault block in the vicinity of the ore deposits and the other eastward from the Macamic highway along the north side of the Andesite fault. There is some uncertainty regarding the eastern continuation of this southwestern zone, but banded rhyolite breccia striking in the same direction occurs in drives on the 975-foot level to within 900 feet of the southeastern termination of the northeastern zone. There are no drives in the intervening distance, and whether bedding is or is not present is not known. The rock in this locality, however, is rhyolite breccia intruded by diorite. The strike of the stratification in the northeastern band is northwesterly and the average dip vertical or steep to the southwest; in the southwestern band the strike and dip are parallel to the Andesite fault. The two zones of breccia and tuff are so similar that it is almost certain that they originally belonged to a single belt. It is possible for such a belt to be broken into two disconnected parts, either by folding and thrusting along the Andesite fault or by movement of the northeast zone eastward along a fault intervening between the two zones. According to the first hypothesis the tops of the two zones would face opposite directions; according to the second the two parts would both face in the same direction. The objection to the second hypothesis is that the mine workings lie between the two zones, and no important fault along which they could be separated from one another has been found between them.

Although there is evidence, as previously pointed out, that the last movements on the Horne Creek fault were approximately vertical, the south side being displaced downward, it is probable, as suggested by Connolly and Hart, that the earlier faults were thrust movements, the rocks on the north side of the fault being displaced eastward relative to those on the south. Furthermore, the numerous, subsidiary, northeasterly trending shear zones that converge towards and merge into the Andesite fault suggest that this break is also a thrust fault, the north side moving eastward with respect to the south. If this is so, then the southwestern belt of pyroclastic rocks is the continuation of the northeastern zone broken and dragged into parallel position with the fault by folding and thrusting, and the Horne ore deposits lie in the broken end of this sharp fold.

Dioritic Intrusives of the Fault Block

The intimate manner in which the Horne ore deposits are intermingled with diorite, especially in the upper workings, and the association of the large U-shaped mass of diorite plunging eastward with the deposits suggest that the dioritic intrusives exercised some control over ore deposition. Throughout Noranda district intrusions of diorite cut across the folds of the volcanic rocks or occur on faults along which the lava belts have been displaced, showing that much of the folding and faulting occurred before the dioritic rocks were intruded. On the other hand, the presence of shear zones in the diorite along the planes of faulting proves that movement occurred along the faults after the intrusion of the diorite. Under these conditions it is obvious that although the ore-bearing emanations undoubtedly penetrated through the diorite in places, the passage ways were less open and much more difficult in the diorite than in the volcanic rhyolite, rhyolite breccia, and tuff. To this extent, therefore, the diorite served as a barrier to further ascent and promoted replacement of the rhyolitic rocks. The north-south cross-sectional diagram through shaft No. 3 (Figure 3) shows that the dioritic intrusions occur chiefly in the upper workings, directly above the upper H ore mass, and that a considerable enlargement of the lower H ore deposit occurs beneath an intrusion of diorite on the 17th level. All of these relationships suggest that to some degree at least ore deposition in these places was determined by the presence of the diorite. In the mine workings the manner in which the ore terminates abruptly at the diorite margin indicates that the diorite was not nearly so easily replaced as the rhyolite breccia and tuff, and for this reason marks the boundary of the ore deposits.

Faults and Shear Zones in the Fault Block

Almost everywhere throughout the Noranda fault block there are innumerable small fractures and faults that trend in every direction. In addition to these minor breaks there are numerous longer shear zones up to 30 feet or more wide, some or all of which almost certainly could have served as major channelways for the ore-bearing emanations. Some of the best developed of these are the northeasterly trending zones of shearing that lie near or south of No. 3 shaft. Other, less continuous zones, trending west or northwest, occur in the northwest part of the mine workings along or near the northern margin of upper and lower H ore-bodies.

Northeast Shear Zones. In the upper mine workings, there are at least four zones of shearing south of shaft No. 3. These all trend northeasterly and dip to the southeast. They, therefore, converge towards and, where they have been followed in the mine workings, merge into the Andesite fault both to the west and with depth. The most southerly of these zones of shearing, No. 1, is that in which ore deposits 3, 5, and 16 occur (*See* Figure 2). It lies 550 feet south of No. 3 shaft on the 2nd level, has an average dip to the southeast of about 77 degrees, and has been followed from the surface to its junction with the Andesite fault on the 7th level, east of the section shown in Figure 3. Zone No. 2 includes deposits A or 1, 17, and 18. The last two lie on opposite sides of the north-south diabase dyke between the 2nd level and the surface, and, therefore, are not shown in Figures 2 and 3. Zone 3 includes deposits 2, 4, and 11, and lies close to zone 2. These descend to increasing depths towards the northeast, hence deposit No. 4 in Figure 3 terminates just below the 2nd level, whereas the No. 11, which lies east of the north-south diabase dyke, continues down to the 4th level. Below the ore deposits the shear zones enter the southwestern extension of the large, U-shaped intrusion of diorite in which the shearing is less intense than in the rhyolite, and is, therefore, more difficult to follow. On the 5th, 6th, and 7th levels only single drives have been extended south from No. 3 shaft across the zones of shearing. However, on all these levels northeasterly trending and southeasterly dipping belts of shearing cut the diorite on the downward continuation of the No. 3 zone. On the 725-foot level the zone lies only 100 feet north of the Andesite fault. On the 850-foot level the workings have not been extended to this locality, and before the 975-foot level is reached it presumably merges with the Andesite fault.

The No. 4 zone of shearing is that along which ore deposits 19 and 20 occur. It has been followed in drives, stopes, and in diamond drill holes from the 400- to the 1,475-foot level, but most extensively on the 9th level where it can be seen in drives 3,921 and 3,914 from the north-south, later diabase dyke southwesterly to its junction with the Andesite fault, a distance of about 500 feet. It has also been intersected in diamond drill holes for 400 feet to the east of the north-south diabase dyke. Above the 9th level, the 19 and 20 ore-bodies become intermingled with diorite intrusions and finally terminate against the southern prolongation of the main U-shaped mass. The workings on most levels are not extensive in this part of the property, but northeasterly trending zones of broken and sheared rock occur along the margins of the ore deposits and on the continuation of the ore zone from the 8th to the 5th levels. The dip of the zones of shearing between these levels is about 70 degrees to the southeast. From the 9th to the 10th levels the ore zone maintains the same strike and dip, but below the 10th level it passes into the Andesite fault zone in which it continues to the 13th level.

A fifth zone of shearing belonging to the northeasterly trending system is that lying along the southeast margin of upper H or No. 8 ore-body. It has been followed in the mine workings from the surface down to the 1,225-foot level. It consists of zones of shearing up to 10 feet wide within a belt of broken rock of varying widths up to a maximum of 100 feet. From the surface to the 4th level the zone lies on the northwest contact, and within the south extension, of the large U-shaped mass of diorite. Below the 4th level it is in rhyolite breccia intruded by dykes or sills of diorite. The average dip of the zone from the surface to the 9th level is about 80 degrees. From the 9th to the 11th level it is about vertical. Horizontally the zone has been followed in diamond drill intersections from the north-south later diabase dyke southwesterly 600 feet, to within 300 feet of the Andesite fault. Whether it continues to the Andesite fault had not been determined. From the 9th to the 11th level the deformation along this zone appears to be less intense, and coinciding with this there is a decrease in the size of upper H ore deposit.

Northwest to West Shear Zones. In the northwestern part of the upper workings of the mine and extending into the southern workings in the lower levels are zones of fracturing and shearing belonging to a northwest to westerly trending system. In the drives connecting No. 3 and No. 4 shafts a zone of fracturing and faulting commencing at the 300-foot level continues downward to at least the 13th level. From the 3rd to the 7th levels this zone consists of fractures and minor local zones of shearing. From the 7th to the 11th levels it is more intensely developed and delineates the northeastern margin of upper H ore deposit rather sharply. The dip in this interval is about 80 degrees to the southwest. On the 12th level, on the direct downward continuation of the zone northwest of No. 3 shaft, there is a northwesterly trending zone of shearing lying along the southwestern margin of lower H or 21 ore-body. Thus, in the interval between upper and lower H ore-bodies, the zone of shearing passes from the northeast to the southwest sides of two ore deposits, one of which is almost vertically above the other. On the 13th level the lower H ore mass, which extends from this point progressively farther to the southeast with depth, is delimited on its southwest margin by a similar zone of deformation, and at the southeast extremity of the main mass, situated about 125 feet west-southwest from No. 3 shaft, a tongue of ore 5 to 10 feet wide extends east-southeast for 300 feet along a zone of small faults. This extension is parallel to and lies 250 feet north of the Andesite fault. From the 13th to the 20th level this zone of fracturing and shearing and the southern boundary of lower H ore-body, which follows it, dip southward at an angle of 77 degrees. Below the 20th level the zone of shearing at the ore contact is vertical or dips steeply to the north to the 23rd level (2,725 feet) where it meets the Andesite fault. In addition to the zone of deformation just described and the Andesite fault, zones of shearing have been intersected in several localities in the lower levels to the north or northwest of lower H ore deposit, but, with the possible exception of an east-west trending zone of shearing to the northwest of H ore mass on the 23rd and 25th levels, no important faults had been found up to the time the writer last visited the mine workings (October 1938).

Permeable Breccia and Tuff of the Fault Block

Some of the smaller ore deposits occur in broken, massive rhyolite adjacent to zones of shearing and faulting, and some ore occurs along the Andesite fault, but by far the greater part of the ore masses, including the huge H deposits, are found entirely within the northeastern band of pyroclastic breccia and tuff that extends across the Noranda fault block to the southwest of No. 3 and No. 4 shafts. This association presumably is not accidental, but arises from the more permeable texture of the rhyolite breccia and tuff.

Chadbourne Breccia

In the Chadbourne property adjacent to, and northeast of, the shaft there is a roughly rectangular area about 1,600 feet long and at least 800 feet wide occupied by a peculiar breccia. Only the western and southwestern part of this breccia mass is exposed at the surface, but in the long drive to the Chadbourne on the 9th level similar breccia occurs 1,200 feet northeast of the Chadbourne shaft. As indicated on the Rouyn map (No. 453A), the breccia occurs in rhyolite at the south end of the area and in andesite in its central and northern part. In drive No. 3919 on the 975-foot level, however, diorite and syenite porphyry have also been brecciated. The diorite intrusions are everywhere highly fractured and more or less broken, but except for 20 feet or less along their outer margins they are not transformed to breccia to any great extent. A considerable part of the syenite porphyry, on the other hand, is highly brecciated. The fragments of the breccia range in size up to 20 feet in diameter, but on the whole are small, angular, and characteristically tabular in form (Plate XIV B). The matrix consists chiefly of rusty weathering carbonate, quartz, pyrite in cubes and areas up to 3 or 4 inches in diameter, a very little chalcopyrite in places, and some specularite filling fine fractures. The average gold content is sufficiently high for the breccia to be mined as flux ore.

The manner in which this breccia was formed is uncertain. As it includes fragments of andesite, rhyolite, quartz diorite, and syenite porphyry, it is obviously not an original feature of the rocks in which it occurs, and the absence of lava or other igneous rock in the matrix proves that it is not igneous breccia. The rectangular, tabular forms of many of the fragments suggest a typical fault breccia, but faulting occurs linearly and not in rectanguar areas. Furthermore, a fault on which so much brecciation has occurred would normally be accompanied by a great dislocation of the adjacent rocks, yet the Chadbourne breccia crosses the contact of the Chadbourne andesite and the Lake Trémoy rhyolite with little if any displacement. Another possibility, as suggested for the Newbec breccia, is that it is an explosive breccia. Whatever its mode of origin it is similar in so many respects to the Newbec breccia it is possible that both rocks were formed in the same way.

ORE-BODIES

The ore deposits of the Horne and Chadbourne properties belong to two main classes: (1) copper-gold-bearing ore-bodies and (2) gold-bearing, pyritic, flux deposits. In class (1) are included those ore masses that contain either copper or gold, usually both in sufficient amounts to be ore. Price divides these into three groups: (a) those consisting wholly or almost wholly of massive sulphides; (b) those containing silicia (mainly, if not wholly, that of the original rhyolite, rhyolite breccia, or tuff not replaced by ore) in sufficient amount to be "self fluxing"; and (c) high-grade gold ores containing little if any copper. All of these, however, are merely variations in the proportion of the mineral constituents of the ore. The gold-bearing, pyritic flux deposits contain little or no copper and are mined for their silica as flux and their gold content[1], which ranges in value from \$3 to \$5[2] a ton.

Distribution and Structural Relations

The distribution of the ore deposits within the Noranda fault block is controlled in part by the presence of the belt of pyroclastic breccia and tuff in which the greater part of the ore deposits are found, in part by the intrusions of diorite that occur so abundantly within and adjacent to the deposits, and in part by the zones of fracturing, shearing, and faulting with which they are also associated. These zones for the most part, either horizontally or vertically or both, converge towards and merge into the Andesite fault, which in its turn converges at an acute angle both horizontally and vertically towards the Horne Creek fault. It is also probable, as previously noted, that the H ore masses lie in the disrupted apex of a sharp, eastward pointing, overthrust fold within the Noranda anticlinal fault block.

The ore deposits, which have been designated with letters of the alphabet or numbers in the approximate order of their discovery, are seen on the mine plans to lie in linear groups according to the zone of shearing and

[1] Hall, Oliver: Mining at Noranda; Trans. Can. Inst. Min. and Met., vol. 40, 1937, p. 148.
[2] At \$35 an ounce.

faulting with which they are associated. These zones belong, for the most part, to a northeasterly trending system, but north-northwest and west-northwest systems are also present.

Northeast Zones. The northeasterly trending system is confined to the southeastern part of the upper workings, in which most of the smaller deposits are found. The zones of shearing in this part of the mine not only trend northeasterly but dip to the southeast, so that in general they occur farther south with depth on successive levels (*See* Figure 3). The ore deposits within this system occur in five groups, which numbered in succession from south to north are as follows:

Group	Deposit	
	Copper-gold	Gold-bearing flux
1	3(C), 5(E)	16
2	1(A), 17, 18	
3	2(B), 11(K), 4(D)	
4	19	20
5	G(7) copper, H(8), 9, 12, 22	G(7) flux

Owing to the predominance of diorite throughout most of the workings in the southeast part of the mine, it is uncertain in places what the rock replaced by ore may have been, but the deposits of groups 1 and 2 and deposit G are all in massive rhyolite and have presumably replaced rhyolite. In these deposits the rhyolite that remains is highly fractured, and it is the broken condition of the rock that has made mineralization possible. The other deposits of the system lie, for the most part, in, and have replaced, rhyolite breccia and tuff. The northeasterly, elongated form of most of the deposits, including the eastern end of upper H, which lies on No. 5 zone, is obviously determined by the zone of shearing in which they occur.

North-northwest Zones. In the western part of the mine workings on the first level, according to Price, there is a zone of deformation and shearing extending from west of upper H ore-body to southwest of No. 4 shaft, on which ore deposits Nos. 6, 10, and 13 occur. This strikes north 30 degrees west and dips steeply to the northeast. Price states: "The whole zone, so far as it is known, resembles not so much a definite fault system as a vague line of weakness up which mineralizing solutions were able to ascend with ease." The workings in this part of the mine are not now accessible and this zone was, therefore, not seen by the writer. The deposits associated with it all lie within the belt of pyroclastic breccia and tuff and close to upper H ore-body.

West-northwest Zones. The chief zone of shearing belonging to this system in the upper workings lies along the northeast side of upper H ore mass from the 300-foot level downward, whereas in the lower workings, due to its southwesterly or southerly dip, it lies along the southwest or south margin of lower H (21) ore-body. The strike of the zone down to the 12th level is wholly northwesterly. On the 13th level, the eastern end of the zone lying south of No. 3 shaft trends west-northwest parallel to the Andesite fault, and from this point downward to the west the strike becomes progressively more westerly to the 15th level, below which the entire southern margin of the ore-body trends west-northwest parallel to the Andesite fault. On the 23rd and 25th levels, other zones of shearing trending east-west were noted on the north side of lower H ore mass. Little has been determined regarding the continuity of these up to the present, but they presumably belong to the west-northeast system. All of the zones of shearing and faulting just described occur in the pyroclastic breccia and tuff. It is probable that the northwesterly extensions of upper H ore-body from the 2nd to the 10th level, and of lower H from the 11th to the 15th levels are related in part at least to the northwesterly trend of the easily permeable, pyroclastic, rhyolite breccia and tuff. On the other hand, the well-defined, northeastern margin of upper H ore mass adjacent to the northwesterly trending zone of shearing on the 9th and 10th levels, and the similar, well-defined, southwestern margin of lower H on the 12th and 13th levels show that the northwesterly trending zone of shearing exercised strong structural control over the form of the ore deposit.

Chadbourne Ore-body. The Chadbourne ore deposit includes all of the Chadbourne breccia that has been sufficiently mineralized with gold to warrant mining for flux and for the gold that it contains. It includes most of the area indicated on the map as Chadbourne breccia, and on the 975-foot level some masses to the northeast beyond this area. The fragments of the breccia consist of whatever rock was originally present at the time the brecciation occurred. This, except where intrusions of diorite or syenite porphyry are brecciated, consists of rhyolite at and south of the shaft and andesite to the north.

Composition

Copper-gold-bearing Ore. The ore deposits of the Horne property belong almost wholly to the gold-copper-bearing class. They consist chiefly of pyrrhotite, pyrite, chalcopyrite, and magnetite, with some sphalerite in places. Other minerals present, but not abundant, are galena, native gold, tetrahedrite, numerous gold tellurides, quartz, ankerite, and carbonate. The copper content of the ore may range from almost nil to that of pure chalcopyrite. The gold content has no definite relationship to the amount of copper present.

Pyrrhotite is an abundant constituent of most of the ore deposits. It occurs most extensively, however, in the upper H ore-body, where there are huge masses of pyrrhotite, solid except for crystals or grains of pyrite here and there. The pyrite inclusions are usually not more than one-quarter inch in diameter, but crystals up to 2 inches in diameter were noted in one locality. Pyrrhotite is also the chief constituent in the upper part of lower H (21) ore-body. In places where pyrrhotite is associated with chalcopyrite the two minerals occur interbanded with one another. The width of the bands of pyrrhotite range from one-sixteenth inch or less up to 1 inch. The width of the chalcopyrite bands ranges from that of the pyrrhotite up to 2 inches or more. Chalcopyrite is an abundant mineral, and in places is the predominant mineral in most of the smaller ore deposits. It is also predominant or especially abundant in the lower and southern parts of upper H and the southern part of lower H ore masses. Pyrite is a common constituent of most of the copper-gold ore-bodies. It occurs most extensively in the northern part of lower H ore mass, but is present in varying proportions almost everywhere in the rhyolite breccia adjacent to the ore masses. The gold content is greatest along the southern margin of upper H ore-body, in the adjacent southern extensions known as deposits Nos. 9 and 22, and in places throughout most of lower H ore mass. Sphalerite is not an abundant constituent of the Horne ore deposits. It occurs in places, however, in the vicinity of No. 5 shaft for almost the entire depth of the mine, and it is the predominant mineral in ore deposit No. 10, occurring from the surface to the 300-foot level, southwest of No. 4 shaft. Magnetite although not conspicuously present in the ore is seen from microscopic examination to be one of its most common constituents. It was also observed in places in masses or zones up to 5 feet wide, notably along the southern margin of No. 5 deposit east of the Noranda north-south later diabase dyke.

Gold-bearing Pyritic Flux Ore. The ore-bodies of this class contain, in addition to a gold content of $3 to $5 a ton, sufficient silica that they can be used as flux for smelting the copper-sulphide ores. For the most part, they contain little or no copper. Those occurring within the Horne group of claims consist of grey, sericitized rhyolite in which pyrite, partly in disseminated crystals or grains and partly filling fractures, is present in varying amounts. The gold content is roughly proportional to the amount of pyrite contained in the rock, a relationship indicating that the gold is associated with the pyrite. Microscopic examination confirms this association. There are, at least, nine[1] ore deposits of the flux type within the Noranda fault block. These include deposits G (7), 16, 20, the large mass of pyritic, gold-bearing, rhyolite breccia and tuff below lower H ore-body, and other occurrences lying chiefly on the margins of the sulphide ore masses here and there in the mine.

The deposit of flux ore occurring in the Chadbourne property is of a different character. It consists of angular, and in part altered, fragments of andesite, rhyolite, and, in drive 3919, diorite and syenite porphyry in a matrix of quartz, ankerite, pyrite, a very little chalcopyrite, and some specularite. The included fragments in places contain disseminated crystals or areas of pyrite. In other places they are rusty weathering from the presence of ankerite with which they have been impregnated. Price found from microscopic examination that gold was associated with the pyrite partly on the borders of the crystals and partly as veinlets in the pyrite.

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[1] Hall, Oliver: Trans. Can. Inst. Min. and Met., vol. 40, 1937, p. 146.

AMULET MINE

Previous Descriptions:

Cooke, H. C., James, W. F., and Mawdsley, J. B.: Geology and Ore Deposits of the Rouyn-Harricanaw Region, Quebec; Geol. Surv., Canada, Mem. 166, pp. 206-218 (1931).

MacGregor, J. G.: Structural Features of Certain Rouyn Orebodies; Can. Min. Jour., vol. 49, 1928, pp. 456-460. Exploration in Rouyn Camp; Trans. Can. Inst. Min. and Met., vol. 32, 1929, pp. 41-50.

Wilson, M. E.: Amulet Mine, Noranda District, Quebec; Geol. Surv., Canada, Sum. Rept. 1933, pt. D, pp. 83-120.

DISCOVERY AND DEVELOPMENT

The property formerly owned by Amulet Mines, Limited, since acquired by Waite-Amulet Mines, Limited, includes three groups of claims in Rouyn district. The most important of these is group A, which lies across the boundary between Dufresnoy and Duprat townships. The claims included in the group are M.L. 1889-1892, M.L. 1896-1898, and A 1394-1403, all of which were staked by Joseph and Peter McDonough in the winter of 1922-23, and were sold by them in 1923 to the late R. E. Popham and associates who organized a company known as Amulet Gold Mines, Limited (later changed to Amulet Mines, Limited) to take over the ownership of the property. The first discovery of ore (mineralized area No. 1) was made in the autumn of 1924 in claim M.L. 1897; in 1925, three additional areas of mineralization, No. 2 in claim M.L. 1891, No. 3 in claim M.L. 1889, and No. 4 in claim 1890, were found; and in 1929 the No. 5 (or F) group in claim M.L. 1897, east of area No. 1, was discovered by diamond drilling. Mineralized area No. 1 lies 3,000 feet northwest of the present Amulet mill; No. 5 or F is 1,000 feet east of No. 1; No. 3 is 2,200 feet south of No. 1; No. 4 or C is 1,200 feet south of the mill; and No. 2 or A is 2,600 feet southeast of the mill. All these occurences of ore, as they were discovered, were delimited by systematic diamond drilling, and groups of deposits Nos. 4 (C) and 5 (F) were further developed by vertical shafts and lateral workings. During the summer of 1929 and the following winter a concentrating mill with a capacity of 300 tons a day was built on the property. This mill was completed in April 1930, and from that time the mine and mill were operated continuously until the following October, when, owing to the decline in the price of copper and zinc, work on the property was discontinued. In September 1933 a union with the Waite-Ackerman-Montgomery mine, which adjoins the group A claims of the Amulet on the north, was effected, ownership of the combined properties to be vested in a new company to be known as Waite-Amulet Mines, Limited. In April 1937 preparations were undertaken for resumption of mining operations from the 5 (F) group of ore deposits, and on July 3 operation of the mill was resumed. Pending reconstruction of the aerial tramway to F shaft, ore was taken until August 10 from the ore dump at C shaft. From that time to the present (May 1940) all ore from the Amulet property treated in the mill has been obtained either from the F ore-bodies or from development work in the Lower A ore mass.

