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GEOLOGY AND SULFIDE DEPOSITS OF THE MATAGAMI AREA, ABITIBI-EAST COUNTY

QUEBEC DEPARTMENT OF NATURAL RESOURCES

Honorable Paul-E. Allard, Minister

MINES BRANCH

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GEOLOGY AND SULFIDE DEPOSITS
of the
MATAGAMI AREA

Abitibi-East County

by

John I. Sharpe

QUEBEC
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MINERAL DEPOSITS SERVICE

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INTRODUCTION

Summary statement

A group of Early Precambrian rhyolitic rocks and a younger group of lavas and pyroclastic rocks are intruded by a layered gabbro-anorthosite pluton. Both the pluton and the volcanic rocks are folded and intruded by granite. Thirteen deposits of chalcopyrite and sphalerite have been found; mining of three of these began in 1963. The deposits are restricted to a stratigraphic zone near the contact between the volcanic groups. The upper limits of metallization are concordant against lava or chert units of the younger group, whereas the lower extremities of some deposits follow transverse structures.

Mineral and fabric relations indicate that, except for some layers of sulfides in chert, the ores are epigenetic. Geothermometric data from sphalerite and pyrrhotite indicate temperatures of crystallization above 425°C. The sulfide masses are deformed and appear to be intruded by pre-orogenic dikes. Close relations between metallization and volcanic lithology and stratigraphy, and the preliminary investigation of the fabrics and crystallization temperatures of the ores, suggest that they were formed by replacement, at high temperatures, in the volcanic environment.

Gold-bearing veins, small amounts of bismuth, molybdenite and disseminated chalcopyrite also occur within the map-area.

Location and topography of the area

The Matagami area, as described in this report, is considered to be an area of 155 square miles, near latitude 49°45' and longitude 77°45'. It comprises ranges I to VII in Isle-Dieu township, the east halves of ranges I to VII in Daniel township, and the north half of Galinée township.

The Matagami townsite, at the Bell river, is 112 miles by road from the town of Amos and hydroelectric and railway lines have been extended into the area. The main rivers are navigable except for the rapids in the Bell river near the townsite and Inlet rapids at Matagami lake. Inlet rapids can be run except at times of low water.

The land surface is level, the few hills and irregularities being subdued by lacustrine deposits of glacial-lake Barlow-Ojibway. Outcrops are scarce except in the northeast, where the Mount Laurier hills extend west into the area, and along the main waterways, the Bell and Allard rivers, and Matagami* lake. The rivers flow north into the lake and thence into Nottaway river and northward to James Bay.

Field work

The extensive exploration activity, precipitated by the discovery of a major base metal deposit in 1957, made it desirable to compile and integrate the rapidly accumulating geologic data. The field work was done in 1961, 1962, and 1963 and included geologic mapping, at scales from 100 feet to the inch to 1,000 feet to the inch, according to the complexity of the geology. In many areas, such as in northwest Galinée township, information on bedrock is derived principally from drill-hole data. Detailed geophysical surveys performed by mining companies over much of the area were useful in outlining certain rock units. Networks of cut lines over the area provided survey controls. Most of the laboratory work was done at McGill University.

A comprehensive, though preliminary, study has been made of the sulfide deposits, large and small. The main aims have been to: present a description of each deposit; study each in relation to the general geology; and to compare and contrast the deposits and their environs in hope of determining the disposition of the metallization in space and time.

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* The official spelling is now "Matagami" (previously "Mattagami").

Previous work

The earliest recorded geological observations are those by Robert Bell (1895, 1900), who crossed Matagami lake on his trip down the Nottaway river. Bancroft's (1912) survey for the Quebec Bureau of Mines included descriptions of some outcrops in the area and the recognition of a large mafic igneous complex. By 1936, Freeman and other workers of the Geological Survey of Canada had outlined the basic features of the geology.

Systematic mapping was undertaken by the Quebec Bureau of Mines in 1938 and resulted in the publication of 1 inch to 1 mile maps, by Longley (1943), Freeman and Black (1944) and Béland (1953), which encompass the Matagami area. Specific studies of the Bell River mafic complex are provided by Freeman (1939) and Black (1942).

Prospecting activity had been desultory, because of the lack of rock exposures, until the advent of geophysical techniques. The promising geologic features prompted airborne magnetic and electromagnetic surveys by the Mattagami Syndicate in 1956 which led to the discovery of the large base-metal deposit of Mattagami Lake Mine in 1957. A dozen other sulfide deposits have been discovered since then, all by geophysical techniques. Miller (1960), Joklik (1960) and Jenney (1961) have published descriptions of some of the deposits.

Acknowledgements

The writer is indebted to the Quebec Department of Natural Resources for material assistance and the encouragement to focus this study on the sulfide deposits.

The report embodies the principal material of a thesis submitted to McGill University and prepared under the guidance of Dr. J.E. Gill. Thanks are also due to professors L.A. Clark and G.R. Webber of McGill University who provided instruction on the use of the diffractometer and X-ray fluorescence techniques and the use of standard samples.

The rock analyses and optical spectroscopy were done at the Laboratories of the Quebec Department of Natural Resources.

Numerous members of the mining industry, active in the Matagami area, provided access to their data and ideas. Acknowledgement to individuals is tendered in the descriptions of the deposits.

The field work was done with the aid of senior assistants: Michael Katz, Mark Graham and Hughes Simoneau and student assistants: André Legault, Haram Redman, Umberto Maccarone, Jean-Guy Légaré, Richard Hardy and Jean-Roch Labrie.

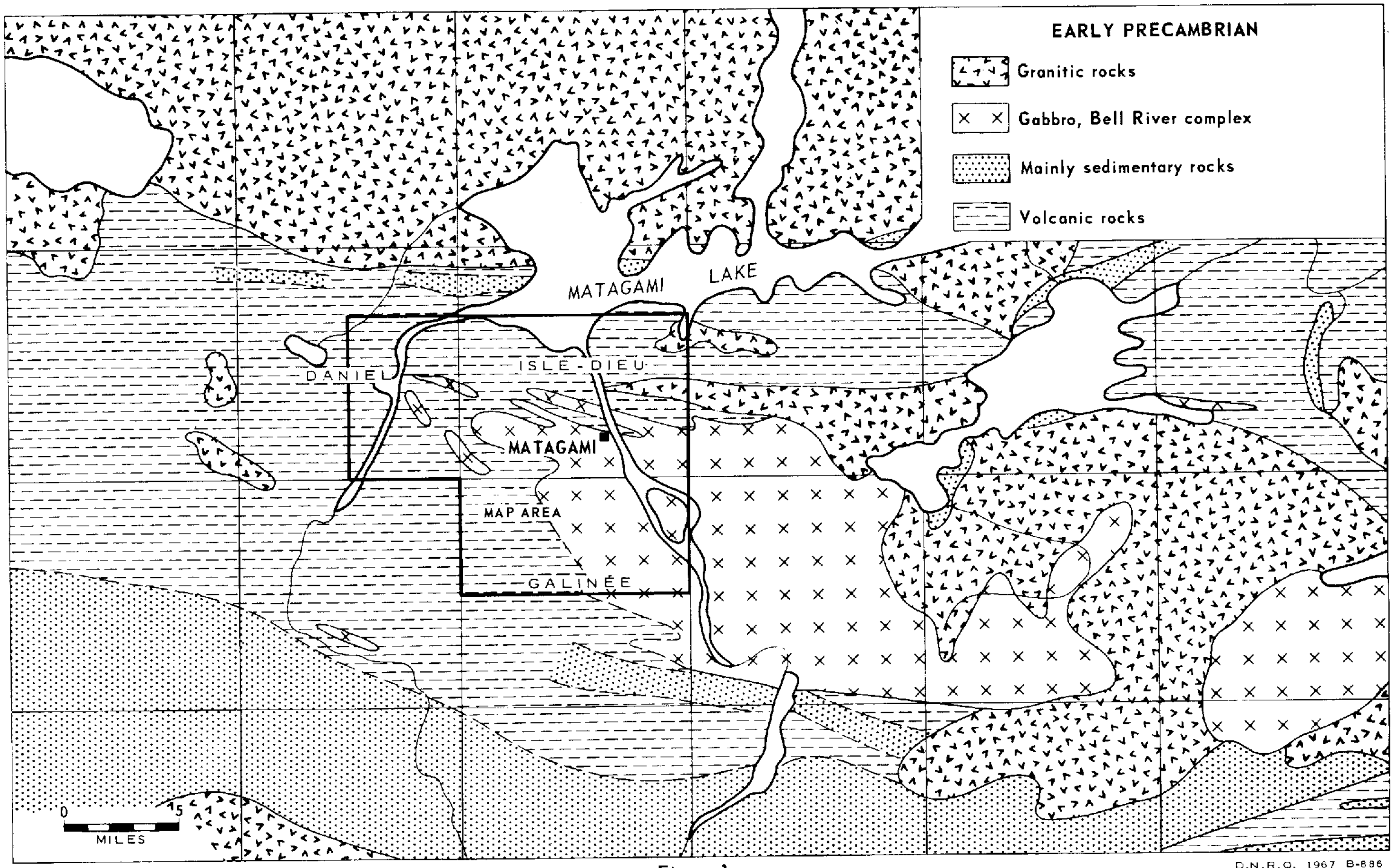

Figure 1

REGIONAL SETTING OF MATAGAMI AREA

REGIONAL GEOLOGIC SETTING

Bands of folded Precambrian volcanic and sedimentary rocks, invaded by elongate granitic masses, form the Superior province in northwestern Quebec. The Matagami rocks are a central portion of one of the more northern volcanic bands which extend westward across the Ontario boundary and eastward to Chibougamau area and the Grenville "front".

Two volcanic bands coalesce in the region of Matagami lake, and encompass the western nose of a massif of gabbroic and granitic rocks (Figure 1). Metamorphosed sedimentary rocks are intercalated with volcanic units to the north and south of a thick volcanic complex. The northern sedimentary rocks are the "Matagami series" of Bancroft (1912). Little is known about the southern band of sedimentary rocks. On the basis of diamond drill data and the continuity of magnetite iron-formations, the writer considers that the thick sequence in Berthiaume township (Claveau, 1951) extends westward as shown.

Large, elongate masses of granitic rocks and migmatite delimit the flanks of the volcanic and sedimentary assemblages.

All workers in the region regard the volcanic and sedimentary rocks as Early Precambrian in age. Longley (1943, p. 13) suggests that the "Mattagami sedimentary series" may be interbedded with the volcanic rocks; a relation observed elsewhere in the region.

GENERAL GEOLOGY