All of the ore deposits in the Amulet property except Upper A, which is in andesite flow breccia about 1,000 feet above the rhyolite[1], occur in the open, scoriaceous top of Amulet rhyolite flow breccia beneath the relatively impermeable, overlying Amulet Hills andesite. It was probable, therefore, that the ore-bearing emanations from which the Upper A ore masses were deposited would first deposit ore in the rhyolite breccia before ascending into the andesite, provided the open cavernous texture present in the rhyolite breccia where it outcrops to the westward persisted to this point. With this possibility in mind, in February 1938 the extension of diamond drill holes formerly drilled through No. 2 or Upper A mineralized area downward to the Amulet rhyolite flow breccia was undertaken, with the result that the large ore mass known as Lower A was discovered. For mining this new ore-body two new vertical shafts have been put down, one to the southeast of the mill, from the bottom of which a drive about 2,500 feet in length has been driven, and the other from the surface directly above to the Lower A deposit. A new mill of 1,000 tons capacity has also been built.

The writer is indebted to the officials of Amulet and Waite-Amulet Mines, Limited, for their co-operation in his work. Thanks are especially due to Mr. F. M. Connell, president of the original company; to Mr. W. G. Hubler, in charge of the Amulet at the time of the writer's examination; to Mr. J. G. MacGregor for the large amount of geological data shown in plans prepared by him at the Amulet; to Mr. R. Porritt, former manager, and to Mr. Thomas E. Little, present manager, of Waite-Amulet Mines, Limited, and to the geological staff of the Noranda Company for information regarding the geology of the F ore masses and the recent diamond drilling operations in the No. 2 (A) mineralized area.

PREVIOUS WORK

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

[1] Geol. Surv., Canada, Sum. Rept. 1933, pt. D, pp. 111 and 117.

GEOLOGY

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

Proterozoic (Late Precambrian)	(14) Quartz diabase dyke
Archæan (Early Precambrian)	(13) Albite granite in small masses included in andesite
	(12) Granodiorite in dykes and Lake Dufault stock
	(11) Andesite dykes
	(10) Dacite (feldspar) porphyry dykes
	(9) Aplite dykes
	(8) Quartz diorite and diorite in masses, dykes, or sills
	(7) Rusty weathering, epidotized dyke rock
	(6) Andesite dykes or sills
	(5) Rhyolite (quartz-albite) porphyry in small masses, dykes, or sills
	(4) Andesite dykes and sills
	(3) Amphibole dacite (quartz-feldspar) porphyry
	(2) Quartz diabase in masses or sills
	(1) Volcanic rocks: chert, andesite, andesite flow breccia, rhyolite, and rhyolite flow breccia

NOTE: The relationships of rocks designated by Nos. 9 to 11 to one another have not been determined. The masses of albite granite (13) have been placed later than the granodiorite because of their lithological similarity to the Powell (albite) granite.

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

The andesite in contrast with the rhyolite and rhyolite breccia is largely a fine, massive, fairly uniform, green weathering rock. It is commonly amygdaloidal, exhibits pillow and pahoehoe structure in several localities, is concentrically laminated and banded in places, and, notably in the vicinity of Upper A mineralized area, contains zones of rounded breccia. Where it overlies the Amulet belt of rhyolite and rhyolite breccia, however, it is for the most part dense and massive.

On the east slope of a knob of andesite about 50 feet north of the north shore of Turcotte Lake, rusty weathering, banded and laminated chert impregnated, in some bands, with pyrrhotite, is exposed in several outcrops. The bands range in width up to a maximum of 1 inch. They appear to be gently folded into minor anticlines and synclines, so that on the surface they resemble the grain of wood. The dip of the zone in general is about 30 degrees to the southeast. The maximum exposed width of the belt is about 30 feet, but the actual thickness is probably less than half that amount. This presumably lies along the contact of two lava flows, and is probably the silica deposited from hot springs during the interval that elapsed between the successive andesite extrusions.

Quartz Diorite and Diorite. Next to the lavas just described the most abundant rock in the property is diorite. This is present chiefly in the part of the Dufresnoy dioritic belt lying east of the mill and camp buildings. Elsewhere in the property it occurs in dykes, the most extensive and continuous of which trend northeasterly. The diorite of the main mass is an exceedingly variegated rock both in texture and in the distribution of its minerals, the white feldspar and its dark green weathering, ferromagnesian minerals occurring in irregular aggregates of varying size and form. Coarse- and fine-grained phases also occur heterogeneously mixed and fading into one another. In places white weathering, feldspathic seams and zones are common, whereas at other points the ferromagnesian minerals are so abundant as to form masses of amphibolite several feet in diameter.

There are three important dykes of diorite in the property, one lying east of Turcotte Lake and northwest of mineralized area No. 2, another cutting across an anticline in the direction of shaft 5 (F), and a third, northwest of mineralized area No. 1. The first of these has an exposed width of 30 to 80 feet and dips northwesterly at an angle of about 60 degrees. The second has a width at the surface of about 200 feet, but dips about 25 degrees to the northwest and hence has an actual thickness of about 125 feet. There are no outcrops of this dyke northeast of the rhyolite-andesite contact, but in the direction along which it would continue, if present, the same rock was intersected in numerous diamond drill holes. The third diorite dyke is not well exposed, but was intersected by several diamond drill holes. It has a superficial width of about 25 feet, but unlike the other dykes dips to the southeast at an angle of about 50 degrees.

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

One of the most common of the minor intrusions is the rhyolite (quartz-albite) porphyry, which occurs abundantly in small masses and dykes, mainly in the eastern part of the property. It is a fine-grained, siliceous-looking, pale grey weathering rock in which, as a rule, small phenocrysts of albite or albite and quartz are disseminated. A dyke of this porphyry associated with the No. 2 group of deposits is from 12 to 25 feet wide, strikes northeast, and dips steeply northwest. It can be followed continuously for 550 feet, beyond which to the southwest the same rock occurs in a succession of disconnected masses up to 100 feet long. The mode of occurrence of these masses suggests that they are fragments of a once continuous dyke.

STRUCTURAL FEATURES

Folding. The structure of the lavas in the Amulet property has been determined from the course and attitude of the contact of the rhyolite and rhyolite breccia with the overlying andesite, from the attitude of the andesite as shown by the rounded tops and flattened bottoms of pillows ("bun structure"), and from the strike and dip of zones of breccia at the tops of flows in the andesite. All of these features show that the rocks have been folded into a succession of five minor anticlines and synclines, having dips on the limbs up to 45 degrees and plunging eastward at an angle of about 20 to 25 degrees. These have been numbered from 1 to 5, commencing with the most northerly, and are referred to by these numbers in the descriptions of the mineralized areas. Taken as a whole, the structure is an anticlinorium.

Faulting and Fracturing. Fractures and fracture zones, some of which are faults, are common in the property. Numerous fractures filled with quartz, calcite, or epidote were also observed in many of the diamond drill cores. The many dykes that intersect the andesite, rhyolite, and rhyolite breccia also obviously occupy fractures, and the manner in which the dykes of rhyolite porphyry have been broken into fragments is additional evidence of the intense fracturing to which the rocks of the area have been subjected. The predominant strike of the faults, fractures, and dykes is northeasterly.

In the workings in the No. 4 or C group of deposits, a northeasterly trending fault has been followed in drifts for about 1,500 feet. Along this fault the rock has been broken and is cut by so many subsidiary fractures that it is not everywhere possible to determine definitely the position of the main line of dislocation. In places a zone of gouge up to 6 inches wide occurs in what appears to be the main fault plane. The fracture zone has a width in places of 10 feet or more. Slickensiding and grooving were observed on both the 150- and 250-foot levels. Striæ on the walls of drives along the fault dip 10 degrees to the east, showing that the last movement along the fault was nearly horizontal. The fractures of the fault zone are filled with either calcite or quartz, but ore minerals, so far as observed, are absent, and if present at all occur in very small amounts. On the 150- and 250-foot levels the fault lies 20 and 30 feet, respectively, to the northwest of its position on the 75-foot level. Its dip is, therefore, about 75 degrees between the 75- and 150-foot levels and 84 degrees between the 150- and 250-foot levels.

At the F or No. 5 group of ore deposits there are numerous faults with slickensided surfaces associated with the ore, but the zone of broken rock along each fault exposed in the accessible workings at the time they were examined by the writer, in October 1938, in no case exceeded 1 foot in width. The manner in which the ore ascends with a straight boundary to a peak in the overlying andesite at one point suggests that the rhyolite-andesite contact has been dislocated by a fault, but there is no shearing or fracturing in the rock adjoining the ore and if a fault is present it has been entirely replaced by ore. That a larger fault occurs near the F group of deposits, however, is indicated by the broken rock intersected in diamond drill holes to the southeast of the ore masses. In many of these, notably No. 359, considerable thicknesses of broken rock cut by veinlets of quartz and carbonate were noted. An important fault was also intersected in a diamond drill hole from the 355-foot level. It can be concluded, therefore, that the ore deposits of the F, or No. 5, group are associated with minor faults, which were channels of access for the ore-bearing solutions, but that a more important fault or fault zone is probably present nearby to the southeast or below the ore deposits, which may have been the route by which the ore-bearing emanations ascended from depth.

At the A or No. 2 group of deposits there are, as yet, no extensive underground workings and information regarding any faults that are present can be ascertained only from the surface geology. In the Lake Dufault property, which adjoins the Amulet on the east, C. S. Davidson and R. C. Hart, by detailed mapping, have found that zones of eastward dipping, rounded breccia in the andesite, presumably flow tops, have been displaced to the westward along two westerly converging valleys that merge into one another southeast of the A ore deposits. The southerly of these valleys lies on the eastern continuation of the depression that extends westward to Turcotte Lake. The relationships just described indicate that there is a fault in this valley and that the displacement along the northeasterly branch valley occurs on a fault subsidiary to it. Diamond drill holes in the Lake Dufault property have intersected north-south, easterly dipping faults; it may be possible that a fault parallel to these underlies the major, north-south, drift-filled valley that lies east of the A ore deposits.

In places fine, intersecting seams of quartz occur, which weather as criss-cross ridges, resulting in what has been described as "grid structure." This structure, although not wholly restricted to mineralized areas, is common within them or in their vicinity. It occurs in many places in mineralized area No. 4 and southward into the Area property, and is also well developed in a rock face west of the hoist-house at No. 5 (F) shaft.

ORE DEPOSITS

The known ore deposits of the Amulet occur in five groups. With the exception of the Upper A(2) ore-bodies, they all occur in the rhyolite breccia of the Amulet belt adjacent to its contact with the overlying Amulet Hills andesite. The Upper A deposits occur in a zone or zones of rounded andesite breccia at a point about 1,000 feet above this contact. All are associated with, and lie chiefly above, masses of the alteration rock, dalmatianite. The ore masses are for the most part tabular in form, the highest grade ore, in the case of ore associated with the rhyolite breccia-andesite contact, lying directly beneath the andesite cover. The ore consists predominantly of chalcopyrite and sphalerite in proportions ranging from two to one in the large Lower A ore mass to one to two in the smaller ore masses.

Group No. 1. No. 1 mineralized area lies on the crest of the north or No. 1 anticline and in the rhyolite and rhyolite breccia to the west of its contact with the andesite, which here as elsewhere plunges eastward. In places the associated alteration to dalmatianite extends into the andesite, so that the contact is obliterated. The boundary of the area of alteration is very indefinite, but a roughly circular area about 500 feet in diameter has been completely transformed to dalmatianite. Alteration continues beyond this mass, however, for variable distances up to 300 feet. Numerous dykes of basic or intermediate composition are exposed in the area and others, not exposed, were intersected by the diamond drill. The largest of these dykes is that of diorite lying along the northwest margin of the area of intense alteration. It is about 25 feet wide, trends northeasterly, and, as determined by drilling, dips about 50 degrees to the southeast. Other dykes trend east-west, north-northeast, or south-southeast. Those in the southern part of the dalmatianite mass have been partly altered to dalmatianite.

There are seven pits within the No. 1 area, in all but one of which some ore is exposed. The ore consists mostly of pyrite and chalcopyrite, or pyrite, pyrrhotite, and chalcopyrite, disseminated in aggregates or in irregular veins. Sphalerite was not observed, but may be sparingly present. Chalcopyrite, on the whole, is not very abundant in any of the pits, so that the ore would be classified for the most part as low grade. The contact between the rhyolite and the andesite lies about 300 feet east of the mineralized area and if projected westward at its angle of plunge would pass about 120 feet above the deposits. They are, therefore, probably remnants of larger ore masses largely removed by erosion.

Thirteen diamond drill holes have been drilled within or near the No. 1 mineralized area. The rocks encountered in these, except for the dykes previously described, consist of rhyolite, a considerable part of which is in various stages of alteration to dalmatianite. In most of the drill cores more or less pyrite, pyrrhotite, chalcopyrite, and, in some, a little sphalerite were found, but only in No. 134 at a depth of 86½ to 94 feet was high-grade ore intersected. In No. 131 low-grade ore was cut between 149¾ and 156 feet, and 192 and 201 feet.

Group No. 2 (A). The ore masses of the No. 2 or A area of mineralization occur at the crest of a minor anticline of the Amulet anticlinorium, at a point about one-half mile east of the outcrop of the rhyolite breccia-andesite contact. They lie at two horizons, Upper A, to which the deposits outcropping at the surface originally discovered in this locality belong, and Lower A, the large ore-body recently discovered by diamond drilling beneath the rhyolite breccia-andesite contact at a depth of about 1,000 feet.

The ore of the Upper A horizon is associated with a mass of dalmatianite and related altered rock about 600 feet long and 500 feet wide, which lies for the most part on the southeast side of a northwest dipping diorite dyke 35 to 40 feet wide. This dyke, within the dalmatianite, has itself been transformed to dalmatianite for a length of 350 feet. The dalmatianite is more or less mineralized throughout its entire extent, but the ore masses occur mainly in three localities[1]: (1) in an area extending south from pit 10 on the eastern margin of the dalmatianite mass; (2) in a triangular-shaped area extending from pits 23 and 24 to pits 28 and 29 at the southeastern corner of the dalmatianite mass; and (3) on either side of the northeasterly trending diorite dyke. The chief ore-bodies of the group, Nos. 1 and 2, are more or less tabular-shaped masses lying along the easterly dipping, upper contact of the dalmatianite. The northern, or No. 1, as determined from its outcrops in pits 10, 13, 14, and 16, and six diamond drill intersections, is about 250 feet long, 100 feet wide, and 4 to 68 feet deep. The southern, or No. 2, has a maximum length of about 200 feet, a maximum width of about 150 feet, and a thickness from 15 to 32 feet in four diamond drill intersections. The diamond drill holes bored through the Nos. 1 and 2 ore masses, intersected ore almost continuously from the bedrock surface, or from points a few feet below the bedrock surface, down to varying depths up to a maximum of about 68 feet, and here and there small masses of ore minerals, chiefly chalcopyrite, down to a depth of 275 feet. All these scattered masses, however, are probably too small or too widely separated to be workable. The northwesterly or No. 3 occurrences of ore that adjoin the diorite dyke are almost entirely in dalmatianite, and consist chiefly of pyrite, pyrrhotite, and chalcopyrite, with very little sphalerite. They are, for the most part, of very small extent and of low grade. They lie mainly in a zone along the west margin of a mass of andesite that occurs within the dalmatianite. The character and extent of the ore occurring at the Lower A horizon has been determined, so far, almost wholly from diamond drill intersections. Within the Amulet property it is known to be about 700 feet long from north to south, 500 feet wide from east to west, and up to 313 feet thick.

The occurrence of ore in the A or No. 2 mineralized area well illustrates the mode of emplacement of the ore deposits of the Amulet type. The factors that made the deposition of ore in this locality possible were the presence of: (1) a vertical channel of ascent, almost certainly a fault, extending through both the rhyolite and the andesite to depth, along which the ore-bearing emanations could penetrate; (2) open, easily permeable breccia (a) in rhyolite for the Lower A horizon and (b) in andesite for the Upper A horizon; (3) dense, impermeable andesite above the breccia zones both at the Lower A and Upper A horizons; and (4) numerous fractures, affording minor routes of access through the lavas. The small ore masses in the northwest part of the mineralized area at the time they were deposited were presumably beneath the northwesterly dipping diorite

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[1] *See* Figure 6, Geol. Surv., Canada, Sum. Rept. 1933, pt. D, p. 96.

dyke, and the small extent of dalmatianite above the dyke suggests that it was also an obstruction to the upward ascent of the ore-bearing emanations.

The occurrence of well-developed "bun" type of pillows in the andesite to the northeast of Upper A deposits, the flattened bottoms of which dip northeast, and the north-south strike and easterly dip of flow contacts in the andesite, to the east of the A area of mineralization, show that the No. 1 and No. 2 ore masses of the Upper A zone are structurally above the dalmatianite outcropping to the westward, and that the mineralized area as a whole lies at the crest of a minor anticline of the Amulet anticlinorium.

Group No. 3. Mineralized area No. 3 occurs in the rhyolite breccia beneath its contact with the andesite on the northwest limb of a small subsidiary syncline, a part of the south limb of the No. 2 anticline. Some basic dykes occur nearby. Ore is exposed for a length of 150 feet and for a maximum width of 10 feet in three pits excavated along the contact of the andesite and rhyolite breccia. It consists of pyrite, chalcopyrite, and sphalerite, occurring in numerous small fractures, in aggregates, and in vein zones. Two diamond drill holes, Nos. 140 and 142, were drilled across the ore zone. In No. 140, 6 feet of medium grade ore was intersected at a vertical depth of about 50 feet. Ore was not intersected in hole No. 142. To the northwest of the deposit, and hence structurally below the ore mass, there are several outcrops of dalmatianite. A shaft, inclined 60 degrees to the south, said to be 53 feet deep, has been sunk in the zone. It was filled with water at the time the writer examined the property.

Group No. 4. The ore deposits of group No. 4 or C occur on the south limb of the No. 4 anticline adjacent to the No. 4 or C shaft. They occur in the rhyolite beneath the andesite contact on either side of a northeasterly trending fault and form an almost continuous zone of mineralization about 900 feet long, 40 to 240 feet wide, and from a few feet to nearly 200 feet thick. The rhyolite breccia-andesite contact has been displaced vertically downward 80 feet on the south side of the fault with respect to the north, and for this reason the ore occurs at correspondingly greater depth on the south side than on the north.

The No. 4 zone of mineralization is exposed below the andesite contact northwest of shaft No. 4. West of this contact, which is marked in places by a zone of laminated pyrite, there is a broad area of rhyolite breccia consisting of numerous blocks of white to grey weathering, sericitized, and silicified rhyolite enclosed in a cavernous or hackly weathering matrix. Here and there throughout this area, the matrix, or in places the entire rock, has been transformed to dalmatianite. A dyke of dacite (feldspar) porphyry from a few inches to 6 feet wide, continuous for almost a half mile and dipping steeply to the northwest, crosses the No. 3 anticline in a northeasterly direction on the northwest side of the area. Southwest along the rhyolite breccia-andesite contact is an ore zone exposed in pits Nos. 38 to 43, nearly 1,000 feet southwest of the other ore masses of the group. Possibly this deposit should be classified as a separate mineralized area, but, so far as known, it is not of great extent and lies on the same anticline as the other deposits and has, therefore, been included in the larger group. There are altogether forty-three pits in the outcrop of the No. 4 zone of mineralization, in nine of which ore masses, all lying in the rhyolite breccia either along its contact with the andesite or less than 200 feet away (considerably less than 200 feet at right angles to the contact), have been discovered. These deposits are for the most part small, although in some the ore is of high grade. The deposits in pits 19 and 25 are, however, the superficial exposures of larger deposits at depth.

Diamond drilling and other underground development work near shaft No. 4 have shown that large masses of ore, much of it high grade, lie below the andesite-rhyolite contact in this locality. Scattered, more or less isolated, small masses of ore occur at depth outside the main group of deposits, but disregarding these, four ore masses, designated D, B, C, and E from northwest to southeast, respectively, are known to be present: D and B lie on the northwest side of the fault with which the ore is associated, whereas C and E are on the southeast.

The B ore mass, which adjoins shaft No. 4 on the northwest, so far as it has been delimited, appears to be in horizontal plan a hook-shaped body about 300 feet long (225 feet in a straight line), having a horizontal width ranging from 40 to 60 feet, and a vertical thickness of 100 to 200 feet. Within this mass there are inclusions of dalmatianite and altered rhyolite in which there is little, if any, ore minerals. On the other hand, in some diamond drill holes as much as 50 to over 100 feet of continuous high-grade ore was intersected.

The C ore mass, which lies to the southeast of shaft No. 4, so far as its dimensions are known has horizontally a maximum length of about 440 feet and a maximum width of about 240 feet. The average width is about 140 feet. Vertically the ore occurs at intervals in the rhyolite and rhyolite breccia, from the andesite contact downward to a depth of nearly 100 feet. In parts of this mineralized mass the ore is concentrated in two zones, one 3 to 22 feet thick lying directly beneath the andesite contact and the other 20 to 30 feet thick but 40 to 50 feet lower down. In other parts the upper ore zone joins the lower, and at such points (diamond drill holes 115 and 175) there is continuous ore for as much as 68 feet. The ore directly beneath the andesite-rhyolite contact is almost entirely high grade, whereas that in the lower zone is mostly low grade.

The D ore-body is a smaller mass lying close to the surface, about 250 feet northwest of shaft No. 4 and below an open raise near the east end of the depression underlain by rhyolite (*See* Map 454A). It has a diameter of about 70 feet horizontally and a vertical thickness of about 40 feet.

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

Group No. 5. This group of mineral deposits discovered by diamond drilling lies on the south limb of the No. 1 anticline close to its crest and, so far as developed, from 135 to 690 feet beneath the surface. Owing to the extended rock alteration, it is difficult to determine the character of the original rock adjacent to the deposits, but it seems certain that in its western part the upper limit of the mineralization is at the andesite contact, which at this point has a depth of 250 to 275 feet. In diamond drill hole 238, however, high-grade ore was intersected at only 135 feet. At this point, therefore, either there was a prominent elevation on the rhyolite surface, or the contact has been dislocated by faulting, or the mineralization has extended beyond the contact into the andesite for about 100 feet. The ore deposit in this locality is about 350 feet long from east to west and 150 to 270 feet wide from north to south. Vertically its limitations are difficult to define. For varying thicknesses, from 10 to 125 feet, there is practically continuous high-grade ore along the top of the mineralized zone, and below this, low-grade ore continues for as much as 75 feet or recurs at intervals down to a depth of 450 feet. At this depth a flat diorite dyke about 50 feet thick was intersected, so that the ore deposits so far developed lie in the main between the andesite and the diorite dyke. To the southeast of the ore deposits the diorite dyke bends upward to a nearly vertical attitude. Three diamond drill holes were continued through the dyke, and in one of these ore was intersected below the dyke at 489 to 500 feet and below a second dyke, or the same dyke displaced by faulting, at 669 to 888 feet.

Ore Reserves. According to the annual report of the company for 1939, the ore estimated to be present in the Amulet property at the end of the year was as follows:

——	Tonnage	Copper Per cent	Zinc Per cent	Gold Oz. a ton	Silver Oz. a ton
Lower A ore-body.........	3,157,136	6·24	4·65	0·05	1·62
Other than Lower A ore-body................	270,000	2·7	10·00	0·05	2·5

FUTURE DEVELOPMENT

In the search for other ore masses in the Amulet property the following data regarding the known ore deposits are important.

(1) All the ore deposits are associated with faults and areas of intense deformation and alteration. The andesite overlying the ore masses of the No. 4 group is well exposed in many places, so that, there, it is possible to observe the structural and other features that characterize the rocks above the ore deposits. These are: (a) zones of closely spaced, platy fracturing; (b) feather fracturing; (c) zones of fine, intersecting joints giving the rock a rubbly appearance; (d) grid weathering; (e) rusty zones resulting from the weathering of pyrite; and (f) bleached and silicified zones adjoining fractures. It was these features, especially the grid weathering, in outcrops near the site of shaft No. 5, that directed the attention of J. G.

MacGregor to the possible occurrence of ore beneath the andesite at this point. The anticlinal structure of the rocks, the occurrence of dalmatianite beneath the andesite contact to the west, and the plunge of the anticline to the east, however, were also important data suggesting the possibility of ore at depth in this locality.

(2) A vesicular, scoriaceous or other structure in either the rhyolite or the andesite that makes it easily permeable is favourable for ore replacement.

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

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

(5) Four of the five groups of ore-bodies occur at or near the crests of anticlines.

The future possibilities of the Amulet property can best be discussed with reference to its eastern and western parts, for in the eastern part the contact of the Amulet rhyolite breccia with the overlying Amulet Hills andesite, beneath which almost all the ore so far discovered in the property is found, occurs at depth, whereas in the western part this contact is absent and any ore that may be present must occur at a lower horizon in the succession of lava flows.

The rhyolite breccia-andesite contact, except in the northeastern part of the original Amulet A group of claims, where it is cut off by intrusions of diorite and granodiorite, extends with increasing depth from its outcrops in the middle of the property to its eastern margin. In this territory, therefore, ore may be present wherever the contact or other zones of permeable, easily replaceable rock are intersected by a fault along which the ore-bearing emanations could make their ascent. The only faults known to intersect the contact at present are those associated with the ore deposits. There is, however, considerable territory, notably along the eastward continuation of anticline No. 2, where few rocks are exposed in which faults may be present. It is also possible that beneath drift-filled depressions, even within the areas where rocks are well exposed, there are faults that have not been noted.

In the western part of the property dalmatianite occurs in four separate areas, proving: (1) that channels, presumably faults, along which ore-bearing emanations could make their ascent are present in these localities; and (2) that masses of ore, since removed by erosion, were almost certainly originally present above the dalmatianite. It follows from these conclussions that if below the dalmatianite there is present a cavernous, permeable rhyolite or andesite beneath either massive andesite or rhyolite, or a low-dipping dyke that would serve as a barrier, the ore-bearing emanations would permeate the open rock of this lower horizon depositing ore before ascending to the upper. It has been previously pointed out that the Rusty Ridge andesite belt lying to the southwest of the dalmatianite areas is underlain by the Bedford rhyolite and rhyolite breccia, in which an open texture is present in places. This contact would be a favourable locality for deposition provided it persists northeasterly as far as the dalmatianite area. Lava belts are neither as uniform nor as continuous as sediments, however, so that it is not possible to estimate even approximately the depth at which this contact may occur. It may also be observed that the Rusty Ridge andesite belt terminates towards the southeast and in places narrows down to a thickness of only a few hundred feet. It is possible, therefore, that it pinches out towards the northeast and is absent beneath the dalmatianite. Despite all these difficulties, the presence of the dalmatianite is positive proof that ore-bearing emanations have permeated the rhyolite breccia in these localities, and this alone would warrant some exploratory development in the areas where the dalmatianite is present.

WAITE-ACKERMAN-MONTGOMERY MINE

Previous Descriptions:

Cooke, H. C., James, W. F., and Mawdsley, J. B.: Geology and Ore Deposits of Rouyn-Harricanaw Region, Quebec; Geol. Surv., Canada, Mem. 166, 1931, pp. 219-221.

Gill, J. E., and Schindler, N. R.: Geology of the Waite-Ackerman-Montgomery Property, Duprat and Dufresnoy Townships, Quebec; Trans. Can. Inst. Min. and Met., vol. 35, 1932, pp. 398-416.

Peale, Rodgers: The Geology of the Waite-Ackerman-Montgomery Ore Deposit; Trans. Can. Inst. Min. and Met., 1931, pp. 198-210.

Porritt, R. V.: Trans. Can. Inst. Min. and Met., vol. 34, 1931, pp. 210-215.

Wilson, M. E.: The Multiple and Complementary Sills and Dykes at the Waite-Ackerman-Montgomery Mines, Noranda District, Quebec; Royal Soc., Canada, Trans., 3rd ser., vol. 28, sec. 4, 1934, pp. 65-74.

DISCOVERY AND DEVELOPMENT

The Waite-Ackerman-Montgomery mine includes a group of twenty-eight claims, Bl. 1-3, Bl. O-Z, and Bl. 11-23, lying on either side of the Duprat-Dufresnoy township line, and about 8 miles in a straight line (11 miles by road) north-northwest of Noranda. The original discovery of ore in the property was made by Thomas Montgomery in block Q, Duprat township, and was staked by Montgomery on behalf of himself, I. C. Waite, and C. H. Ackerman, in the summer of 1925. Later in the same year, Waite, Ackerman, and Montgomery gave an option on an 85 per cent interest in the property to N. A. Timmins, who, in turn, after developing the ore deposit by trenching and diamond drilling, sold his interest to Noranda Mines, Limited. Early in 1927, a company known as Waite-Ackerman-Montgomery Mines, Limited, was formed to acquire the group of claims and proceed with their development. Shaft sinking was immediately undertaken. An electrical power transmission line was built from Noranda to the mine in 1927 and the construction of a branch of the Canadian National Railways to the mine completed early in 1928. Production commenced in August of the same year and continued actively to May 1930, when, owing to the decline in the price of copper, shipments were discontinued. Development of the property, both by diamond drilling and shaft-sinking, was continued, however, until March 1932, when, because of the continued low price of copper, all operations were terminated and the workings allowed to fill with water. In September 1933 an amalgamation of the Waite-Ackerman-Montgomery and Amulet mines was effected, the ownership of both properties being taken over by a new company, known as Waite-Amulet Mines, Limited. Early in April 1937 operations were again undertaken on the property. The camp buildings destroyed by forest fires in 1932 were rebuilt and a shaft and hoist house constructed at the new No. 2 shaft. Shipment of high-grade ore to the smelter was resumed early in August. On the completion of the new aerial tramway from the Waite No. 2 shaft to the Amulet mill, shipment of concentrating ore commenced. The shaft at the time the writer last visited the property, in October 1938, had a depth of 1,231 feet.

The writer's study of the Waite-Ackerman-Montgomery mine in 1931-32 included the preparation of a geological map of an area 3,500 feet long by 2,400 feet wide adjacent to the ore deposits, on the scale of 100 feet to 1 inch, and an examination of the workings down to the 300-foot level. The workings below the 300-foot level were filled with water at the time. The lower workings were seen, however, in October 1938. All the diamond drill cores housed at the mine were destroyed by fire, so that all the information contained in this report regarding the results of diamond drilling has been obtained from the company's records and plans. The thanks of the Geological Survey are due to the officials of the Waite-Ackerman-Montgomery mine for their helpful co-operation in its work, especially to Mr. Oliver Hall, consulting engineer, to Mr. R. V. Porritt, former manager, and Mr. Thomas E. Little, present manager, of the mine.

PREVIOUS WORK

The principal published geological descriptions of the Waite-Ackerman-Montgomery mine are those of Rodgers Peale, H. C. Cooke, and J. H. Gill and N. R. Schindler. Peale spent the summer of 1929 on the property and, under the direction of L. C. Graton, prepared a map of an area adjacent to the ore deposits 3,200 feet long by 1,200 feet wide, on the scale of 50 feet to 1 inch. The underground workings down to the 300-foot level, the depth to which they had been carried at that time, were also mapped. Cooke examined the property in 1926 and again in 1929 and described it in Memoir 166 of the Geological Survey. During the summer of 1931, Schindler, under the direction of Dr. Gill, prepared a map of the entire Waite-Ackerman-Montgomery property on the scale of 200 feet to 1 inch. A description of the property by Gill and Schindler based on this study was published the following year. The history of the development of the mine is described in much greater detail than in this account in the reports on mining development in northwestern Quebec by A. O. Dufresne and R. H. Taschereau in the annual reports of the Department of Mines of Quebec.

GEOLOGY

The rocks in which the ore deposits of the Waite-Ackerman-Montgomery mine occur, with the exception of a north-south trending dyke of late Precambrian quartz diabase outcropping about one mile east of the mine, all belong to an early Precambrian basal complex, composed chiefly of lavas cut by numerous intrusions of various lithological characters and ages. The volcanic rocks of this region, although considerably deformed, have escaped the intense deformation to which the complex has been subjected in most other parts of western Quebec.

The rocks occurring in the vicinity of the ore deposits, with the possible exception of a few small outcrops of chert, are all of igneous origin, the approximate succession of which is as follows:

Archæan
- (Early Precambrian)
  - (14) Albite granite in small masses included in andesite
    - (13) Pyroxene lamprophyre (camptonite) dykes
    - (12) Andesite dykes
    - (11) Dacite (feldspar) porphyry dykes
    - (10) Aplite dyke
  - (9) Quartz diorite dykes
  - (8) Diorite dyke
    - (7) Andesite dykes or sills
    - (6) Rusty weathering, epidotized dyke rock
    - (5) Andesite dykes or sills
    - (4) Rhyolite (quartz albite) porphyry in masses, dykes, or sills
    - (3) Quartz diabase in masses, dykes, or sills
    - (2) Andesite dykes or sills
  - (1) Volcanic rocks: chert, variegated and massive andesite, rhyolite

The relationships of rocks designated by Nos. 10 to 12 to one another have not been determined.

The oldest and most extensively exposed rocks in the Waite-Ackerman-Montgomery property are lavas. At the surface near the ore deposits, these are entirely andesite, but at the northern and southern extremities of the property, and in the lower workings, rhyolite occurs. The andesite has been classified into two groups, one of which exhibits numerous internal features that are characteristic of lavas and the other of which is massive and lithologically similar to the sills and dykes of andesite common in the area but, so far as observed, are not intrusive in their relationships.

The strike and dip of the andesite lavas are indicated by flow contacts, by zones of breccia overlain by chert, and by the distribution of the massive and variegated andesite. The strike varies from east to north and the dip from 25 to 35 degrees to the south, east, or southeast. The andesite near the Waite ore-body lies on the eastward continuation of the syncline between the Quebec-Copper and Waite anticlines, but, presumably due to faulting where the ore occurs, the flows have an east strike and a dip of about 30 degrees to the south. In the eastern part of the fault block, however, the strike is nearly north and the dip 25 degrees to the east.

In several localities in the Waite-Ackerman-Montgomery property, there are outcrops of dense, laminated, banded, and rusty weathering chert. In some places the lamination of the chert is irregular, following the contact of the adjacent andesite. In other places the bands or laminæ converge into one another. Where the adjacent rocks are exposed the chert lies here and there as remnants on the surface of andesite or andesite breccia, and obviously lies on the top of lava flows. In outcrops about 150 to 200 feet west of the water tank there are remnants of rusty weathering, laminated chert up to 1 foot thick resting on andesite breccia, the largest area being about 50 feet long and 1 foot wide. The strike is about north 58 degrees east and the dip 30 degrees southeast. In the southeast part of the property there is an easterly dipping surface of andesite and andesite breccia, on the lower slope of which, and in the trench, remnants of chert were observed in three localities in an interval of 400 feet along the strike. The strike of this zone is about north-south and the dip about 25 degrees east.

Within the Waite-Ackerman-Montgomery property intrusives of at least thirteen different ages intersect the lavas. All of these, with the exception of intrusions of gabbro, diorite, and granodiorite, occur only in small dykes or sills and are, therefore, grouped together as minor intrusives.

Diorite and quartz diorite occur in several localities within the Waite-Ackerman-Montgomery property. The most extensive of these occurrences is the part of the Dufresnoy quartz diorite belt that lies along the eastern margin of the property and the large east-west trending dyke that crosses its southern part. Nearer the ore deposits there are two other occurrences, an east-west trending dyke of ribboned diorite outcropping in the north-facing slope of the ridge lying southeast of the mine and the dyke that crosses the same ridge diagonally towards the northeast.

The ribboned diorite is a uniform, moderately fine-grained, massive, grey rock that in one outcrop is characterized by a peculiar, finely banded or ribboned structure. The dyke ranges in exposed width from 10 feet or less to 40 feet and where its contacts were observed dips steeply to the north. The ribboned structure results from the intrusion of innumerable parallel dykes of similar rock, from one-quarter to one inch or more wide, into the dyke rock and into one another. This dyke intersects an intrusion of older diabase and a dyke of the post-rhyolite porphyry andesite, and in the Duprat property, which adjoins the Waite-Ackerman-Montgomery on the west, a dyke of similar ribboned gabbro is cut off by a dyke of diorite. The ribboned diorite is, therefore, probably older in age than the quartz diorite.

The dyke of quartz diorite crossing the ridge to the southeast of the ore deposits ranges in width from 35 to 110 feet and dips 60 to 80 degrees southeast (*See* Map 455A). Where the dyke is widest, the rock is coarsely variegated and contains irregular, feldspathic areas. Elsewhere it is medium-grained and uniform except for numerous intersecting seams filled with epidote. The boundaries of the dyke are sharply defined and the texture along its margin dense for varying widths up to 2 or more inches. In the hand specimen this diorite is a medium-grained, dark grey, finely speckled rock that under the microscope is seen to consist of abundant blue-green to yellow-green amphibole (hornblende), prismatic crystals of plagioclase almost completely altered to epidote and zoisite, quartz, and granophyre, and a black, opaque mineral, probably magnetite.

The Lake Dufault granodiorite mass underlies the southeastern part of the property. Along its border dykes of granodiorite up to 2½ feet wide intersect both andesite and quartz diorite. The andesite near the granodiorite contact has been altered, as shown by the presence of an abundance of granular quartz and brown mica.

Within the Waite-Ackerman-Montgomery property adjacent to the ore-bodies there are numerous intrusions of both acid and basic rocks. Six of these intrusives are older than the diorite and quartz diorite and four younger. Among the oldest of these dyke and sill rocks is a quartz diabase that is remarkably well preserved. The intrusions older than the diorite and quartz diorite also include andesite of three different ages, rhyolite (quartz-albite) porphyry, and a rusty weathering, epidotized dyke rock. The intrusions later in age than the diorite and quartz diorite include aplite dykes, dacite (feldspar) porphyry, andesite, and lamprophyre. The age of these rocks has been determined from the manner in which they intrude one another, from their relationships to the diorite and quartz diorite, and, in the case of the pyroxene lamprophyre, from its presence in dykes intruding the Lake Dufault granodiorite. The most extensive of the minor intrusives is the andesite (No. 3) and the rhyolite (quartz-albite) porphyry. The first of these has been intruded in a multiple manner along the contacts of preceding intrusions of the same rock. The second in most of its occurrences has been intruded into the middle less commonly along the margins of intrusions of the No. 3 andesite.

STRUCTURAL FEATURES

The Waite-Ackerman-Montgomery mine is situated in an area where the lavas are not only cut by numerous intrusions, but have been folded, fractured, and faulted. The territory included in the property may be divided structurally into five areas. These are: (1) the southern part occupied by the crest of the Waite anticline or anticlinorium; (2) the claims north of Duprat Creek, which include a part of the south limb of the Quebec-Copper anticlinorium; (3) the faulted blocks lying between Duprat Creek and the No. 4 or Trail fault; (4) the north-south trending Dufresnoy quartz diorite belt that underlies most of the eastern claims; and (5) the Beaver Hill extension of the property to the east of the Dufresnoy quartz diorite underlain by eastward-dipping flows of andesite.

Faulting

The chief faults within this territory are the following:

Fault No. 1. This fault is known only in the mine workings between the 200- and 700-foot levels, where it has been followed along the strike for about 1,300 feet to the northeast of the No. 1 shaft, on the 300-foot level, and for 1,200 feet to the southwest on the 700-foot level. Its average strike in this distance of 2,500 feet is about 41 degrees east of north. Its dip is to the northwest, 82 degrees between the 200- and 300-foot levels, 83 degrees between the 300- and 500-foot levels, 85 degrees between the 500- and 600-foot levels, and 68 degrees between the 600- and 700-foot levels. On the 200- and 300-foot levels the fault is marked

TABLE X

No.	Local name	Strike	Dip	Width of fracture zone Feet	Displacement
1	Northeast..............	N. 41° E.	Average 78° NW.	5–10	Horizontal displacement of a dykelet about 40 feet.
2	Duprat Creek...........	N. 70° E.	About 70° N.-NW.	10	?
3	Upper South Dipping....	About N. 55° E.	About 30° SE.	10	?
4	Trail..................	N. 73° E.	Not exposed	Not exposed	Horizontal displacement of steeply dipping dykes 440 and 600 feet.
5	Lower South Dipping....	N. 75° E.	50° south	2½–6	?
6	Shaft South Dipping.....		40°–45° south	?	
7	Notch..................	N. 50° E.	?	?	Horizontal displacement of dykes about 30 feet.

by a zone of gouge or finely broken rock from a few inches to 18 inches wide, on one or both sides of which are numerous fractures or masses of breccia for widths of 5 to 10 feet. Fractures are common, however, within 25 feet or more of the fault. The material filling the fractures and forming the matrix of the breccia is chiefly white calcite, less abundantly quartz, and, in a few places, epidote or epidote and quartz. Aggregates of pyrite are common in association with the fault, but were not observed filling fractures or in the breccia matrix. The striæ and grooves on the fault face trend either horizontal or within a few degrees of horizontal, indicating, as noted by Gill and Schindler, that the last movement was approximately horizontal. On the 300-foot level about 430 feet from the end of the drift, along the No. 1 fault, a basic dykelet 4 to 5 inches wide, passing diagonally down the southeast face with a dip of about 45 degrees to the northeast, is cut off abruptly by the fault. On the northwest wall of the drift the dykelet recurs 42 feet to the southwest. Almost all of the ore below the 200-foot level lies on the southeast side of the No. 1 fault.

Fault No. 2. This fault was discovered in the north crosscut about 1,475 feet north-northwest of the No. 1 shaft on the 700-foot level and was followed in a drift for about 825 feet. It lies at this point about 200 feet north of Duprat Creek. In an outcrop of andesite on the south bank of Duprat Creek, about 800 feet east of the road to the Waite-Ackerman-Montgomery gravel pit, there is a zone of fracturing and shearing 6 feet wide that trends north 70 degrees east and lies almost directly on the continuation of the Duprat Creek fault (*See* Map 455A). Where seen in the mine workings the presence of the fault is shown by a zone of broken rock about 10 feet wide in which there are one or two bands of schistosity 2 to 4 feet wide, a zone or zones of gouge up to 4 inches wide, and veinlets of calcite or quartz and a very little pyrite. The dip of the zone is about 70 degrees to the north, and if projected upward at this angle occurs at the surface close to Duprat Creek and, as previously noted, almost directly on the continuation of the zone of shearing observed at the surface to the east near the creek. The striæ on the fault face are approximately horizontal.

Fault No. 3. This is a low-angle fault intersected in the main crosscut on the 200-foot level about 370 feet southeast of the No. 1 shaft. It is marked by a zone of highly broken, schistose rock 10 feet wide that trends about north 55 degrees east and dips southeast about 30 degrees. Several parallel minor faults were also observed nearby. In the south crosscut on the 700-foot level a similar, south-dipping fault occurs that is almost certainly the continuation of the No. 3 fault. The dip between this point and the intersection on the 200-foot level is 35 degrees.

The No. 3 fault, if projected to the surface with a dip of 30 degrees would outcrop about 20 feet southeast of the shaft. It is probable, therefore, that its outcrop lies beneath the glacial drift and clay that fills the valley in which the shaft is situated. The junction of the No. 3 and No. 1 faults has not been cut in the mine workings, but it is probable that No. 3 is a thrust fault of later age than No. 1, along which the rock on the upper side has moved north or northwestward, for (1) if the No. 1 fault continued without interruption to the surface its extension to the southwest would cut across numerous dykes and sills that are well exposed to the southwest of the ore deposits, and no evidence of such displacement has been observed; and (2) below the No. 3 fault the ore deposits lie almost entirely on the southeast side of the No. 1 fault, whereas above the No. 3 fault they lie directly on its continuation, a condition that suggests a movement towards the northwest.

Fault No. 4. The outcrop of this fault is not exposed. Its presence is indicated, however, by the well-defined depression that extends across the Waite area about 1,000 feet south of the No. 1 ore deposits, and by the manner in which the rocks on either side of the depression are displaced with respect to one another. Its strike is about north 73 degrees east. Its dip is unknown. A northeasterly trending dyke of quartz diorite, a northeasterly trending dyke of rusty weathering, epidotized rock, and the contact of the Amulet rhyolite belt and the Waite andesite have all been displaced towards the west on the north side of the fault 450, 600, and 1,600 feet, respectively. The quartz diorite dyke, where its contact is exposed, dips from 60 to 80 degrees to the southeast, and the contact of the rhyolite breccia and andesite about 30 degrees to the east. The dip of the epidotized dyke rock has not been determined beyond the fact that its attitude is nearly vertical. On the direct eastward continuation of the fault at a bend in Duprat Creek, two outcrops of andesite lie on the south side of the fault line adjacent to an area of quartz diorite on the north. The relationships just described, and the small strike slip of the quartz diorite dyke, which dips steeply to the east, compared with that of the rhyolite breccia-andesite contact, which dips at a low angle in the same direction, show that an important fault underlies the depression and that the movement on the fault plane was probably more nearly vertical than horizontal.

Fault No. 5. This is a south-dipping fault intersected in the north crosscut on the 700-foot level about 275 feet north of the No. 1 shaft and on the 1,000-foot level about 130 feet southeast of the No. 1 shaft and 20 feet south of the No. 2 shaft. The width of broken rock is 3 feet on the 700-foot level and 6 feet on the 1,000-foot level. Irregular zones of shearing and well-defined zones of gouge up to 8 inches wide occur within the broken rock. Zones of quartz up to 1 foot wide and aggregates of chalcopyrite up to one-half inch wide were observed in broken rock on the 1,000-foot level. The average dip from the 700- to 1,000-foot level is 50 degrees. Its strike is northeasterly.

Fault No. 6. In the No. 2 shaft below the 1,200-foot level another fault dipping 40 to 45 degrees south was crossed. This was not observed by the writer.