The volcanic rocks are thick units of Early Precambrian lavas and pyroclastic material. The Bell River complex, a layered pluton, and associated gabbro dikes and sills intrude the volcanic rocks. Both the complex and the volcanic rocks appear to be folded, metamorphosed to various degrees, and intruded by granitic rocks. Later diabase dikes transect all other rocks.

The base of the volcanic pile has been disrupted by the Bell River complex and rocks older than the lavas have not been recognized.* The lower extrusions are siliceous, whereas the younger are predominantly feldspathic and mafic lavas. General and local metamorphism accompanied the volcanicity, the intrusions and the regional deformation.

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* Pebbles and cobbles of granitic rocks are found in the sedimentary formation to the north of the map-area. Perhaps very old granitoid rocks, now intruded and metamorphosed by later granites, exist in the gneissose orogen to the north.

Table of Formations

CENOZOIC	Recent fluvial and paludal deposits. Pleistocene till, glacial-lacustrine and glacial-fluvial deposits.		
	Unconformity		
LATE PRECAMBRIAN	Diabase and gabbro dikes		
	?		
EARLY (?) PRECAMBRIAN	Younger Intrusive Rocks (mainly synorogenic or post-orogenic)	Hornblende and biotite granite, granodiorite, quartz diorite, siliceous, feldspathic and mafic dikes	
EARLY PRECAMBRIAN	Older Intrusive Rocks (mainly prefolding)	Peridotite, diabase, lamprophyre dikes (age relations uncertain)	
		Bell River complex and subsidiary intrusions	Layered gabbro and anorthosite, pegmatitic gabbro-anorthosite, uralitized pyroxenite, gabbro, quartz gabbro, diorite, porphyritic gabbro, magnetite-ilmenite segregations
	Volcanic Rocks	Sedimentary rocks ("Mattagami Series") (not exposed in map-area; in part intercalated with lavas and pyroclastic rocks)	
		Wabassee Group	Dacitic lavas (rhyodacite, dacite, sodic trachyte), andesite-basalt, tuff, agglomerate, cherty rocks ("tuffite"), sub-volcanic intrusions
		Lac Watson Group	Porphyritic and spherulitic rhyolite and rhyodacite, tuff, agglomerate, brecciated and silicified and chloritized rhyolitic rocks, chloritized intermediate volcanic rock, mafic lavas, highly metamorphosed volcanic rocks. (base not exposed)

The emplacement of the Bell River complex presumably accompanied tectonic disruptions but, as the complex is folded, the main deformation occurred later. The few granite plutons lack deformation fabrics but are faulted. They are post-orogenic or synorogenic intrusions. The later gabbro dikes truncate the other intrusions and deformation structures and, as other similar dikes in the shield, they are considered to be Late Precambrian in age.