Fault No. 7. In the southwestern part of the Waite-Ackerman-Montgomery property (Bl.W) there is a very sharply defined, notch-like depression about 20 feet wide and 20 feet deep extending northeasterly across a ridge of rhyolite breccia along which some small dykes have been displaced. One of these, consisting of dacite porphyry, which meets the depression almost at right angles, has a strike slip of about 30 feet, the north side to the west with respect to the south. It is possible that this fault continues farther to the northeast, but if so it is not marked by a depression or by an exposed fracture zone.

Fault Breccia

In the ridge of andesite that lies west of the glory hole in the Waite-Ackerman-Montgomery property there is much breccia. Part of this may be original flow breccia, but the rock is intensely fractured and much of the brecciation is undoubtedly the result of deformation. This andesite lies directly on the continuation of the No. 1 ore deposit, so that it is probable that it was breccia of this type that was replaced by this ore-body. In the south crosscut on the 700-foot level, 650 feet south of the No. 1 shaft, drifts have been driven to the east and west following a zone of breccia 3 to 10 feet wide in andesite. This breccia consists of abundant subangular to round, grey fragments 2 to 3 inches in diameter in a dark grey matrix mineralized in places with fine, granular pyrite. Many of the fragments are pale grey along their margin as if silicified. Here and there masses of epidosite, arranged in rows, were noted in the zone. Some of these can be seen to lie in fractures. In parts of the zone the matrix consists almost wholly of granular quartz. On the 1,000-foot level, in the crosscut to the No. 2 shaft about 120 feet from the 1,002 drive, a zone of similar breccia in rhyolite was observed. In this the entire rock is highly siliceous, and many of the fragments have pale grey, more or less circular zones up to one-quarter inch wide, similar to those seen in the brecciated andesite along their margins. Adjacent to the ore masses recently discovered on the 700-foot level to the north of the No. 1 fault, chalcopyrite and pyrite were observed to occur along the margins of fragments, and in some places to occur in circular zones around masses of highly chloritized rock, presumably altered andesite. These are somewhat similar to the rings of the breccias previously described and may be replacements of them. The mode of origin of these occurrences of breccia is difficult to determine, but it is almost certain that they are not flow breccias but the result of deformation long after the lavas were extruded. It is probable that the breccia in andesite observed at the surface to the west of the No. 1 ore-body would appear little different from that seen on the 700-foot level if exposed on a freshly broken surface, and that it was breccia of this type that was replaced by the ore deposits.

ORE DEPOSITS

Form and Extent. There are three known ore deposits or groups of ore deposits in vertical succession in the Waite-Ackerman-Montgomery property. Their approximate form and extent have been determined from intersections in the mine workings and from diamond drill holes bored both from the surface and the underground workings. The three assemblages of ore masses that are here grouped together as single ore deposits include numerous masses of rock (chiefly dykes or sills of andesite) that are either not mineralized or not sufficiently mineralized to constitute ore, but are so intermingled with ore that they cannot be separated in mining and must be included with it in calculating the tonnage and average grade of ore in each deposit.

The uppermost or No. 1 deposit outcrops at the surface in a roughly rectangular area 260 feet long and 150 feet wide, the longer direction trending about north 60 degrees east. It dips about 30 degrees to the southeast parallel to the dip of the many sills and andesite lava flows in this locality. The thickness of the ore deposit measured vertically is about 200 feet, and at right angles to the dip about 125 feet. The length parallel to the dip is about 400 feet. On its lower edge the deposit terminates in upper and lower prolongations. Practically the entire ore mass lies above the 200-foot level and the uppermost low-angle (No. 3) fault.

The No. 2 group of deposits lies between depths of 455 and 850 feet. It is separated from the No. 3 below by a mass of rhyolite (quartz albite) porphyry. On the 500-foot level the deposit is 250 feet long and 75 feet wide, and on the 600-foot level, 250 feet long by 150 feet wide. The longer direction trends northeasterly. On its northwest margin, from depths of 455 to 655 feet, it adjoins the lower or foot-wall side of the No. 1 fault. From the No. 1 fault it dips about 60 degrees to the southeast. The dip length is about 400 feet. Its thickness measured at right angles to the dip is about 150 feet.

The No. 3 deposit lies diagonally to the northwest below the No. 2 ore mass between depths of 700 and 1,010 feet. Like the No. 2 deposit, it dips steeply to the southeast. It is about 250 feet along the strike, 100 to 150 feet thick, and 275 feet deep measured along its dip.

Mineral Composition. The chief mineral constituents of the ore deposits are chalcopyrite, sphalerite, pyrite, and pyrrhotite. Other minerals known to be present are galena, native silver, cosalite, a mineral identified by Peale as either electrum or calaverite, apatite, quartz, calcite, and the minerals resulting from the alteration of the wall-rock. Chalcopyrite is the chief ore mineral in the central part of the No. 1 deposit and throughout most of the Nos. 2 and 3 ore masses. Sphalerite predominates in the outer zone of the No. 1[1], in the southern and southeastern part of the No. 2, and the northeastern part of the No. 3 deposit.

Pyrite is common in the deposits and in places is the predominant mineral in considerable masses of ore. In the northeastern part of the outcrop of the No. 1 ore mass there is a zone, about 75 feet long and 25 feet wide along the north margin of the ore mass, consisting almost entirely of fine, granular-looking pyrite intimately intermingled with quartz. Sphalerite is associated with the pyrite, in places filling fractures or the matrix of breccia. At one point in this area round nodules of pyrite up to three-fourths of an inch in diameter occur in a zone about 1 inch thick over the surface of the ore. The matrix between the globular masses consists largely of oxidation products, so that it is probable that these aggregates have been formed superficially by alteration.

The pyrrhotite in the ore is associated, for the most part, with the chalcopyrite. Under the microscope it is seen to occur within the chalcopyrite chiefly in irregular masses, but it is also present in places in fine, vermicular veinlets. J. S. Stevenson, who collected samples of the ore for study while assisting the writer in the field, cites evidence from which he concludes that the fine veinlets of pyrrhotite in the chalcopyrite have been crystallized simultaneously with the chalcopyrite from solid solution (exsolution)[2].

[1] Porritt, R. V.: Trans. Can. Inst. Min. and Met., vol. 34, 1931, pp. 211–13.

[2] Stevenson, J. S.: Vein-like Masses of Pyrrhotite in Chalcopyrite from the Waite-Ackerman-Montgomery Mine, Quebec; Am. Mineralogist, vol. 18, 1933, pp. 445–449.

Sphalerite, where present, occurs almost wholly in separate ore masses. It is not associated, except locally, with the chalcopyrite, the zinc content of the copper ore amounting to less than 1 per cent. Except for a few, small, round inclusions that it contains, sphalerite is not seen in association with pyrrhotite in the ore.

Chalcopyrite with varying proportions of included pyrrhotite occurs in places in the ore deposits in almost solid masses of considerable extent containing as much as 26·4 per cent of copper (equivalent to 76·5 per cent of chalcopyrite). The average copper content of the copper ore in the three ore masses according to the original estimate was 5·9 per cent. Where the chalcopyrite is associated with sphalerite it occurs either in small, irregular grains and small, dot-like areas or in irregular veinlets.

Galena was observed by the writer in the west face of the west glory hole, in an aggregate 1 to 1½ inches wide and 3 inches long, associated with pyrite, sphalerite, and chalcopyrite in an embayment in the north margin of a vertical dyke of andesite. It was also noted by Haycock in small grains in pyrite, sphalerite, and chalcopyrite in a specimen collected by the writer from the ore bins. On a polished surface of the galena and associated minerals from the west glory hole irregular veinlets of galena and chalcopyrite are seen to cut the sphalerite and a zone of chalcopyrite and galena to cut pyrite.

Of the remaining minerals composing the ore, all except quartz and calcite are present in very small amounts and have been observed only under the microscope. Silver was seen by Haycock in a polished specimen of the galena from the west glory hole. Cosalite was noted both by Peale and by Haycock, the latter in a specimen collected by the writer from the outcrop of ore in the main pit. Another of the uncommon minerals in the ore is that identified by Peale as either electrum or calaverite. This was not observed by Haycock. Apatite in abundant, perfect, hexagonal crystals was observed by the writer in a thin section of altered rock enclosed in chalcopyrite, from the ore bin. The associated minerals were chlorite, actinolite, and a small amount of epidote. Quartz is present in the ore partly in the interspaces between pyrite crystals and grains, as previously described, and filling fractures, a zone of which cuts across the outcrop of the main ore mass in a northeasterly direction. Calcite also occurs in veinlets cutting the ore.

OTHER MINERALIZED OUTCROPS

In the northern part of the Waite property (block 3) on the northwest margin of the area of andesite extending west from the gravel pit there is a low ridge in which a band of laminated and banded chert from 1 foot to 2½ feet wide is exposed in prospect pits and stripped areas almost continuously for 200 feet. The strike of the zone is northeasterly and the dip 35 degrees southeast. The laminated phase of the chert has been impregnated with pyrrhotite, pyrite, and chalcopyrite in a zone up to 6 inches or more wide. This chert zone lies on the contact between two flows of andesite, the contact of which has afforded a channel along which ore-bearing emanations have penetrated.

In the southwestern part of the Waite-Ackerman-Montgomery property, near the point where the northeasterly trending, notch-like depression crosses the contact of the Amulet rhyolite and the Waite-Amulet Hills andesite belts, the andesite is mineralized with considerable pyrite and some chalcopyrite near a dyke of rhyolite porphyry. The presence of these minerals in the andesite adjacent to the depression that, as previously pointed out, is almost certainly underlain by a small fault illustrates the close association of mineralization in the area with faulting.

FUTURE POSSIBILITIES

The ore deposits of the Waite-Ackerman-Montgomery mine occur in association with numerous faults and, so far as known, no other channel was available along which the ore-bearing emanations could ascend. It seems reasonable to assume, therefore, that the ore reached the andesite through one or more of the faults, but it is not certain which of the individual faults was the route followed. It is most probable that the ascent of the ore-bearing solutions from depth would occur on vertical faults, and considerable development work was done along the No. 1 fault with this possibility in mind. At that time, however, the existence of the much larger No. 4 fault was not known. This lies about 1,000 feet south of the ore deposits and, although not exposed, is probably steeply inclined or vertical. Another possibility is that the final route of ascent was along the south-dipping faults that occur beneath the No. 1 and No. 3 ore deposits, but these at depth must intersect or merge with the No. 4 fault, and in that case this fault may have been the route of ascent from depth. A crosscut was driven on the 700-foot level about 600 feet south of the ore deposits, but beyond this no development work has been performed near the No. 4 fault. If this fault was the route of ascent, then ore may occur anywhere in its vicinity where breccia is present beneath an impermeable cover. This is equally true of course in other parts of the property where faults occur.

Ore Reserves and Production. The estimated tonnage and grade of ore present in the Waite-Ackerman-Montgomery property on December 31, 1939, were as follows:

Type of ore	Tons	Copper Per cent	Zinc Per cent	Gold Ozs. a ton	Silver Ozs. a ton
Copper ore..................	550,000	4·25	......	0·032	0·34
Zinc ore.....................	300,000	......	11·52	......	......

The production of ore from the property during its early period of operation (almost entirely from the No. 1 ore mass) was as follows:

Year	Tons of ore shipped	Copper Per cent	Zinc Per cent	Gold Ozs. a ton	Silver Ozs. a ton
1928.............	9,023 (Aug.-Sept.)	6·18	3·47	0·087	1·08
1929.............	45,768[1]	8·13	4·9	0·052	2·12
1930.............	21,043[2]	5·29	3·96	0·042	1·14
1931.............	1,011[3]	11·28	0·3	$1.95	0·51

[1] Including 3,252 tons of concentrating ore, the remainder direct smelting.
[2] Including 18,406 tons of concentrating ore, the remainder direct smelting.
[3] From development work.

The production since operations were resumed in August 1937 is as follows:

Year	Tons	Copper Per cent	Gold Ozs. a ton	Silver Ozs. a ton
1937.................	12,814[1]	13·18	0·093	0·46
1938.................	19,761	.....	.....	....
1939.................	174,026	.....	.....	....

[1] Direct smelting.

LAKE DUFAULT MINES, LIMITED

A company known as Lake Dufault Mines, Limited, was organized in 1937 to take over several groups of claims in Dufresnoy township to the east of the Waite-Ackerman-Montgomery and Amulet properties. This territory is underlain by the Waite Hills-Amulet Hills andesite, where not interrupted by the Dufresnoy belt of quartz diorite, diorite, and gabbro and the Lake Dufault granodiorite. It was known from the geological map of the Amulet property that the upper, scoriaceous top of the Amulet belt of rhyolite and rhyolite breccia in which sulphide ore deposits occur beneath andesite underlay this region at depth. It was also known that mineralizing solutions had ascended, presumably along a fault, across the rhyolite-andesite contact and had penetrated 1,000 feet into the andesite to deposit the ore of the Upper A deposit in rounded, andesite breccia. It followed from these relationships that if the open, scoriaceous top of the Amulet rhyolite belt persisted at depth to the eastward that the ore-bearing emanations would probably first fill the openings and replace the rhyolite at this horizon before continuing upward to deposit the Upper A deposit. Having this possibility in mind, the Lake Dufault Company, under the direction of J. G. MacGregor, in December 1937, undertook diamond drilling in their property adjacent to the Amulet east boundary and directly opposite the Upper A group of deposits. Two feet of heavy mineralization consisting of sphalerite with some chalcopyrite and pyrite was intersected at the contact in the first hole drilled, and 4 feet of pyrite with some sphalerite and chalcopyrite in the second. High-grade ore was encountered at the contact in May 1938. In the annual report of the company for 1939 a total of about 430,000 tons of ore is estimated to be present.

NEWBEC

This property includes a group of thirty-two claims in Dufresnoy township, lying northwest of Lake Dufault. Some surface prospecting was done and three diamond drill holes were drilled in a part of these claims by Norbec Mines, Limited, in 1925. No further work was undertaken until 1927 when a company known as Newbec Mines, Limited, was formed to take over the claims formerly owned by Norbec Mines, Limited, and two additional groups known as the Rouyn Gold Pan and the McLeod.

Development work was carried on both underground and at the surface continuously from that time until 1930 when all operations were discontinued. Some additional diamond drill holes were bored in the property early in 1939. At the time operations were discontinued in 1930 the shaft had attained a depth of 270 feet, from which drives had been driven 50 feet to the northeast on the 60-foot level, 205 feet at the 125-foot level, and 270 feet at the 250-foot level. From the extremity of the 250-foot level a winze had been sunk to a depth of 275 feet. In addition to this work, several thousand feet of diamond drill holes were bored and a considerable number of prospect pits and trenches excavated. In March 1930, 278·26 tons of ore, averaging 6·74 per cent copper, was shipped to the smelter at Noranda.

The rocks exposed in the property include rhyolite, rhyolite breccia, andesite, and andesite breccia, areas of quartz diorite, the northern margin of the Lake Dufault granodiorite stock, the unusual mixture of broken rock fragments forming the Newbec breccia, and a dyke of later diabase. The most unusual and extensive rock represented in the property is the Newbec breccia. It includes angular, to round or tabular-shaped fragments of rhyolite, andesite, quartz diorite, and, along the granodiorite contact, fragments of granodiorite. The matrix in some places is fine porphyritic rhyolite, but for the most part it is either dark, fine-grained, and chloritic or composed of quartz, ankerite, and pyrite. In an outcrop west of the shaft molybdenite was observed along the margin of a diorite inclusion.

In the northern part of the property, about 1,200 feet north of the shaft, a north trending contact of andesite overlain by rhyolite is exposed. North of this point, in the east-facing slope of a triangular-shaped outcrop of andesite lying west of the contact, a pit 25 feet long, 4 to 6 feet wide, and 1 to 6 feet deep has been excavated. In three places in the pit zones of pyrrhotite with some chalcopyrite up to 3 feet wide occur along fractures. In the outcrop south of this point, which consists of andesite breccia in its western part and porphyritic rhyolite in its eastern, five small prospect pits, the largest 20 feet long by 5 to 10 feet wide and 2 to 5 feet deep, have been excavated in a length of about 120 feet in the andesite breccia near the rhyolite contact. In these openings breccia is mineralized up to a maximum width of 10 feet with pyrrhotite and pyrite in which chalcopyrite is sparingly present in fractures or in aggregates in the other sulphides.

Except for two outcrops of andesite adjacent to the shaft, there is no rock exposed in the vicinity of the workings and all the information available to the writer regarding the underground geology is that obtained from an examination of the dump and from published descriptions. The rocks observed in the dump adjacent to the shaft include mainly andesite, more or less chloritized, and rhyolite (quartz-albite) porphyry. The ore minerals are largely chalcopyrite, pyrrhotite, and pyrite, mingled with highly chloritized andesite, which microscopic examination showed to contain some brown mica also. In one specimen collected from the dump by the writer numerous, small, metallic-looking specks were present that H. V. Ellsworth of the Mineralogical Division of the Geological Survey determined to be molybdenite. The main shaft and drives follow a zone of faulting that trends northeasterly and dips 82 degrees northwest. In the shaft near the surface there was a zone, ranging up to 10 feet wide, mineralized with chalcopyrite, pyrrhotite, and other sulphides, that continued to a depth of about 40 feet. H. C. Cooke states that the total length of the ore mass is 30 feet. Similar lenses of ore up to 15 feet long and 4 feet wide, averaging up to 10 per cent copper, were intersected both on the 125- and 250-foot levels, and in diamond drill holes bored from the workings,[1] but a large, continuous mass of ore was not found.

POWELL ROUYN MINE

Previous Description:

Cooke, H. C., James, W. F., and Mawdsley, J. B.: Geology and Ore Deposits of Rouyn-Harricanaw Region; Geol. Surv., Canada, Mem. 166, 1931, pp. 236-240.

INTRODUCTION

This property, originally owned by Powell Rouyn Gold Mines, Limited, includes a group of four claims, Bl. 58 to 61, adjoining the Chadbourne property on the north. In September 1922 a gold-bearing quartz vein in claim Bl. 60 was discovered by T. W. Powell. Late in 1922 the Chadbourne-Thompson Syndicate took an option on the group of claims and during the early part of 1923 carried out considerable development work on the vein by stripping, trenching, and diamond drilling. In October 1923, by agreement with Powell and Noranda Mines, Limited, who had acquired the properties of the Chadbourne-Thompson Syndicate, an option was taken on the property by the Nipissing Mining Company. After sinking an inclined shaft at an angle of 55 degrees to the northeast, to a depth of 225 feet, and drifting on the vein for about 240 feet at the 100-foot level, this company, in July 1924, dropped the option. From November 1927 to the early part of 1931, an organization known as Powell Mining Properties, Limited, carried on development operations, chiefly in the northern and northeastern parts of the property. This included stripipng, trenching, and over 1,000 feet[2] of diamond drilling. Early in 1931, 50 tons of oxidized, gold-bearing material from the outcrop of a mineralized zone near the east shaft was shipped to the Noranda smelter.

In 1933 a new company, the Powell Rouyn Gold Mines, Limited, was organized to acquire ownership of the property of the older company of closely similar name. During the following years an intensive program of development and sampling, chiefly on the three northwesterly trending veins or vein zones, known as (1) the Main or Shaft vein, (2) the Northwest vein, and (3) the Southeast vein, was carried on. A large number of trenches were excavated and thirty-two diamond drill holes, having a total length of 6,987·5 feet, were bored, and from these an estimate of the ore reserves down to the depth of diamond drilling was prepared. In June 1936 operations were resumed. The Nipissing inclined shaft No. 1 was continued to a depth of 500 feet for development purposes. Later a new, vertical shaft, No. 2 (Plate I), was sunk to a depth of 825 feet. A road to Noranda was constructed and on September 1, 1937, shipment of ore as gold-bearing flux to the Noranda smelter began and has continued without interruption since that time.

[1] Report, Quebec Bureau of Mines, 1929–30, p. 123.

[2] Quebec Bur. of Mines, Ann. Rept. 1931, pt. A, p. 95.

The thanks of the Survey are due to the officers of the company for their helpful assistance. All the plans and records in their possession were placed at the writer's disposal and every assistance given in making the examination of the property. The writer is especially indebted to the late Duncan Chisholm, managing director; W. E. Leonard, mine manager; J. C. Rogers, consulting geologist; and E. K. Fockler, for their co-operation.
The only published geological description of the property is that of H. C. Cooke, W. F. James, and J. B. Mawdsley, in Memoir 166 of the Geological Survey, but the history of development is given in considerable detail by A. O. Dufresne and R. H. Taschereau in reports of the Quebec Bureau of Mines.

GEOLOGY

The Powell Rouyn property is underlain almost wholly in its northern part by volcanic rocks and in the southern part by the Powell albite granite. The lavas consist mainly of andesite belonging to the Powell-Pontiac area or belt, but also include rhyolitic rocks of three classes. These are: (1) massive rhyolite outcropping in the northeastern part of the property to the north of the Powell-Pontiac andesite and forming a part of the Héré Creek rhyolitic belt; (2) rhyolite and rhyolite tuff occurring in areas here and there within the andesite; and (3) rhyolite near Rosebury Lake in the western part of the property, lying to the south and structurally below the andesite. The rhyolitic inclusions in the andesite are for the most part associated with faults, and most of them have probably been downfaulted into their present positions. The rhyolite near Rosebury Lake is cut off entirely on the south by the Powell granite, but was probably originally a part of the Brownlee rhyolitic belt, which occurs farther east on the Brownlee property. The Powell granite does not differ greatly in composition from the rhyolite, so that the difference between the rhyolite and the granite is largely one of texture. Where the two rocks adjoin one another, because of the recrystallization that the rhyolite has undergone, the boundary is difficult to fix in places. The Powell granite, notably near Rosebury Lake, has been so highly chloritized that it has a more or less dioritic appearance on its weathered surface. Here and there it is intruded by dykes of andesite and rhyolite or rhyolite porphyry up to 20 feet wide. Several dykes of andesite outcrop near or east of the Powell main vein. A northeasterly trending dyke of rhyolite (quartz) porphyry also outcrops about 500 feet northwest of the No. 2 shaft. These, because of their small size, are not shown on the Rouyn map, but similar dykes lying farther south are indicated. In the eastern part of the property the entire complex just described is intersected in a north-south direction by the Powell later diabase dyke. This dyke at the south end of claim Bl. 61 is displaced 700 feet to the west on the south side of the Horne Creek fault, which crosses the property in an east-west direction at this point.

STRUCTURAL FEATURES

The volcanic rocks within the Powell Rouyn property strike northwesterly and have their tops to the northeast, and hence belong structurally to the north limb of the Noranda anticline. The rocks in the property are intersected by numerous faults trending chiefly in an east or northeast direction. It is also probable that there are some large unexposed faults in the property, the existence of which is not indicated by displacements of flow belt contacts or other evidence. Descriptions of the most important observed faults shown on the Rouyn map (453A) are as follows.

No. 1 Fault. This is an east-west trending fault lying about 80 feet south of the main east or No. 3 shaft. It is exposed at intervals for about 3,500 feet. For most of this length the fault is adjoined on the north by andesite and on the south by rhyolite tuff. The total width of schistosity along the fault ranges from 25 to 35 feet. The contact, where exposed, is vertical and is marked by a rusty weathering zone of schistosity in which the rock boundary cannot be fixed within 2 feet. Mineral deposits occur in the andesite adjacent to this fault in two localities.

No. 2 Fault Zone. This zone lies about 900 feet south of the No. 1 fault. It outcrops adjacent to the west side of the Powell later diabase dyke, and from this point can be followed westward for about 1,200 feet. It consists of two or possibly three branches. At its east end the zone intersects andesite, but is on the contact of andesite and rhyolite tuff or in rhyolite tuff at the west. The main fault of the zones lies on its north side and trends east-west. It is marked by a belt of vertical or nearly vertical schistosity 4 to 30 feet wide, along which the weathered surface of the andesite in a belt up to 35 to 70 feet wide presents a peculiar appearance due to the presence of numerous round to elliptical-shaped protuberances. Microscopic examination shows the entire rock of the zone to be highly chloritized and silicified. The protuberances on the weathered surface consist mainly of sericite. Towards the west, where this fault intersects rhyolite tuff, it is adjoined by the No. 2 or F zone of chalcopyrite mineralization. At the eastern termination of the outcrop of the main fault adjacent to the Powell later diabase dyke a diagonal zone of schistosity and fracturing up to 6 feet wide diverges to the southwest. The andesite adjacent to this, as in the case of the main fault, exhibits the protuberant weathering. Farther west, about 150 feet southwest of the main fault, there is a parallel zone of schistosity 3 to 10 feet wide in the rhyolite tuff. All of these faults are almost certainly branches from one another and part of a single fault zone.

No. 3 Fault and Pontiac Rouyn No. 1 Fault. These are northeasterly trending zones of shearing in which, as in the No. 2 zone, chalcopyrite occurs. The No. 3 fault lies about 1,500 feet north of the Powell Rouyn main shaft and about 800 feet northwest of the old road to the Macamic highway. The zone of shearing has a maximum exposed width of about 10 feet and outcrops in three localities in a distance of about 1,000 feet. It intersects both andesite and rhyolite, and if projected northeastward meets the continuation of the No. 1 fault at an acute angle. It is possible, therefore, that the No. 1 fault merges into the No. 3 as a branch beneath the drift cover. The Pontiac Rouyn No. 1 fault is not exposed in the Powell Rouyn property, but projected southwestward from its outcrop adjacent to the road to the Pontiac Rouyn shaft it underlies the drift-filled depression that extends northeastward from Rosebury Lake across the northwest corner of the Powell Rouyn Bl. 60 claim.

SULPHIDE-BEARING ZONES

Zones or areas of rock mineralized with chalcopyrite, pyrrhotite, and pyrite occur in four localities in the northern part of the Powell Rouyn property. All of these lie in or adjoin faults and may, therefore, be designated by the number of the fault with which they are associated.

No. 1 Mineralized Area. There are two masses of mineralized rock associated with the No. 1 fault, one adjacent to the No. 3 shaft and the other in the large outcrop of andesite on the west side of the Powell later diabase dyke and north of the fault. In the first locality the No. 3 shaft, 162 feet deep, has been put down. From this, at 150 feet, drifts have been driven to the east and west for a total distance of 235 feet and crosscuts to the north and south for a total length of 220 feet.[1] That a mineral deposit was intersected in these workings is shown by aggregates of chalcopyrite, pyrrhotite, and pyrite up to 1 inch or more in diameter, in broken rock, exposed in the dump. A few fragments of quartz containing aggregates of chalcopyrite up to one-third inch in diameter were also noted.

In the andesite outcrop to the west of the Powell later diabase dyke seven prospect pits, the largest 40 feet long, 6 to 18 feet wide, and 3 to 6 feet deep, have been excavated. In all these openings the andesite is rusty weathering, fractured, and traversed by small faults. Here and there in the rock there are cavities lined with crystals of quartz and pyrite, and in other places aggregates of chalcopyrite, pyrrhotite, and pyrite up to 2 inches in diameter. One diamond drill hole (No. 6) was put down in this deposit at an angle of 45 degrees. It is said to have intersected sulphide minerals similar to those at the surface. The deposit at this point is strikingly similar to the material in the dump from the No. 3 shaft. In both occurrences the sulphides have been deposited adjacent to the No. 1 fault, and the fracturing and faulting in both localities is evidently related to it.

No. 2 Mineralized Zone. This occurrence of sulphides is associated with the western exposure of the north branch of the No. 2 fault zone. It lies about three-fourths of a mile from the Macamic highway and on the west side of the old road from the highway to the No. 1 shaft. The mineralized zone is almost continuously exposed for about 300 feet in an east-west direction and ranges in width from 6 inches to 4 feet. It lies along the fault zone and consists chiefly of mingled chalcopyrite and quartz. It is obliquely displaced in places by minor faults. An average sample taken by the writer across a width of 2½ feet at the east end of the zone, assayed by J. A. Rivington of the Bureau of Mines, contained 10·09 per cent copper, 0·02 ounce gold, and 2·92 ounces silver a ton. Six diamond drill holes were put down at angles of 45 or 60 degrees to intersect the zone at depths varying from 44 to 140 feet, by Powell Mining Properties, Limited. The thickness and grade of the zone intersected, according to a report prepared by Andrew Walz, are included in the following table:

[1] Taschereau, R. H.: Rept. Bur. of Mines, Quebec, 1929–30, p. 111.

TABLE X

Number of hole	Angle of dip Degrees	Vertical depth of intersection Feet	Mineralization		Copper Per cent	Silver Ozs. a ton
			Width on D.D. hole Feet	True width Feet		
1	45	44	5	4	5·77	3·60
2	45	50	5	4	13·93	5·88
3	45	45	5·9	4·7	7·92	3·00
4	45	53	5	4	9·16	3·16
6	60	140	6	4·8	3·70	3·60
7	45	90	2		1·68	1·00
8	60		Not intersected			

No. 3 Mineralized Zone. This zone of chalcopyrite mineralization outcrops in three localities in a length of about 1,000 feet. The most northeasterly exposure occurs at the point where the No. 3 fault crosses the eastern extremity of an elongated outcrop of andesite; a second outcrop occurs in rhyolite at the southern extremity of the same rock area; and the third exposure on the margin of an outcrop of rhyolite a short distance west of the second. In all of these outcrops the deposits consist of abundant chalcopyrite, some quartz, and varying proportions of pyrite in veins from 3 inches to 8 inches wide. The total width of the zone of shearing ranges from 1 to 7 feet and the total width of vein material within the zone from 4 to 18 inches.

GOLD-BEARING QUARTZ VEINS

Within the Powell Rouyn property there are at least five quartz veins or vein zones. Of these the most important are the three vein zones extending in almost direct alinement with one another in a northwesterly direction across claims Bl. 61 and Bl. 60.

Main Vein Zone. This vein zone is exposed at the surface in outcrops, trenches, and stripped areas at intervals for about 1,000 feet, and in underground workings for over 1,800 feet. The wall-rock is mostly Powell albite granite, but at the north end the vein zone intersects rhyolite. In places the wall-rock has a dark grey appearance due to chloritization. The average dip of the vein or vein zone is about 58 degrees to the northeast. The width of the mineralized zone ranges from 1 foot or less to over 20 feet, the average being about 10 feet, of which about one-half is quartz. The vein zone consists of individual quartz veins ranging from 1 inch or less up to 20 feet wide. It includes considerable breccia in places, especially along its west side or foot-wall. The vein zone is intersected by numerous transverse faults along which it has been dragged out of alinement. The most important of these faults so far intersected is that crossing the vein zone in an east-west direction to the north of the No. 1 shaft. The horizontal displacement along this dislocation is about 40 feet, the north side moving eastward with respect to the south. Along these transverse faults, veins filled with quartz, ankerite, and calcite occur.

The vein material of the main zone is mostly milk-white quartz in which pyrite occurs in scattered crystals or irregular grains or aggregates of crystals and grains. The only other ore minerals observed were specularite and gold. In the transverse fault zones the minerals commonly present are quartz, pyrite, calcite, ankerite, specularite, chalcopyrite, marcasite, and gold. A grey variety of mica forming part of the matrix enclosing cubes of pyrite up to three-fourths inch in diameter was also noted in one locality. The calcite was originally present in considerable masses, for caverns, from which the calcite had been dissolved away, up to 18 inches wide and 5 feet in diameter along the vein, occur in the transverse veins down to the eighth level, the lowest working at the time the writer last visited the property (October 1938). In one locality minute crystals of chalcopyrite were found on the walls of a cavity in the calcite. Chalcopyrite is also present in the transverse veins, associated with pyrite and specularite in aggregates up to several inches in diameter. The specularite occurs in lamellar aggregates forming the matrix around crystals of pyrite. Its contact with the pyrite crystals is fairly definite but not sharp, and so far as observed it does not penetrate the pyrite. The chalcopyrite, on the other hand, occurs in fractures traversing the pyrite. Quartz was also observed in zones cutting the pyrite. The gold is largely if not wholly associated with the pyrite and Mr. Rogers states that assays show that the amount of gold is higher in the transverse veins than in the main zone. M. H. Haycock, who examined specimens from a shipment of Powell Rouyn ore at the Ore Testing Laboratory of the Bureau of Mines microscopically, found the pyrite to contain grains of galena.[1] The amount of this mineral present is exceedingly small, however.

Southeast Vein Zone. In the western part of claim Bl. 61 there is a long, northwesterly trending outcrop of Powell granite, along the eastern margin of which a quartz vein or vein zone, dipping about 60 degrees to the northeast, is exposed at intervals at the surface or in prospect pits for about 800 feet. It lies southeast of and almost directly in alinement with the Main vein zone. The width of quartz in the zone ranges from 1 to 15 feet. According to the estimates of the company, the average width of gold-bearing vein material and mineralized rock at the surface for a length of 594 feet is 9 feet and the average width of quartz 5·3 feet. The average width of mineralization for a length of 750 feet from bore-hole intersections, at an average depth of 178 feet, is 14·3 feet, of which nearly one-half is quartz. The average for surface exposures and vein intersections combined is 11·9 feet, of which 6·4 feet is quartz. The minerals observed in the vein include pyrite, chalcopyrite, in aggregates up to one-half inch in diameter, and, in one locality, a rusty weathering carbonate, probably ankerite, cut by veinlets of quartz. The average grade of the mineralized zone for the length of 750 feet is estimated by the company to be 0·092 ounce.

Northwest Vein. In the northwestern part of claim Bl. 60 a series of trenches have been excavated for a length of about 850 feet. At the time the writer examined the property nearly all of these had caved in or were filled with water. Near the north end of the group, however, there is a pit in which a northwesterly trending, vertical, slickensided fault surface is exposed. A quartz vein 1 inch wide trending parallel the fault was noted at one point. According to a plan prepared by E. K. Fockler, a north-

[1] Investigations in Ore Dressing and Metallurgy; Mines Branch, Dept. of Mines, Canada, July to December 1934, p. 159.

south trending vein exposed in the trenches and intersected by diamond drill holes has been displaced about 120 feet to the northwest on the north side of this fault. Fockler also states this vein has been explored by trenching and shallow test bore-holes for a distance of 1,200 feet, and that the combined results of assays of surface samples and ten bore-hole intersections indicate an average grade of 0·198 ounce of gold a ton over an average width of 3 feet. Excluding surface results, the average grade obtained from intersections in nine of the above holes is 0·207 ounce a ton for an average core width of 3·2 feet over an explored length of 830 feet. In places within this length there are local ore shoots averaging from 0·3 to 0·5 ounce of gold a ton. It is noteworthy that this vein lies directly north of and almost in alinement with the main vein zone. Its dip is to the east.

Vein No. 4 (E). This is a northwesterly trending vein zone occurring in the south-central part of claim Bl. 58 to the east of the Powell diabase dyke. It is exposed at intervals in outcrops and prospect pits for about 400 feet. It consists of veins of quartz containing some pyrite, in a zone up to 4 feet wide in rhyolite. Fockler states that a length of 303 feet along the northern outcrop of this vein carries an average of 0·057 ounce of gold a ton across a width of 6·7 feet of quartz and wall-rock and 0·066 ounce across an average width of 3·5 feet of quartz. A section across the south outcrop of the vein and foot-wall 4·2 feet wide contained 0·057 ounce of gold a ton. This vein is almost in direct alinement with a zone of quartz veins outcropping in the Noranda Bl. 64 claim, and, as indicated on Map 453A, is probably its continuation.

Vein No. 5. In the northern part of claim Bl. 58, to the northwest of No. 3 shaft, there is a northeasterly trending andesite dyke, along the margin of which there is a zone of fracturing and shearing 3 to 4 feet wide in which veins of quartz occur. The total width of quartz exposed ranges from 2 to 4 feet. The quartz is a white variety and so far as observed contains no other mineral.

PRODUCTION, ORE RESERVES, AND FUTURE POSSIBILITIES

The production from Powell Rouyn property since it began operation in 1937 is as follows:

Year	Tons produced	Value
1937 (from Sept. 1)- 1938[1]	47,857	$ 251,541.00
1938-1939[1]	191,279	$1,056,441.91
1939–1940[1]	261,698	$1,330,517.67

[1] Year ending March 31.

The ore reserves, estimated by J. C. Rogers, on March 31, 1940, were:

—	Tons	Gold Ozs. a ton
Main vein	1,032,559	0·135
Southeast vein	175,000	0·084
Northwest vein	13,000	0·207

The future possibilities of the Powell Rouyn property are related (1) to the persistence and grade of the gold-bearing quartz veins at depth, and (2) the possibility of more extensive sulphide ore masses at depth associated with the mineralized fault zones in the northern part of the property. Although the greater part of the Main vein zone and all of the Southeast vein zone occur in granite, the horizontal persistence of the veins and the occurrence of the Southeast vein in the interior of the Powell granite mass indicate that the veins probably persist to considerable depth. It has been previously pointed out that the highly fractured condition of the quartz of the Main vein, the higher gold values in the transverse veins, the presence of so much more chalcopyrite and specularite in the transverse veins compared with the Main vein, the occurrence of tellurides, as at the Horne mine, in the veins, and the fact that the transverse veins trend east parallel to the Horne Creek fault with which the Horne gold-bearing sulphide ore almost certainly made its ascent from depth, suggest that the gold in all the veins came in by way of the transverse faults and from the same source and at the same time as that at the Horne mine.

In the northern part of the Powell Rouyn property there are, as previously described, at least three important faults, along which considerable chalcopyrite has been deposited. There are in these localities, therefore, channels along which copper-bearing emanations have made their ascent. If these faults at depth pass through breccia or other rocks having an easily permeable texture above which there as an impermeable rock that would serve as a barrier to the further ascent of the ore-bearing emanations, ore would almost certainly be present. The Brownlee rhyolite and rhyolite breccia, which lies to the south of the andesite in the northern part of the Powell Rouyn property, probably underlies the andesite at depth and its breccia phase is a favourable rock for ore deposition. Relationships in the northern part of the Powell Rouyn property, however, are complicated by faulting, so that it is somewhat uncertain what rocks are present along the faults or the depths at which they may occur. All that is known is that one of the three most important relationships necessary for the deposition of sulphide ore exists in the northern part of the Powell Rouyn property and the other two may be present.

PONTIAC ROUYN PROPERTY

HISTORY AND DEVELOPMENT

This property includes a group of five claims, Bl. 34 to Bl. 39, in the northwestern part of Rouyn township. It adjoins the Powell Rouyn group of claims on the north. The company owning the property, Pontiac Rouyn Mines, Limited, was organized in January 1927, but did not undertake its development until the summer of 1928 when surface prospecting operations were carried on in blocks 35, 36, and 38. In November 1933 operations were resumed, and during the following year thirty-seven diamond drill holes, having a total length of 9,089·9 feet[1], were bored. Of these, eighteen holes, totalling 4,540 feet, were drilled to intersect the No. 1 vein. The inclined shaft, which had been sunk to a depth of 50 feet

[1] Taschereau, R.: Bur. of Mines, Quebec, Ann. Rept. 1934, pt. A, p. 82.

in 1928, was deepened to a depth of about 250 feet and drifts along the vein extended both to the north and south at the 100- and 200-foot levels. At the time operations ended in the summer of 1935, the drifts on the 200-foot level had been driven 330 feet to the north and 60 feet to the south, and on the 100-foot level 20 feet to the north and 100 feet to the south. These workings were filled with water at the time the writer examined the property, so that all information regarding the deposit at depth except that obtained from the material seen in the dump has been obtained from a report and plans prepared by E. K. Fockler and H. S. Hicks.

GEOLOGY

The rocks outcropping in the Pontiac Rouyn property belong to the Powell-Pontiac andesite area and the overlying Héré Creek rhyolite belt. There is an area of rhyolite extending southwest from the shaft to Rosebury Lake, but this has obviously been brought into its present position by faulting. Along the northeast margin of the Powell-Pontiac andesite there is a band of stratified andesite tuff striking northwest and dipping steeply northeast. The strike and dip of this zone and the presence of pillows in the andesite having their tops towards the northeast prove that the andesite lies on the north limb of the Noranda anticline and that the Héré Creek rhyolite and rhyolite breccia overlie the andesite. In places, notably in the ridge southeast and south of the shaft and adjacent to the road to the shaft near the Powell later diabase dyke, the andesite has been highly silicified and on its weathered surface has numerous round protuberances. For this reason it is difficult to distinguish the altered andesite from rhyolite, and it may be possible that some of the rock mapped as rhyolite southeast of the shaft, especially near the andesite contact, is silicified andesite.

Numerous small faults cut transversely across the vein, but the important known faults in the property are the two northeasterly trending dislocations to the north and south of the shaft. The No. 1 fault, which lies to the south, is exposed for 150 feet in prospect openings and stripped areas in an outcrop on the east side of the road from the Macamic highway to the shaft. At this point there is a zone of sheared and broken rock up to 15 feet wide mineralized with chalcopyrite, pyrite, and quartz. The No. 2 fault, which underlies the Héré Creek depression to the north of the shaft, is not exposed at the surface. Its presence is indicated by the manner in which the contact of the andesite and the rhyolite has been apparently displaced horizontally to the northeast about 2,000 feet on the south side with respect to the north. It is noteworthy that to the northwest of the No. 2 fault the andesite-rhyolite contact again turns abruptly to the southwest. This abnormal relationship suggests that another northeasterly trending fault, although not indicated on Map 453A, may be present at this point.

SULPHIDE ZONES AND GOLD-BEARING QUARTZ VEINS

The most important sulphide zone in the Pontiac Rouyn property, so far as known, is that associated with the No. 1 fault. In the outcrop adjacent to the east side of the road to the shaft a zone or zones of broken and sheared rock mineralized with abundant chalcopyrite, some pyrite, and considerable quartz is exposed for 150 feet in prospect pits and stripped areas. The mineralized zone consists of irregular aggregates and lenticular veins of chalcopyrite, from 1 inch up to 5 feet wide, distributed through a zone up to 15 feet wide. The proportion of chalcopyrite in the aggregates and veins may amount to one-half or more, with almost solid chalcopyrite in zones up to 1 foot wide in places. The chalcopyrite can be seen to occur in veinlets or zones intersecting the quartz. Pyrrhotite was not observed to be present, but pyrite is abundant in places. Under the microscope the pyrite is seen to occur as included crystals, and round grains within the chalcopyrite. A few rounded areas of sphalerite were also observed to be present along the margin of the pyrite grains or near by.

In an outcrop of stratified andesite tuff on the east side of the Powell later diabase dyke and about 100 feet north of the road to the Pontiac Rouyn shaft there is a vertical zone of schistosity 2½ feet wide, striking a few degrees north of east, in which quartz mingled with pyrite and chalcopyrite has been deposited in veins and zones up to 1 foot wide. The proportion of chalcopyrite is not large, however. The exposed length of the zone is about 50 feet.

The most important ore deposit so far discovered in the Pontiac Rouyn property is the vein zone on which the No. 1 shaft has been sunk. This zone of gold-bearing quartz veins trends in a northwesterly direction and dips about 60 degrees to the northeast. It has been followed in underground workings and in diamond drill intersections for 660 feet. The width of quartz ranges from veinlets an inch or less wide up to a maximum total of 8 feet. The average, however, excluding mineralized wall-rock, is probably about 3 feet. The similarity of this vein zone in strike and dip to the Northwest, Main, and Southeast vein zones in the Powell Rouyn property, all of which are in alinement with one another, suggests that it was originally located on the continuation of the Northwest Powell Rouyn vein zone and has been displaced about 1,000 feet to the eastward by faulting.

The material in the dump from the shaft includes some quartz diorite, considerable albite granite, similar lithologically to the Powell granite, buff weathering carbonate containing aggregates of chalcopyrite, and white quartz in which pyrite is disseminated in places. Specularite was also noted in filling fractures in the granite. According to the plan of the 200-foot level an acid intrusive forms the hanging-wall of the vein for about 500 feet in the north drive. This is almost certainly the albite granite seen in the dump and indicates that an offshoot of the Powell granite occurs at this point. It is possible, therefore, that at depth this zone, like the Powell Rouyn Main and Southeast vein zones, intersects granite. H. S. Hicks states that the vein contains pyrite, chalcopyrite, and a small amount of a flaky black mineral, probably graphite.

Both at the surface near the shaft and in the workings, as shown on the plan of the 200-foot level, the Pontiac Rouyn vein zone is interrupted by numerous transverse faults ranging in strike for the most part from east-west to northeast. The horizontal displacement on most of these faults is small, ranging from 1 to 5 feet. South of the shaft at the surface the vein is displaced nearly 40 feet to the east on the north side of a transverse fault. E. K. Fockler states, however, that the displacement on this fault on the 200-foot level is only 20 feet. The presence of quartz-carbonate veins carrying chalcopyrite in the Pontiac Rouyn workings suggests that these, like those in the Powell Rouyn property, may lie along the transverse faults or fractures formed at the time of the transverse faulting. It is also noteworthy that in the Pontiac Rouyn vein zone where the transverse faults are numerous, the gold values are high. The estimate of ore so far developed, according to the annual report of the company, is 160,000 tons, of which 72,000 tons averages 0·233 ounce of gold a ton.

QUEBEC COPPER CORPORATION

Four groups of claims, blocks 24 and 25, blocks 34 to 36, and blocks 27 to 33, in the eastern part of Duprat township, and blocks 80 and 81 in the western part of Dufresnoy township, formerly owned by the Quebec Copper Corporation, occur in Noranda district. In most of these the development work performed by this company consisted only of surface trenching. In block 34 two prospect pits in rhyolite were excavated, but the only evidence of mineralization seen in these was some fragments of vein quartz an inch wide in the dump. In the andesite above the rhyolite contact about 400 feet northeast of this point a vein of magnetite one-half to one inch wide is exposed for 10 feet. In blocks 35 and 81, where the Powell diabase dyke crosses the Duprat-Dufresnoy line, some trenches, a prospect pit, and a surface crosscut were excavated, and 1,500 feet of diamond drilling, in nine holes, was bored.[1] The rock adjoining the diabase dyke in this locality is andesite. Some chalcopyrite occurs in fractures cutting the andesite exposed in the pit and surface crosscut, according to R. H. Taschereau. In the northeast part of claim 36, to the east of the Quebec Copper Corporation cabins, the rhyolite of the Amulet belt is intersected by fracture zones up to 3 inches or more wide filled with specularite.

NORTH WAITE GROUP

This group consists of seventeen claims, A3002 to 3005, A3458, and A3459 in Dufresnoy township, and A3007 to 3009, A2966 to 2970, and A3810 in Duprat township. These include the territory adjacent to and south of Waite Lake, and are owned by the North Waite Mining Company, Limited. The rocks occurring in the property are lavas belonging to the following belts, named in succession from west to east: (1) Amulet rhyolite and rhyolite breccia, west arm of Waite Hills andesite belt, Waite Lake rhyolite breccia, Waite Lake siliceous rhyolite, and the east arm of Waite Hills andesite belt; (2) the Dufresnoy quartz diorite; and (3) the Powell late Precambrian diabase dyke. Development work so far performed on the claims consists of the excavation of some surface trenches and small prospect openings. On the northwest edge of the most southerly outcrop in which the contact of the Waite Hills andesite and the Waite Lake rhyolite breccia is shown there is a pit 12 feet long from north to south and 6 to 8 feet wide from east to west. In the north and east faces, the only faces exposed, there is pillowed andesite, rusty weathering from the presence of disseminated pyrite and pyrrhotite up to a height of 10 feet where the contact with the Waite Lake rhyolite breccia occurs. Along the contact of the Waite Lake siliceous rhyolite and the east arm of the Waite andesite belt the andesite is everywhere considerably altered and in places rusty weathering from the presence of disseminated pyrite.

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[1] Taschereau, R. H.: Min. Oper. in the Prov. of Quebec; Dept. of Highways and Mines, Quebec, 1928, pp. 88, 97–98.

BEAVER MOUNTAIN COPPER MINES, LIMITED

This property includes six claims in Dufresnoy township, two, Nos. A6463 and A6464, situated about 1,000 feet to the south, and four, Nos. A2797 to A2800, about 1,500 feet to the northwest, of Beaver Hill. About 1,000 feet of diamond drilling was bored under option on these claims in 1930.

In the north group of claims prospect pits have been excavated at intervals of 30 to 70 feet for a length of about 250 feet along the northwest face of an irregular area of andesite. These openings range in size up to a maximum length along the face of 25 feet, a maximum width of 8 feet, and a maximum depth of 8 feet. The rock exposed in the pits is pillowed andesite in which pyrite, pyrrhotite, and some chalcopyrite occur disseminated and in aggregates up to 8 inches in diameter. Some of the pyrite and pyrrhotite occur in round or elliptical-shaped areas and are probably amygdules. Near the top of the westward facing scarp that commences a few hundred feet north of the northern exposure of the mineralized zone, just described, a band of rusty weathering, pillowed andesite 20 feet wide is overlain by a bed of laminated chert 6 inches to 1 foot wide. The chert fills in the inequalities of the underlying, pillowed surface. It is rusty weathering from the presence of disseminated pyrite and pyrrhotite. The proportion of chalcopyrite in this mineralized zone is much too small for the deposit as exposed to be of value, but the presence of ore minerals shows that ore-bearing emanations penetrated along the flow contact and that a channel of ascent, almost certainly a fault, for these emanations must be present nearby. As the flow contact dips to the east, this fault probably lies in that direction.

In the southern group of claims five shallow pits and surface crosscuts have been excavated in two outcrops lying east of the Beaver Hill trail and south of the main rock area composing Waite Hills. These openings range from 30 to 70 feet long, 2 to 12 feet wide, and 1 to 5 feet deep. The andesite in which the pits and crosscuts occur is intersected by numerous fractures and has a bleached and altered appearance on its weathered surface. The only mineral of the sulphide ore association observed in the pits and crosscuts was pyrite. This occurs in seams and in aggregates. It was no doubt because of the rusty weathering of this pyrite that the prospect openings in this locality were excavated.

RHYOLITE ROUYN GROUPS

The Rhyolite Rouyn property includes three groups of claims in Duprat township, to the southeast of Lake Duprat. The numbers of the claims are: group 1, blocks D to I; group 2, blocks J to M; and group 3, 75 to 79, 110, and 125 to 136. Groups 1 and 2 were originally owned by a company known as Duprat Mines, Limited, but were transferred in exchange for stock to Rhyolite Rouyn Mines, Limited, in 1927. The development work so far performed on these groups of claims includes surface prospecting by Duprat Mines, Limited, during the summers of 1927 and 1928, and by Rhyolite

Rouyn Mines, Limited, in 1928 and 1937. Ten diamond drill holes were also put down by Rhyolite Rouyn Mines, Limited, during the summer of 1928,[1] and five holes in 1937. Except for diamond drilling in the territory west of the Waite-Ackerman-Montgomery mine, most of the development work was confined to the southern part of the property, to the east of Lake Fourcet.

The seven most westerly claims of the Rhyolite property are outside Noranda district. The remaining claims lie in the western part of Amulet area and are occupied chiefly by the Rusty Hill andesite and the Amulet rhyolite and rhyolite breccia, but also include the north end of the Bedford area of rhyolite and rhyolite breccia, a small part of the marginal facies of the Flavrian Lake granite batholith, the Fourcet Creek diorite mass, and, at the north end of the property (claim J), a single outcrop of the Waite andesite belt. The property thus extends across most of the Amulet and Waite anticlines and the synclines between these anticlines. Part or possibly all of the faults that occur at the Waite-Ackerman-Montgomery mine, although not exposed, cross the northern claims. Several small faults, most of which are indicated on Map 454A, also occur in the southern part of the property. Along one of these, trending about north-south, two dykes of rhyolite porphyry are faulted about 80 feet, and along another the contact of the Rusty Hill andesite and the Amulet rhyolite and rhyolite breccia has been dislocated 40 feet.

The chief deposit so far discovered in the property occurs in the Rusty Hill andesite about 1,000 feet to the east of the northeast end of Lake Fourcet. In this locality a north-northwest trending fault-vein zone, from a few inches to 20 feet wide, is exposed at intervals in pits and stripped areas for 600 feet. This consists of quartz breccia matrix, and veinlets of quartz in which chalcopyrite is disseminated in places. The total width of quartz in the zone ranges from 1 to 2 feet and the average proportion of chalcopyrite from nil to about 10 per cent. An assay of an average sample of the quartz containing chalcopyrite from pit 3 gave: silver 0·95 ounce, gold 0·03 ounce, copper 4·80 per cent. This copper content is equivalent to 13·6 per cent of chalcopyrite, but the sample represented only the part of the vein about 10 inches wide in which chalcopyrite was present. Some diamond drill holes were put down to intersect the deposit at depth, but the results presumably did not show any change from the surface and hence did not warrant further work. More detailed descriptions of the pits and stripped areas on the zone, numbered from north to south, are given in the following table.

On the northwest edge of the group of outcrops at the northwest end of Rusty Ridge, four pits or surface rock crosscuts have been excavated, partly in andesite and partly in intrusive rhyolite porphyry. In one of these openings there is a northeasterly trending fracture zone about 1 foot wide. The fractures of this zone have been filled with veinlets of a carbonate

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[1] Dufresne, A. O.: Min. Oper. in Prov. of Que.; Dept. of Col., Mines, and Fish., 1925, p. 123, 1926, p. 123.

Dufresene, A. O., and Taschereau, R.: Min. Oper. in Prov. of Que.; Dept. Col., Mines, and Fish., 1927, p. 117.

Taschereau, R.: Min. Oper. in Prov. of Que.; Dept. of Highways and Mines, 1928, pp. 88, 89.

TABLE XI

Number	Pit or stripped area	Dimensions	Description
1	Pit	10 feet long, 8 feet wide, 10 feet deep.	Bottom covered. Fragments of vein quartz up to 1 inch wide in dump. Some disseminated pyrite.
2	Stripping	25 feet long.	Very irregular veinlets of quartz, most of them one-quarter inch wide or less. One veinlet 1 to 2 inches wide.
3	Pit and stripping	A shallow excavation 3 to 12 feet wide and 1 to 3 feet deep. Total length of pit and stripping 30 feet.	A vertical or nearly vertical zone of quartz veins and breccia 5 feet wide sharply defined on west, indefinite on east. Veins concentrated along west margin of zone. Average total width of quartz in whole zone about 1 foot. Chalcopyrite in zones from 3 inches to 1 foot wide. Average chalcopyrite content in total width of quartz estimated less than 10 per cent.
4	Pit	30 feet long, 5 to 8 feet wide, 3 to 7 feet deep.	Main vein 3 inches to 2 feet wide. Chalcopyrite occurs in veins for an average width of about 10 inches. An average sample assayed by J. A. Rivington, Mines Branch, contained silver 0·95 oz., gold 0·03 oz., and copper 4·80 per cent. West wall of vein slickensided.
5	Pit	20 feet long, 8 feet wide, 8 feet deep.	A zone of quartz veins and breccia with a quartz matrix, 2 feet wide. Some disseminated chalcopyrite. East wall slickensided.
6	Stripping and outcrop	150 feet long.	Quartz veins for a width of 20 feet. Abundant in the west 10 feet.
7 South end of zone exposure	Pit	6 feet long, 3 to 5 feet wide, 3 feet deep.	Quartz veins and breccia. A zone 3 feet wide. Disseminated chalcopyrite, about 5 per cent.

(either calcite or ankerite) up to three-fourths inch wide. The only other mineral observed in this locality was pyrite, disseminated, in aggregates, and filling small fractures. Two diamond drill holes were put down from one of the pits.

The territory included in the Rhyolite Rouyn groups of claims originally attracted attention because of its proximity to the ore deposits on the adjacent Amulet and Waite-Ackerman-Montgomery mines. The factors favourable to the discovery of ore deposits of the sulphide type in the areas are, the abundance of replaceable breccia in the rhyolite and in places in the andesite, and the probable presence of unexposed faults in the northern part of the property and in the depression north of Lake Fourcet. The unfavourable factor is the absence of good impermeable barriers except possibly beneath the lower contact of the Rusty Hill andesite belt. The most favourable locality for further exploration is probably in the depression north of Lake Fourcet, especially if breccia is present in the rhyolite beneath the Rusty Ridge andesite at this point. It is also probable that the territory west of the Waite-Ackerman-Montgomery mine has not been fully explored by the diamond drilling so far done.

BEDFORD GROUP

This property includes nine claims, Nos. A1949 to 1953, 2372 to 2374, and 3992, in the southeast part of Duprat township. It adjoins the Amulet on the west. Development work in these claims was carried on by the Consolidated Mining and Smelting Company during 1926 under an option from Mr. Patrick O'Leary, by whom they were orginally staked. This was largely confined to the ridge of rock that extends in a northwesterly direction across the corner of claims A1915, 1952, 1953, and 3992, and included eleven surface crosscuts and trenches from 50 to 175 feet long, 2 to 12 feet wide, and 3 to 10 feet deep, and three diamond drill holes having a total length of 733 feet. Most of the crosscuts and trenches trend east-west.[1]

The rocks of the main rock ridge, except for two masses of andesite at its southeast end, consist of rhyolite and rhyolite breccia. The breccia is confined largely to the northeastern margin of the ridge and consists of angular to subangular, pale grey weathering fragments of pale grey, fine-grained, flint-like rhyolite in a grey-green matrix that is rusty weathering from the presence of disseminated pyrite. As it is known that the tops of the lava flows in this locality face to the eastward, this breccia underlies the andesite that outcrops at the southeast tip of the ridge and, therefore, forms the top of a flow. To the westward across the ridge the coarse breccia gives place first to rhyolite in which scattered angular depressions up to one-half inch in diameter formed by weathering occur, and then to massive rhyolite in which there are areas characterized by mesh weathering. All of this rock is rusty weathering in patches and zones. At the northwest extremity of the main rock ridge and in one of the small scattered outcrops adjoining the main ridge on the southwest, fine, spherulitic structure

[1] Taschereau, R. H.: Rept. Min. Oper. in the Prov. of Que.; Dept. of Col., Mines, and Fish., Que., 1926, pp. 122-23.

was noted. In the western part of the property the highly siliceous, coarsely micropegmatitic eastern edge of the Flavrian Lake batholith occurs.

In the rock crosscuts and pits that have been excavated in the rhyolite and rhyolite breccia pyrite is seen to be present in scattered aggregates up to 6 inches in diameter, in disseminated grains and crystals (chiefly cubes), and in seams and veins up to an inch or more wide. The proportion of pyrite in the rock, as a whole, however, except in three localities where it was estimated to form not less than 5 per cent nor more than 10 per cent of the rock, is small. The most extensive of these more highly pyritic masses occur in the southwest corner of claim A1951. At this point both chalcopyrite and sphalerite in aggregates and zones up to one-half inch wide were noted, but the amounts of these minerals present are too small to constitute any considerable masses of ore. The rhyolite and rhyolite breccia adjacent to the deposit on microscopic examination was found to consist almost wholly of quartz and chlorite, the latter mineral resulting, presumably, from the alteration of the plagioclase.

In the Flavrian Lake micropegmatitic granite occurring in the western part of claim A1953, northeasterly trending veins of quartz in zones up to 15 feet wide were noted. Two of the most extensive of these zones are indicated on the Amulet map. The individual veins of the zones range from half an inch or less to 3 inches wide, and the total width of quartz in the zones from 1 to 2 feet. No gold or other ore mineral was observed in these.

The mineral deposits so far discovered in the Bedford group of claims are not of workable grade. The future possibilities of the property, therefore, depend on the possible presence of undiscovered ore masses. The easily permeable rhyolite breccia with which most of the mineralization in the property is associated almost certainly extends both to the north and south beyond the main rock ridge. It is also possible that the andesite that outcrops at the southeast end of the main rock ridge continues beneath the drift considerably beyond the extent indicated on the Amulet map, and, as at the Amulet mine, affords a barrier beneath which ore might occur. In the exposed rock outcrop, however, no evidence of a fault that could afford a channel of ascent for ore-bearing emanations was observed. It is possible, nevertheless, that a fault or faults could occur in the adjacent valleys, and in that case ore deposits could be present.

CORONA GROUP

This group includes thirteen claims, Nos. A11441 to A11473 or Blocks 40 to 53 in the southeast part of Duprat township. They adjoin the Duprat-Beauchastel line near Corona Creek. Development work was carried on in the group by Corona Mines, Limited, in the latter part of 1926, in 1927, and in the early part of 1928. This included a geophysical survey, surface prospecting by trenches and prospect pits, and six diamond drill holes having an aggregate length of 2,000 feet. The company reported that some disseminated chalcopyrite and pyrite were intersected but "not in sufficient quantity to be of economic importance."[1] No further work was performed on the property by the company and the claims were allowed to revert to the Crown.

Rock exposures in the Corona group are confined entirely to the northern claims. In the western part, these belong to the eastern edge of the Flavrian Lake granite batholith, in the central part to the Bedford area of rhyolite and rhyolite breccia, and in the eastern part to the Amulet Hills andesite belt. In the southern part, where no outcrops occur, the bedrock is probably andesite. Near the western margin of claim A11465, and about 200 feet northwest of the andesite contact, there are two small prospect pits about 20 feet apart on a northeasterly trending fracture zone in rhyolite. The southwesterly of the two pits is 20 feet long, 10 feet wide, and up to 4 feet deep, the northeasterly pit is 5 feet in diameter and 3 feet deep. In these openings and in the adjacent rock outcrops a mineralized zone 5 feet wide, consisting chiefly of disseminated cubes of pyrite, is exposed for 50 feet. Along the western edge of this zone there are two calcite veinlets one-quarter inch wide. Chalcopyrite in aggregates and zones up to one-half inch wide were also noted adjacent to these.

About 800 feet north of these pits in claim A11463 there is an east-west trending mesh of quartz veins, 10 feet wide, exposed for 50 feet. The average total width of quartz in the zone is about 1½ feet. No gold or other ore minerals were observed in the quartz.

It is noteworthy that the pyrite and chalcopyrite in claim A11465 occur in a zone of rhyolite and rhyolite breccia close to the contact of the overlying andesite of the Amulet Hills belt. The fracture zone in which the ore minerals occur is not large enough to afford a channel of extensive mineralization, but the presence of the chalcopyrite and pyrite suggests that more extensive deposits might occur in this locality if a sufficiently large fault were present. No evidence of such a fault was observed in the exposed rock outcrops, but it is possible that one could be present beneath the drift cover.

McDOUGALL PROPERTY

This property includes two groups of claims, A1431 to A1437, T605, A2022 to A2028, A2221 to A2222, and A1677 to A1678, all lying along the Duprat-Dufresnoy line south of the Amulet mine. Development work was carried on by McDougall Mines, Limited, in 1926 and 1927. This included six diamond drill holes, numerous prospect pits and trenches, an inclined shaft 120 feet deep, and 850 feet of drifts at the 100-foot level.[2] The property is now controlled by Ventures, Limited.

The rocks outcropping in the area consist mainly of Amulet rhyolite and rhyolite flow breccia and the Amulet Hills andesite. A northeasterly trending dyke of quartz diorite crosses the property near the shaft, and dykes of rhyolite (quartz-albite) porphyry and andesite occur in places. The deposits in the property belong to three classes: (1) veins of quartz and chalcopyrite along the northwesterly trending McDougall fault, which

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[1] Taschereau, R.: Min. Oper. in Prov. of Quebec; Dept. of Col., Mines, and Fish., 1926, p. 123; 1927, p. 117; 1928, pp. 86–88.

[2] Report of Mining Operations in the Province of Quebec, 1927, pp. 123–4.

cuts off the Amulet rhyolite and rhyolite breccia on the south; (2) mineral aggregates in the rhyolite adjacent to the overlying andesite contact similar in relationship to ore deposits of the Amulet property; and (3) east-west trending, mineralized shear zones, probably formed along faults subsidiary to the McDougall fault.

Prospect pits have been excavated at intervals southeasterly from the shaft along almost the entire exposed length of the McDougall fault, a distance of about 2,000 feet. These openings range up to 40 feet long along the fault, 25 feet wide tranverse to the fault, and 10 feet deep. In this distance wherever the fault is exposed a zone of veins and brecciated rock dipping 50 degrees to the northeast is present. The vein material consists mostly of quartz, but chalcopyrite in varying degrees of concentration up to almost solid lenticular masses 2 feet wide and 8 feet long is also present. The individual veins of quartz range for the most part from one-half inch to 6 inches wide. The aggregate width of vein material probably does not average more than 2 feet, and the total average width of the zone 5 feet. Slickensiding was noted in the wall of one of the pits.

The mineral deposits along the rhyolite breccia-andesite contact where exposed consist chiefly of pyrite disseminated and in aggregates and chalcopyrite filling fractures or in aggregates. The vein material in the east-west trending zones of shearing, as along the McDougall fault, consists mainly of quartz and chalcopyrite. More detailed descriptions of the various openings along the contact and in the east-west zones of shearing and faulting are included in the following table:

TABLE XII

Contact of Amulet Rhyolite and Rhyolite Flow Breccia with Amulet Hills Andesite

(Pits numbered from east to west)

Number of pit	Location	Dimensions	Wall-rock	Mineralization	Relations
1	500 feet southeast of the south end of Turcotte Lake.	15 feet long, 3 to 6 feet wide, 10 feet deep.	Rhyolite flow breccia.	Pyrite in disseminated cubes and aggregates up to $\frac{1}{2}$ to 2 inches in diameter and 1 to 3 inches apart; width of mineralized zone 10 feet.	Below zone of bedded chert on contact dipping 45 degrees east and striking north 67 degrees east.
2	400 feet east of McDougall Lake (no name on Map 454A).	40 feet long, 4 to 8 feet wide, 3 to 5 feet deep.	Rhyolite.	Pyrite disseminated and in aggregates in north end. Chalcopyrite in fractures and in aggregates possibly 1 per cent copper in a mass 18 feet by 6 to 12 inches by 4 feet.	In Amulet rhyolite near andesite contact.
3	At about 2,000 feet west of the McDougall shaft.	Shaft.	Rhyolite.	Zone of chalcopyrite in a rusty weathering fracture zone in rhyolite, 3 to 6 inches wide. Blocks of chalcopyrite up to 6 inches in diameter in dump.	Near contact of Amulet Hills andesite.

East-west Trending Zones of Shearing and Faulting

(Numbered from north to south)

1	1,500 feet west-northwest of Turcotte Lake.	8 feet long, 2 to 5 feet wide, 6 to 10 feet deep.	Rhyolite.	Zones of shearing and fracturing 1 to 2 feet wide, including chalcopyrite in lenses and aggregates up to 4 inches wide and 5 feet long. Length of mineralized zone 40 feet.	Zone of shearing dipping 75 degrees north to vertical crossing hill for 900 feet, 6 to 18 inches wide, quartz with chalcopyrite in places.
2	110 feet south of McDougall Lake.	6 feet long, 6 feet wide, 5 feet deep.	Massive andesite.	Zone of fracturing and shearing 18 inches to 1 foot wide. Chalcopyrite exposed in zones up to 6 inches wide, almost solid in places. Some pyrite and quartz also present.	In zone of shearing exposed at intervals for 500 feet up to 2 feet wide. Some chalcopyrite and quartz in places.
3	Adjacent to the McDougall shaft.		Rhyolite breccia.	Fracture zone 6 inches to $2\frac{1}{2}$ feet wide dipping 50 degrees north. A lens of almost solid chalcopyrite 2 feet wide and 8 feet long.	Presumably the continuation of vein followed in shaft.
4	400 feet east of McDougall shaft.	16 feet long, 10 feet wide, 4 to 5 feet deep.	Rhyolite breccia.	A fracture zone 2 to $2\frac{1}{2}$ feet wide filled with quartz containing chalcopyrite. Dip of zone 60 degrees north, chalcopyrite abundant.	Zone outcrops at intervals with a width of 6 inches to $2\frac{1}{2}$ feet for 600 feet.

JOLIET-QUEBEC (BROWNLEE) PROPERTY

This property is a combination of several formerly separate groups of claims in Rouyn township, along the Macamic highway north of Noranda. A geophysical examination of the combined claims was made in 1939 and some diamond drill holes have been bored, but up to the time the writer completed his examination of the district in 1938 most development work in the property was carried on in claims Bl. 98 and M.L. 1768, formerly owned by Brownlee Mines, Limited. Claim Bl. 98 adjoins the Horne property on the north, but is separated from it geologically by the Horne Creek fault. Development work was carried on at intervals in the two claims from 1924 to 1933. This included over 18,000 feet of diamond drilling, about 3,500 feet of trenches and surface crosscuts, and numerous pits or shafts up to a maximum depth of 51½ feet.

The rocks occurring in the property, except for intrusions of diorite, quartz diorite, and diorite porphyry, consist of massive rhyolite and rhyolite flow breccia divided in its western part into two belts by a band of stratified andesite tuff, the eastern end of the Powell-Pontiac andesite belt. The rhyolite and rhyolite flow breccia lying south of and structurally below the andesite tuff has been designated the Brownlee, and that lying to the north and structurally above the andesite tuff the Héré Creek belt. The rhyolite breccia throughout considerable areas contains pyrite disseminated, in aggregates, and filling small fractures. In places in the breccia chalcopyrite occurs either in aggregates up to one-half inch in diameter or filling irregular fractures or fracture zones. In the dump from a shaft in the northwest corner of claim Bl. 98, fragments of granular quartz 2 inches wide traversed by irregular veins of chalcopyrite were observed. The total aggregate width of chalcopyrite was about one-half to three-fourths inch. Chalcopyrite is especially common in the area of chloritized rhyolite breccia lying southwest of diamond drill holes Nos. 12 and 13 in the southwestern part of claim M.L 1768. It is nowhere sufficiently abundant, however, so far as known, to be ore. Average samples of the pyritic rhyolitic breccia were taken by the writer from surface crosscuts in the east-central and northwest parts of claim Bl. 98 and in the southwestern part of claim M.L. 1768. These, according to assays made by J. A. Rivington of the Bureau of Mines, contained silver ranging from a trace to 0·20 ounce a ton, but no gold.

DON ROUYN PROPERTY

This property includes a group of claims, Blocks 140 to 144, and 178 to 180, lying adjacent to, but chiefly north of, the Kirkland Lake highway to the west of the Chadbourne group and southwest of the Powell Rouyn mine. A company, known as Don Rouyn Gold Mines, Limited, acquired these claims in 1925 and carried on an intensive program of development work until May 1929, when operations were discontinued and have not since been resumed. The work performed included: (1) 8,500 feet of diamond drilling; (2) several thousands of feet of surface rock cuts and trenches; and (3) numerous prospect pits, and a vertical shaft 100 feet deep from which crosscuts were driven 91 feet to the south and 86 feet to the north. A drift was also driven 82 feet to the east from the north crosscut.

The rocks exposed in this area consist mainly of the Powell granite, in which masses or bands of quartz diorite and volcanic rocks, chiefly rhyolite, are included. Some dykes of rhyolite and andesite also intrude the granite. The shaft is stated to have been sunk on a narrow, east-west trending, vertical vein of quartz. Aggregates of chalcopyrite occur in the quartz and in the wall-rock near by. In places in the property, partly along inclusions of rhyolite, partly along dykes of andesite, and partly in the granite itself, there are vertical east-west trending zones of shearing, slickensiding, and faulting, almost certainly faults subsidiary to the Horne Creek fault, which lies only a few hundred feet to the south. In these zones veinlets of quartz and ankerite with some chalcopyrite and pyrite have been deposited. The granite adjacent to the zones has been so highly chloritized that the rock has a black appearance, and if it were not for the presence of the quartz of the granite, which has resisted alteration, the original composition of the rock would never be suspected. The zones of deformation range in width up to 5 feet. The chalcopyrite and pyrite veinlets and aggregates are from ½ inch to 6 inches wide. There are places in the zones where as much as 1 per cent copper may be present for a width of 3 or even 4 feet, but the masses of this kind are not sufficiently continuous to constitute a large deposit even of this grade.

QUEMONT PROPERTY

In 1926 an option was taken by United Verde Extension Mining Corporation on six claims, M.L. 1733, 1734A, 1734B, 1745, 1796, and T361, known as the Murray group, lying north of the Horne mine and east of the Brownlee property. In 1926 a vertical shaft was sunk to a depth of 235 feet and 3,000 feet of lateral workings driven at the 215-foot level. Over 5,000 feet of diamond drill holes were drilled from this level. In April 1928 the option was dropped.[1] In 1929 a 90 per cent interest in the property was acquired by the Mining Corporation of Canada, and shaft sinking was resumed. Early in 1929 the Mining Corporation of Canada transferred its interest to a subsidiary company, Quemont Mining Corporation. In that year the shaft, which had attained a depth of 440 feet, was deepened to 926 feet and levels driven at 500 and 905 feet. From these diamond drill holes were bored. Work was discontinued in 1930.

The rocks intersected in the workings consist chiefly of rhyolite intimately intruded by multiple dykes and masses of quartz diorite, and the Noranda north-south dyke of later diabase. The workings cross the Horne Creek fault, which according to the plans of the workings includes several faults in a zone of broken rock 250 feet wide. In the southeastern part of the property to the south of the Horne Creek fault the rhyolite contains varying proportions of disseminated pyrite. An average sample of the parts of the drill core containing abundant pyrite, assayed by A. Sadler of the Bureau of Mines, contained 0·17 ounce gold and a trace of silver a ton. An average sample of core in which pyrite was sparingly present carried 0·02 ounce of gold a ton. This rock lies directly northwest of the Horne G. or No. 7 deposit, and is obviously a deposit of the same type or its continuation.

[1] Report on Mining Operations in the Province of Quebec, 1927, pp. 105–6.

BAGAMAC PROPERTY

This property includes two claims, Blocks 41 and 42, lying within and west of the town of Rouyn, owned by a company known as Bagamac Mines, Limited, originally Bagamac Rouyn Mines, Limited, organized in 1926. The rocks exposed in the property consist of rhyolite, rhyolite flow breccia, and andesite intruded by quartz diorite, albite granite, and later diabase. The dykes or masses of albite granite occur locally within the diorite and are believed to be a phase of this intrusive. The outstanding structural feature of the Bagamac is the fault that crosses the property for its entire length from east to west. The displacement of this fault is unknown, but the different varieties of rocks occurring on its opposite sides indicates that it is considerable. The outcrops of the fault are marked by a vertical, schistose zone with parallel or branching zones of fracturing up to 25 feet wide. The rocks adjacent to the fault have been chloritized and impregnated with carbonate.

Development work in the property includes: (1) numerous trenches and prospect pits, most of which are now filled in; (2) the Bagamac shaft; and (3) about 11,218 feet of diamond drilling.[1] Most of the trenches and prospect pits were excavated either in the northeast part of Block 41, now the central part of the town of Rouyn, or along the Bagamac fault. In the openings along the Bagamac fault, zones of disseminated pyrite up to 18 inches wide, and aggregates or veins of quartz and rusty weathering carbonate were noted in places. The company reports that gold was found in some of the prospect pits, but not in a deposit of workable grade and extent. The vertical shaft was filled with water at the time the writer examined the property. R. H. Taschereau, Inspector of Mines, states that it is 210 feet deep with 110 feet of lateral workings at the 200-foot level.[2] The material in the dump includes fragments of vein quartz, chloritized rhyolite schist, sericitized rhyolite schist, and diorite. The diorite occurs at the end of the dump and probably came from the end of a crosscut at the 200-foot level. The highly altered and schistose condition of the rhyolite in the dump indicates that the shaft is in the Bagamac fault zone. The diamond drill holes put down in the property intersected the same rocks and about the same mineral occurrences as those found at the surface except that in a hole put down northeasterly beneath Noranda Lake a pyritic deposit in schist was intersected from 740 to 992 feet. This suggests that a fault occurs beneath Noranda Lake, but whether this is a branch of the Bagamac fault or a wholly separate fault is unknown.

DASSERAT GROUP

This property includes two claims, Blocks 8 and 9, lying along the south shore of Lake Trémoy. The eastern part of Rouyn townsite is in Block 8. Surface development work in the property was carried on in 1924 by Dasserat Rouyn Mines, Limited, and the diamond drilling in 1934 and 1935 by Norlake Mining Corporation, Limited. The rocks in the property

[1] Report on Mining Operations in the Province of Quebec; Que. Bur. of Mines, 1928, p. 73; 1932, p. 75; and 1934, p. 74.

[2] Mining Operations in the Province of Quebec; Que. Bur. of Mines, 1933, p. 95.

consist chiefly of rhyolite intruded by quartz diorite, the main mass of which grades into albite granite along its northern margin. The Noranda north-south dyke of later diabase crosses the eastern part of Block 8. The fault zone that crosses the Bagamac property breaks up into two faults, with a subsidiary branch to the northeastward in the western part of the Dasserat group. There are no outcrops in the eastern part of the property, but the presence of chloritized zones of schistosity in diamond drill cores suggests that it may continue eastward to the south of Lake Trémoy.

All of the trenches and all but one of the prospect pits excavated in the Dasserat group had caved in at the time the writer examined the property. In the most easterly area of albite granite shown on Map 453A there is a pit 60 feet long, 3 to 6 feet wide, and up to 5 feet deep, partly filled with debris. In this the wall-rock is impregnated with carbonate and pyrite across an east-west trending zone 5 feet wide and dipping 60 degrees to the south. Pyrite is fairly abundant in aggregates and seams. It is in this zone that gold was first discovered in the Dasserat group. Numerous diamond drill holes put down in the group intersected zones of schistose rhyolite highly chloritized and impregnated with pyrite. The Norlake Mining Corporation reports that low gold values were present in the diamond drill cores, but they were not sufficiently high to be of workable grade.

GLENWOOD PROPERTY

The Glenwood Mining Syndicate owns two claims in Rouyn township, M.L. 1826 and Block 125. The northern half of Block 125 lies in the extreme southeastern corner of Rouyn map-area. This is underlain in its southern part by the Glenwood rhyolite and rhyolite breccia and in its northern part by the Glenwood andesite. The rhyolitic rocks are more or less sheared and intruded by irregular dykes of diorite. The andesite is partly massive and partly pillowed, with the pillow tops to the north. Between the andesite and the rhyolite there is a group of outcrops in which andesite flows up to 30 feet thick are interbedded with zones of rhyolite-andesite breccia that is probably pyroclastic in origin.

A vertical shaft 50 feet deep has been sunk on the top of the rhyolite ridge, some prospect pits and trenches excavated, and a total of 3,010 feet of diamond drill holes bored.[1] In some of the trenches and prospect pits rhyolite and rhyolite breccia containing disseminated pyrite is exposed, and east of the shaft there is a zone of pyritic rhyolite 3 to 6 feet wide exposed at intervals for 200 feet. In two diamond drill holes put down at angles of 30 and 45 degrees to the north, beneath the clay-covered depression that occupies the northwest corner of Block 125, gold is said to have been found. In one of these holes (No. 2), at its lower end, chloritized, schistose rhyolite, intersected here and there by veinlets of quartz and carbonate, was crossed. This suggests that a fault is present in this locality.

[1] Ann. Rept., Que. Bur. of Mines, 1929, p. 102; and 1931, p. 87.

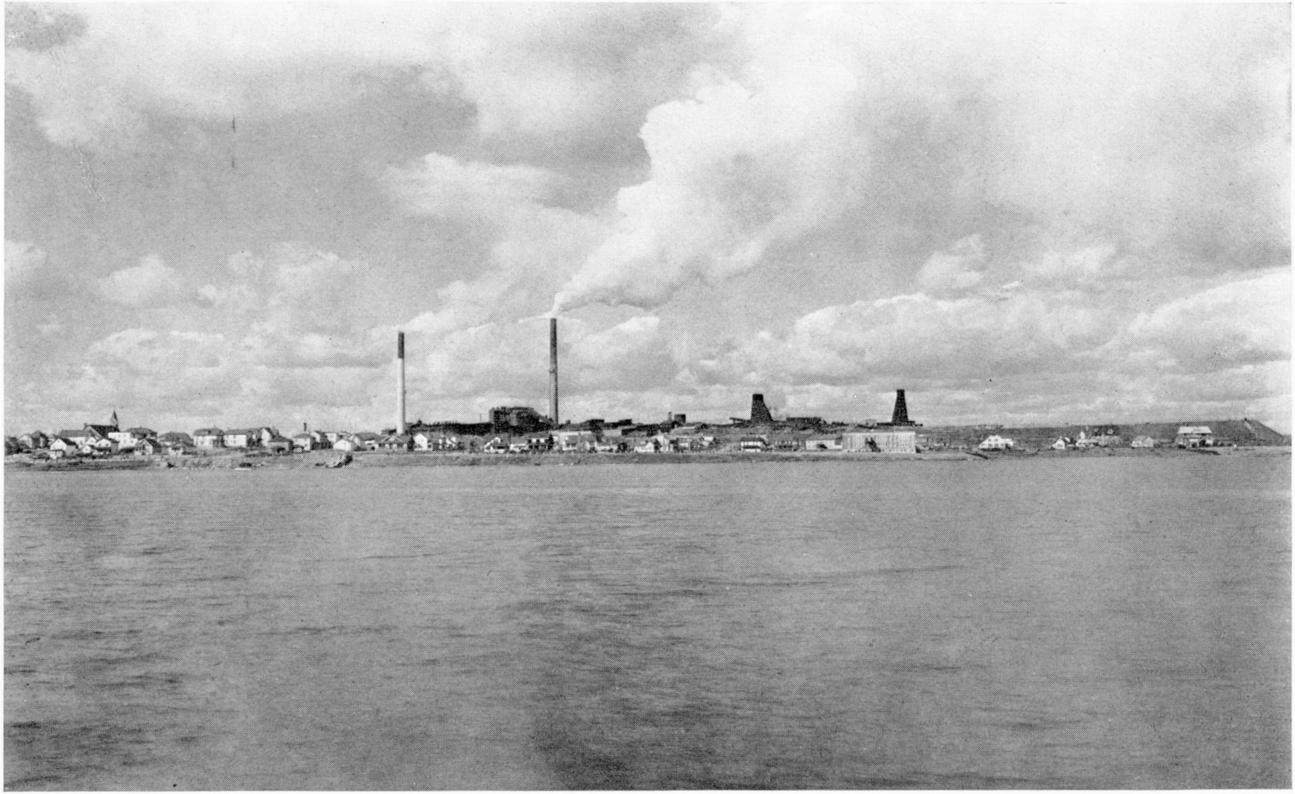
FARRELL PROPERTY

A small marginal part of claim M.L. 2139, lying to the northeast of the Glenwood claims, the property of Farrell Rouyn Mines, Limited, is included in Rouyn map-area. The rock in this locality is the Glenwood andesite. It is intersected by two parallel fracture zones trending west-southwest and lying about 100 feet apart. The northwesterly of the two zones consists of veins of quartz and rusty brown weathering carbonate (ankerite). The individual veins of quartz are from ½ inch to 18 inches wide, and the total width of carbonate and quartz from 1½ to 4 feet. The total width of the zone is 12 feet. Pyrite is disseminated in the schistose wall-rock. The second zone is exposed in only one outcrop. The maximum width of quartz is only 1 foot, but the rock is rusty for a width of 15 feet.

PLATE I

View from air of Powell Rouyn mine, Rouyn township, Témiscamingue county. By Airmaps, Limited, Toronto.

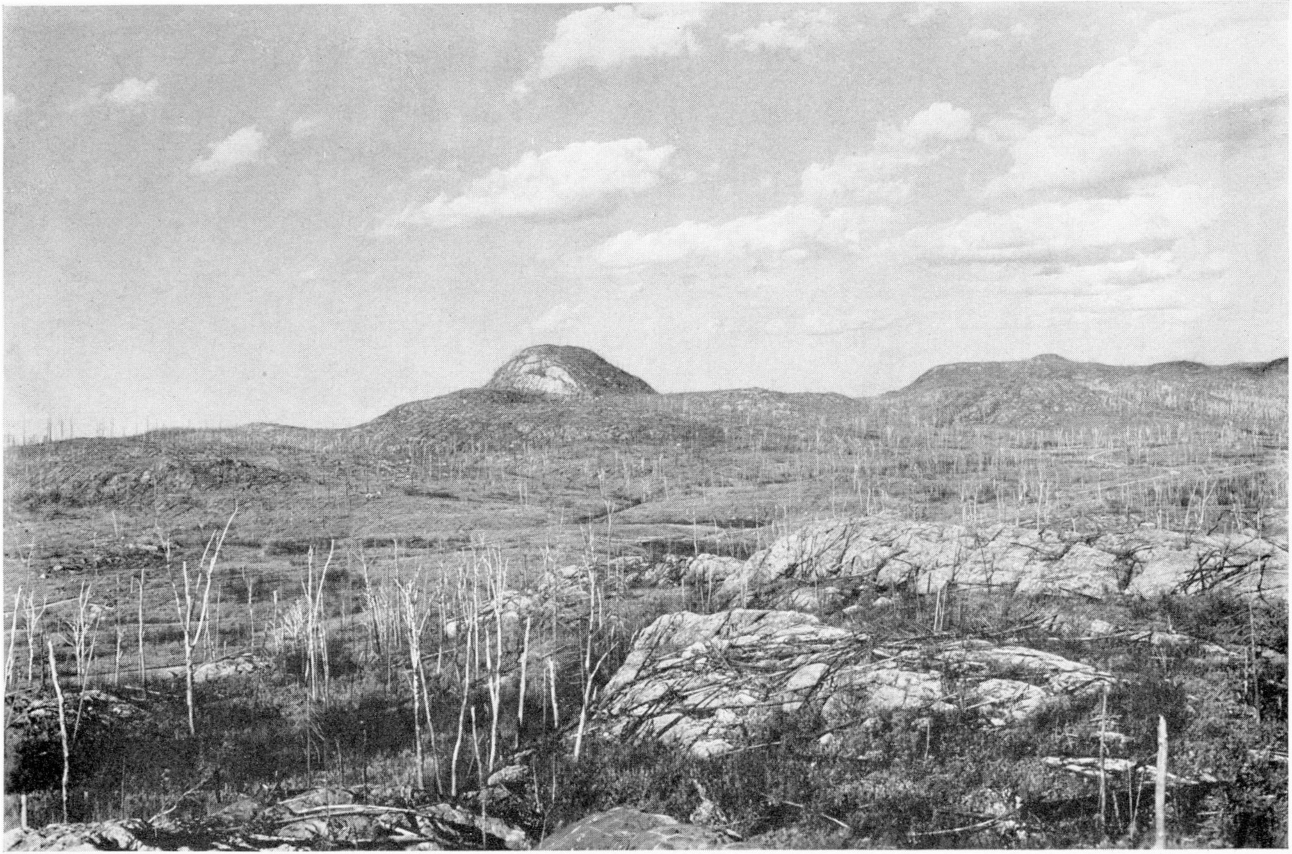
PLATE II



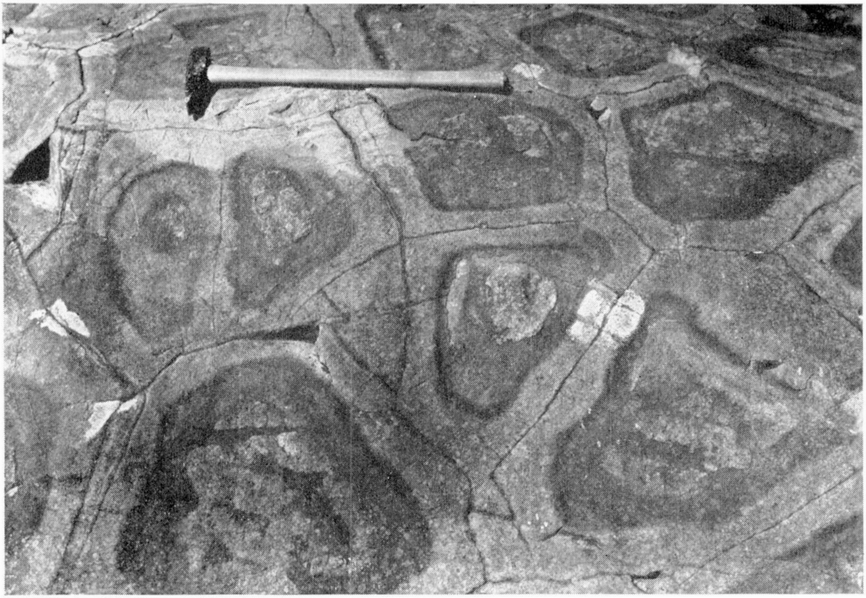
81555 Horne mine, Noranda.

PLATE III

75211 Amulet mine, Dufresnoy township, Abitibi county.



76515 View looking northeast from Waite-Ackerman-Montgomery mine to Beaver Hill.

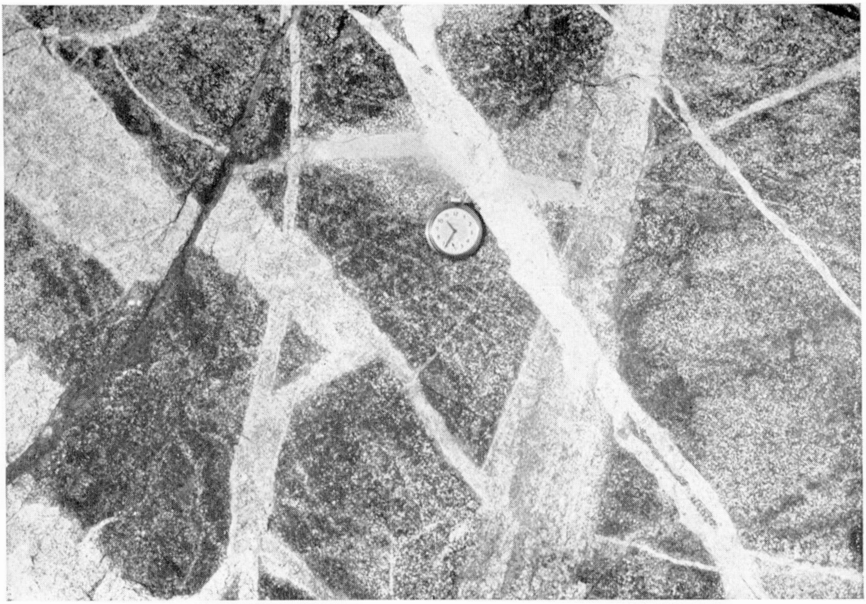


79656
A. Columnar jointage in andesite of Rusty Ridge belt, east of Lake Fourcet, Amulet map-area.

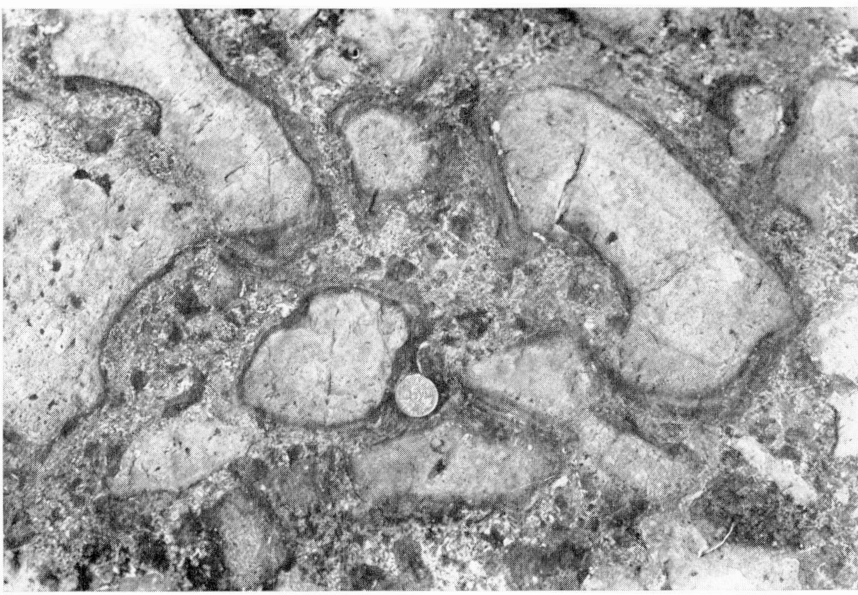
81552
B. Columnar jointage in massive rhyolite of Héré Creek belt, adjacent to Flavrian Lake road near southeast margin of Amulet map-area.

78047
A. Pillow in Waite Hills andesite laminated parallel its margin, east of Beaver Hill triangulation station, east-central part of Waite map-area.

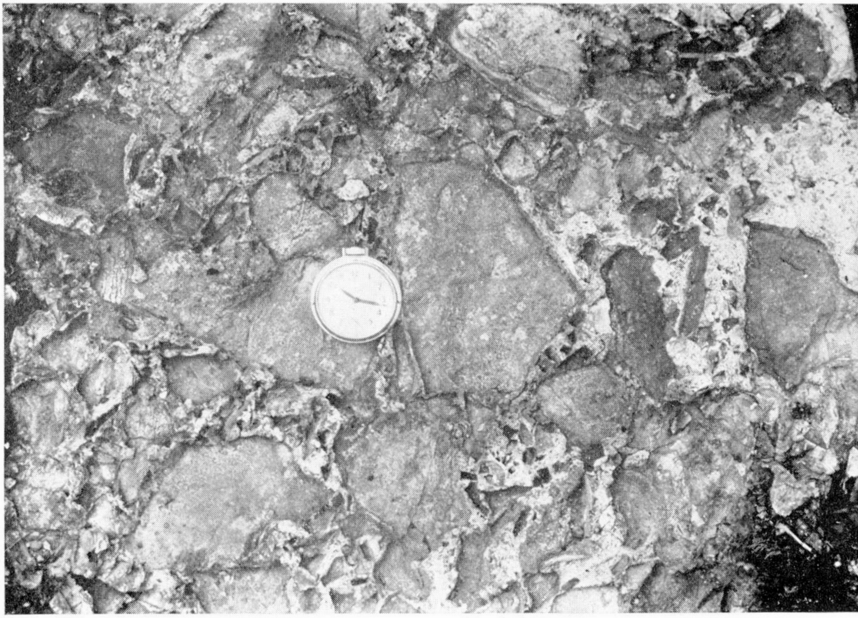
75229
B. Vertical strike cross-section through pillow structure in andesite showing pillows of the mattress, bun, and balloon types, southwest of No. 4 (C) shaft at the Amulet mine, Amulet map-area.



81542
A. Dykes of granodiorite intruding quartz diorite in the contact zone of the Lake Dufault granodiorite stock, northeastern part of Amulet map-area, Dufresnoy township, Abitibi county.

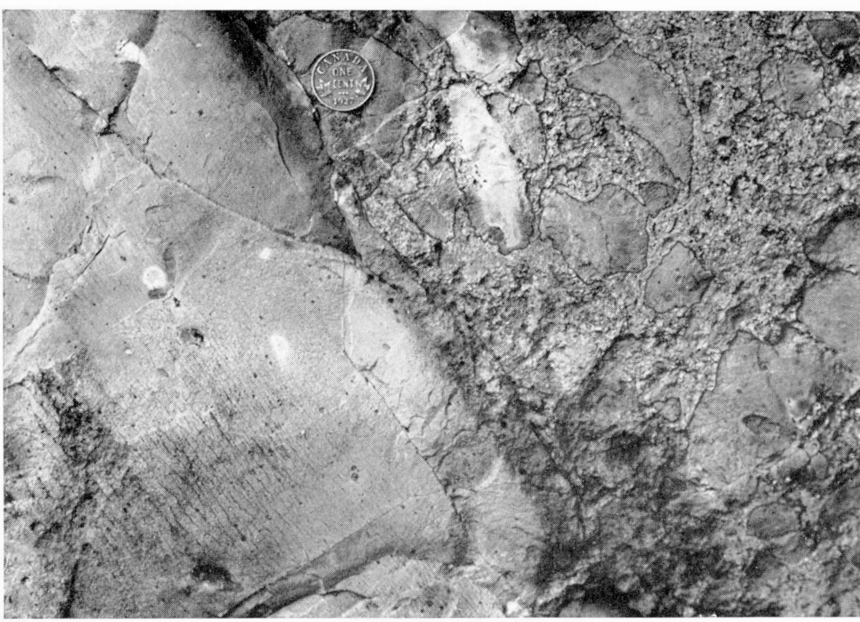


79672
B. Rounded andesite flow breccia from Waite Hills andesite belt near Macamic highway, Newbec map-area, Dufresnoy township, Abitibi county.



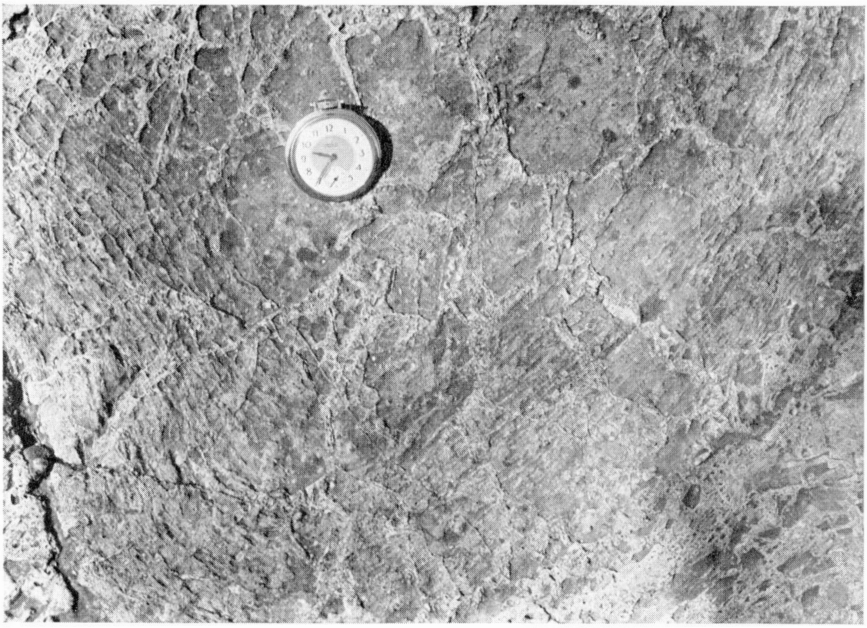
79666

A. Andesite breccia near base of Amulet Hills belt, south of Turcotte Lake, Amulet map-area, Dufresnoy township, Abitibi county.



78045

B. Laminated top of andesite flow in contact with rhyolite breccia of Waite Lake area, looking north, southwest of Waite lake, Waite map-area, Duprat township, Abitibi county.



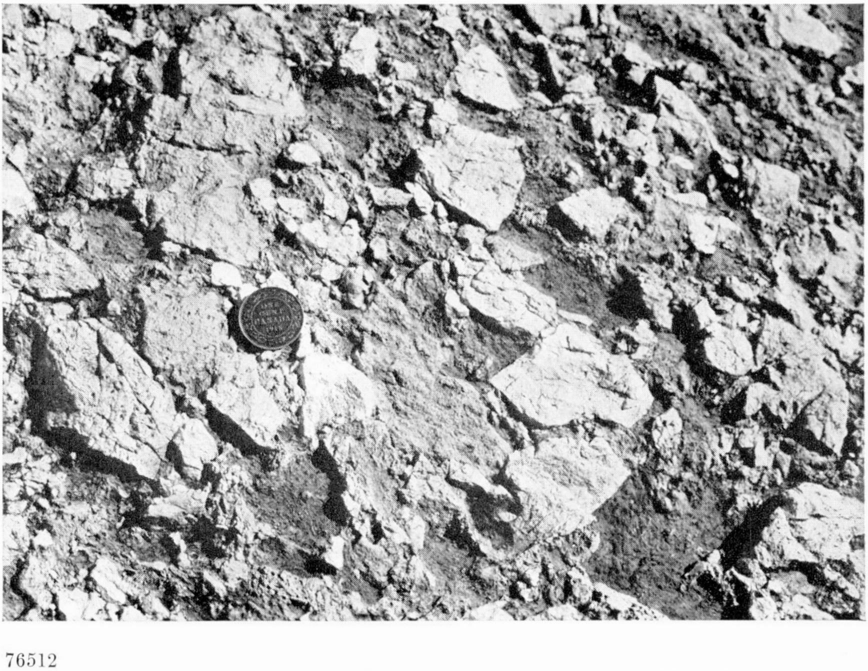
79654

A. Lamination and mesh-weathering in andesite of Rusty Ridge belt southeast of Lake Fourcet, Amulet map-area.

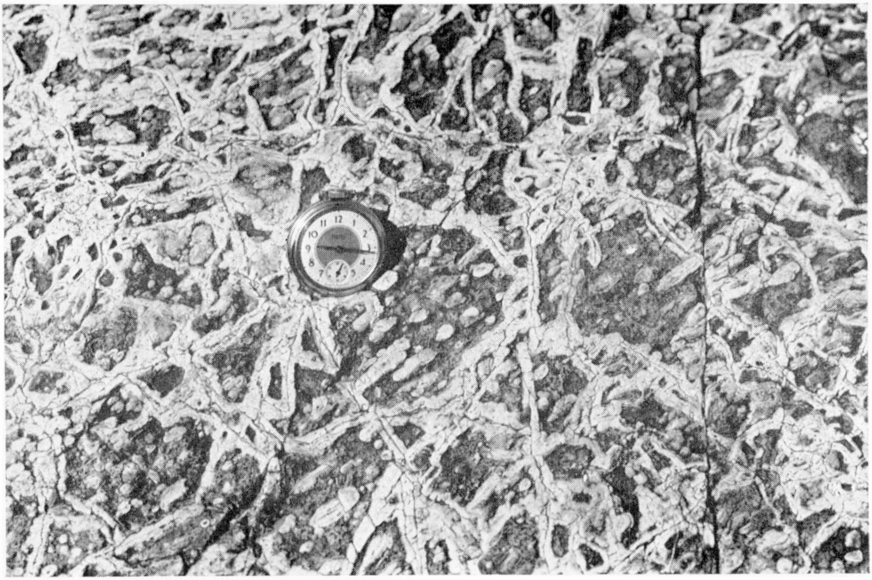
78044

B. "Ribbon" flow breccia from Vauze Creek belt, northeastern part of Waite map-area.

78042
A. Rhyolite breccia from Waite Lake belt near contact with siliceous rhyolite, Waite map-area.

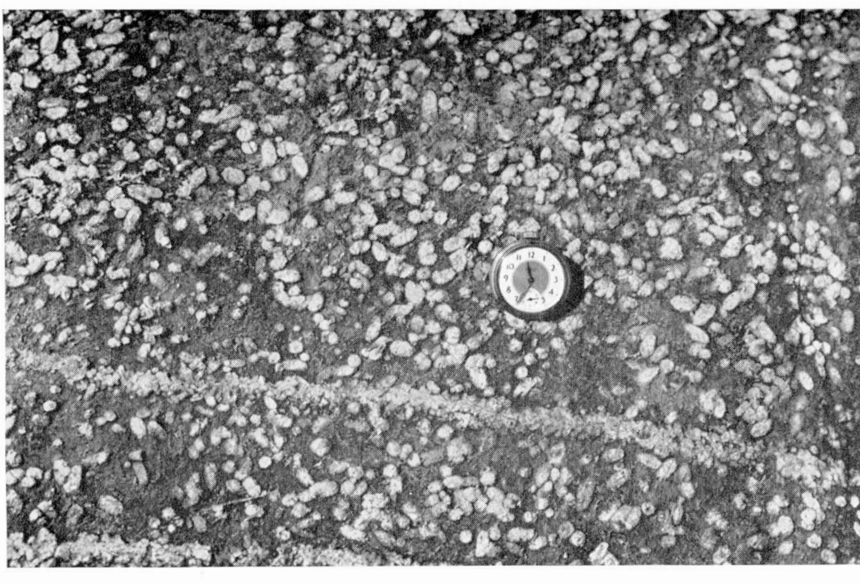


76512
B. Rhyolite flow breccia exposed adjacent to Macamic highway in Brownlee property, Rouyn map-area.



79658

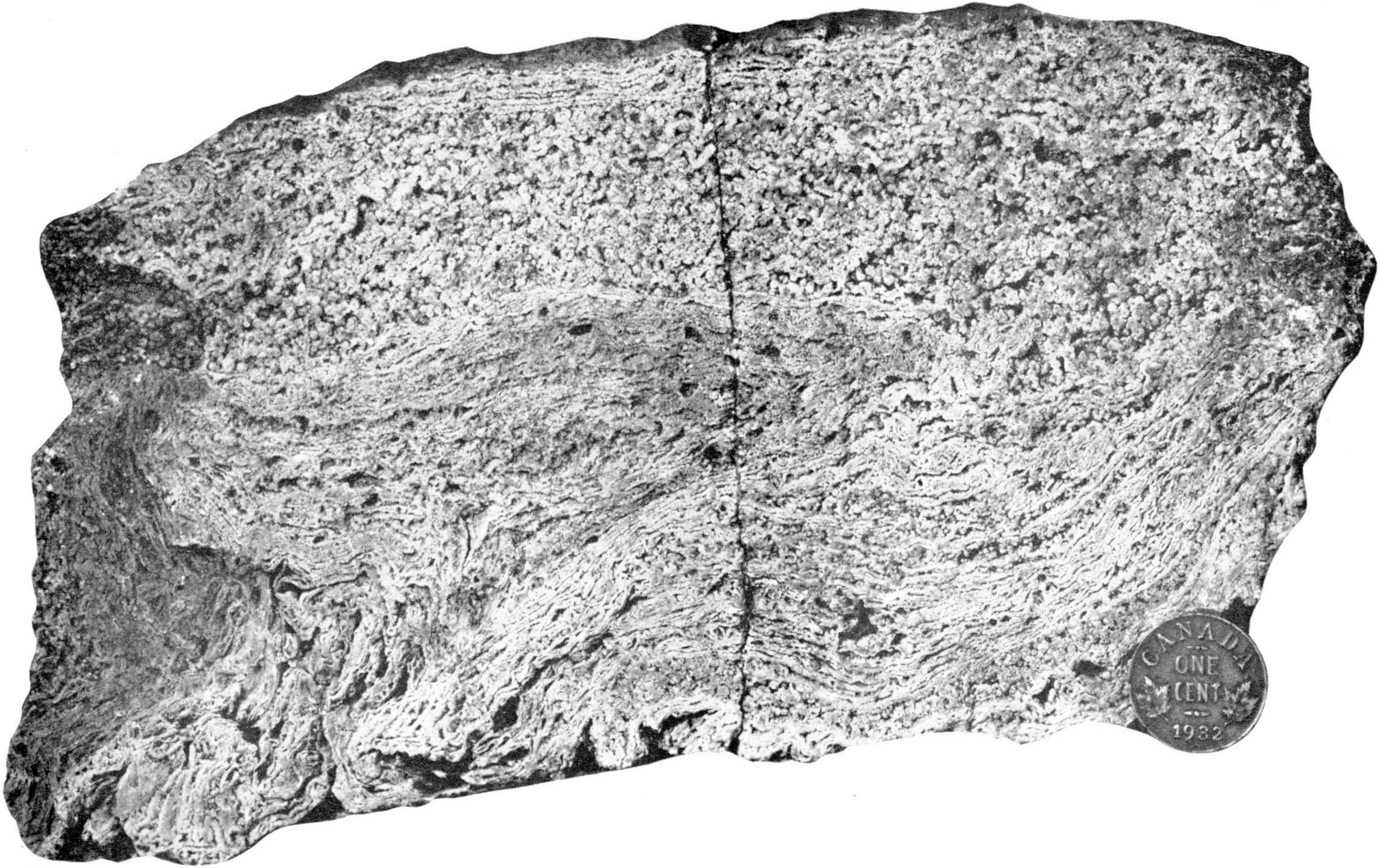
A. Mesh-weathering amygdaloidal rhyolite from Bedford area, southeast of Lake Fourcet, Amulet map-area.



79661

B. Dalmatianite, northwestern part of Amulet property, Duprat township, Abitibi county.

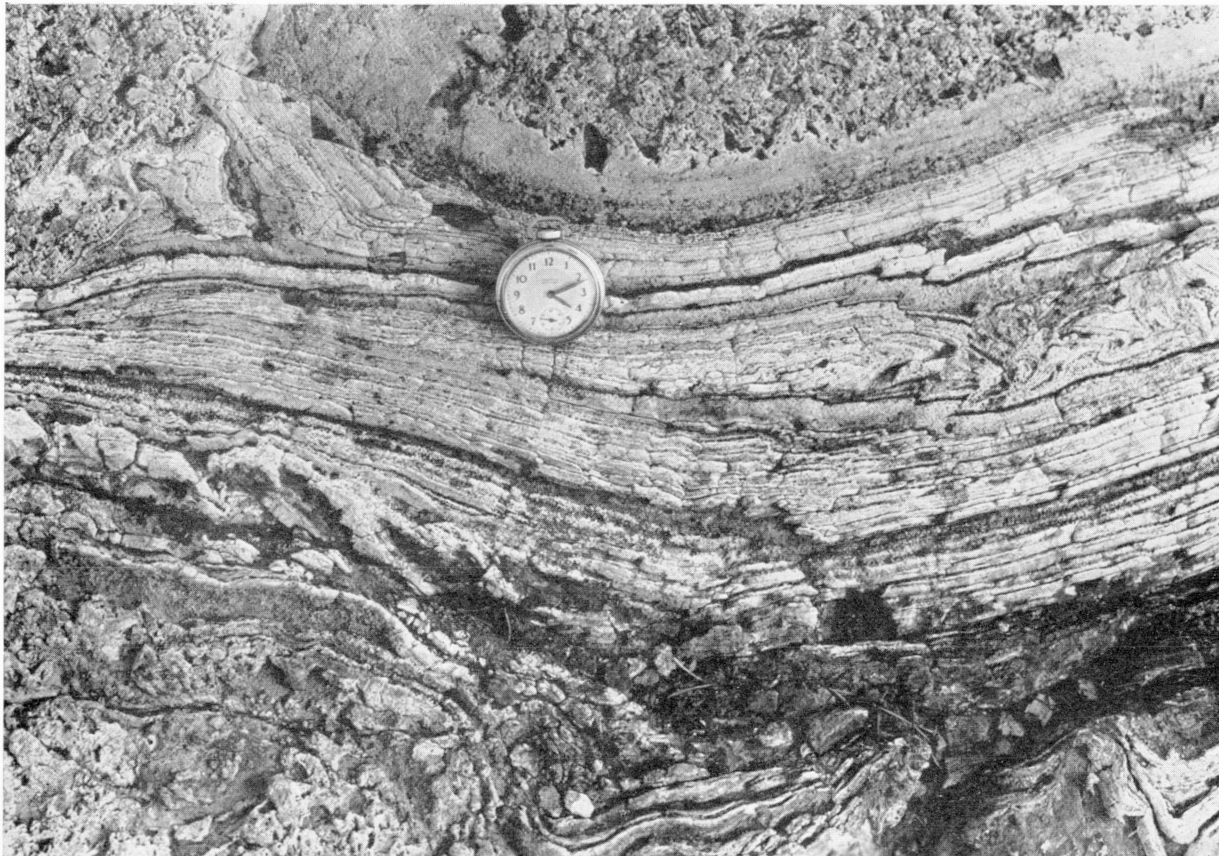
Plate XII



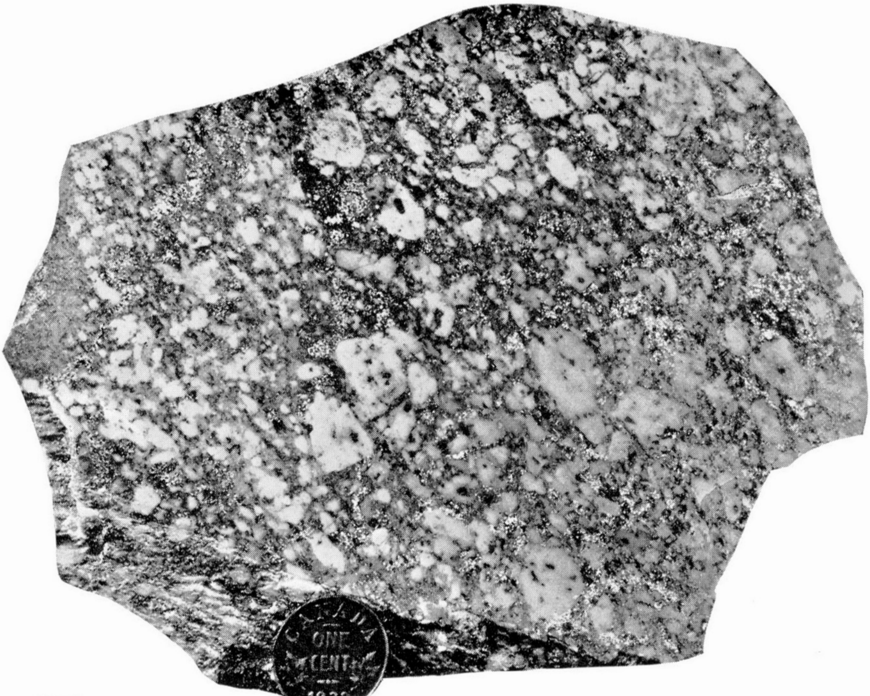
83749

Spherulitic structure and lamination in rhyolite of Amulet belt southwest of Turcotte Lake, Amulet map-area.

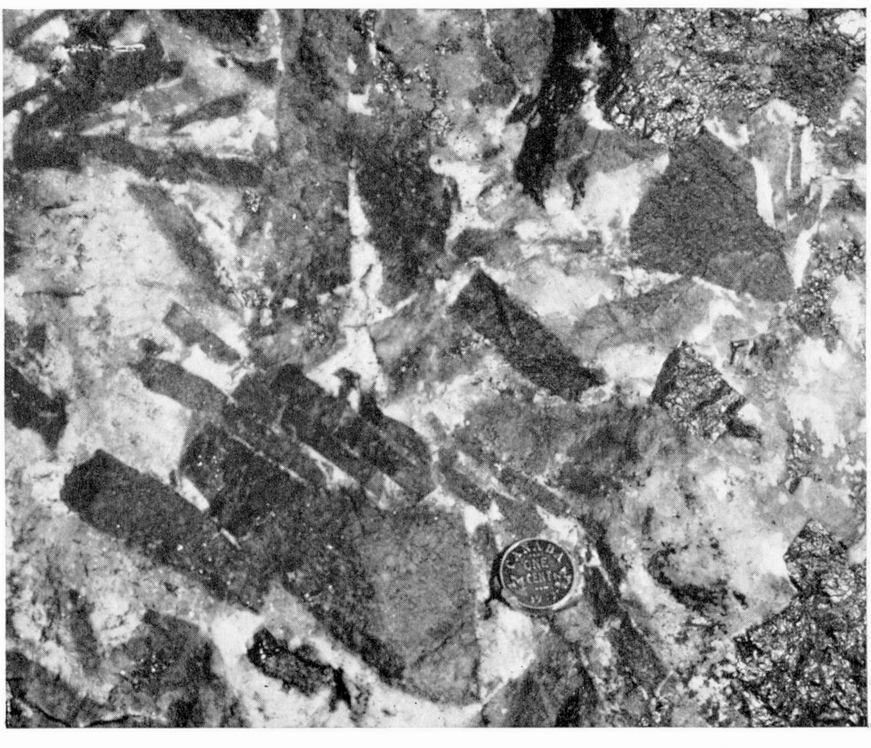
PLATE XIII



79664
Stratified chert and pyroclastic rhyolite breccia at contact of Rusty Ridge andesite and Amulet rhyolite and rhyolite flow breccia, Amulet map-area.



83750
A. Pyroclastic rhyolite breccia, pyrite replacing matrix, Noranda (Horne) mine, Rouyn township, Témiscamingue county.



81548
B. Pyritic breccia, in drive 3919, Chadbourne property, Rouyn township, Témiscamingue county.