Pleistocene glaciers moved south across the area leaving traces of several sets of striae and a few morainal deposits. A thick cover of silt and varved clay blanketing the lower areas was deposited by glacial lake Barlow-Ojibway, which represents the last important event of the Pleistocene.

Glaciation is in large part responsible for the present topography. Active erosion is now confined mainly to gulleys. The main rivers are turbid; laden with silt and clay particles.

Volcanic Rocks

Distribution, subdivision and nomenclature

An assemblage of lavas and related rocks extends across the northern and southwestern sectors of the area, enveloping the Bell River complex (Figure 2). The volcanic rocks north of the complex (hereinafter referred to as the "north band") converge with a band of similar rocks which extends northwestward along the south flank of the intrusive complex. This second band is named the "south band" and, in part, can be correlated with the north band.

A linear persistence of marker horizons and the generally consistent southward dip of stratiform units indicate that the south band approximates a homoclinal structure which dips moderately southwest. Top determinations are not abundant but, in combination with the consistency of lithologic units and structure, are sufficient to indicate that these volcanic rocks face southward and thus are upright.

Stratiform units in the north band are nearly vertical or inclined steeply northward or southward and the rocks are complexly folded.

The south band consists of two contrasting stratigraphic groups. The older is characterized by a predominance of metamorphosed rhyolitic rocks and is here named the Lac Watson Group. The second unit consists predominantly of dacitic, andesitic and basaltic lavas and is named the Wabassee Group.

The lavas of the north band are lithologically identical to those of the Wabassee and Lac Watson groups. In the area adjacent to Bell River complex they have a similar though reversed sequence and, from a few top determinations, face northward. Thus they are correlated with the volcanic units to the south of the Bell River complex.

The delineation and study of the contact zone between the two groups is important as it reflects a broad-scale change in the nature of the volcanic eruptions. Also, most of the ore deposits throughout the region occur adjacent to this contact.

There is some intercalation of lithological units of the two groups and precise correlations are, in some places, uncertain. For these reasons, only lithological units are shown on the detailed maps. The general stratigraphic subdivision is indicated on Figure 2.

A precise and meaningful petrographic classification of the many varieties of volcanic rocks is extremely difficult, due to the fine-grained or devitrified textures of the rocks and the pervasive alteration of primary components to secondary minerals.

The nomenclature used herein is based essentially on the field appearances, supplemented by chemical analyses and optical examination. The field criteria on which it is predicated are listed below. In general, the application of the suffix "ic" such as "dacitic" implies that, in a stricter petrographic sense, the rock might be "rhyodacite" or a light-colored variety of "andesite".

1) andesite-basalt, Andesite: Brownish weathered surfaces; dark green to greenish black rock with lithoidal to ophitic textures. Fluidal structures and large elongate pillows are common. Amygdules are usually carbonate. As no sharp distinction can be made between less mafic andesitic varieties and basalt, the rocks may be generally referred to as "andesite". Altered varieties are chloritic.

2) dacitic lavas: Light-colored, chalky weathered surfaces. Rock is gray to apple green with dense lithoidal textures, commonly with quartz and feldspar phenocrysts and varioles. Flow breccia facies and small rounded pillows characteristic. Amygdules usually quartz and clinozoisite. Altered varieties sericitic; locally rock is dark and chloritic.

3) rhyolite, rhyolitic lavas: Variable in appearance. Fresher varieties range from dark, hard aphanitic rocks to quartz feldspar porphyry. Spherulitic textures common. Best characteristic of altered varieties is abundant "quartz-eyes". Extremely welded felsic pyroclastic rocks may have the appearance of a rhyolite lava. Therefore, the term "rhyolite", as used herein, does not exclude ignimbrites.

4) agglomerate: The term is restricted to completely clastic volcanic material with abundant fragments greater than 2 cm. in size. Volcanic breccias and lapilli tuffs are also included. Bombs may or may not be recognizable.

5) tuff, tuffaceous rocks: Very fine to medium-grained material, bedded or stratified with lavas. The tuffaceous rocks are particularly susceptible to alteration and deformation and only in rare instances are the textures distinct.

Individual outcrops, as shown on the maps, may be mixtures of lithologic types or gradational varieties. Such cases are indicated by combinations of symbols and the first symbol designates the predominant lithologic type.

All the volcanic rocks are altered to some extent. Where this is unusual or extreme the nature of the alteration is indicated on the map by a suffix.

Lac Watson Group

A band of rhyolitic and altered volcanic rocks, defined here as the Lac Watson Group, extends southeast from the area north of Watson (Lalanne) lake across the northwest quarter of Galinée township. The type locality encompasses the properties of Mattagami Lake Mines, Orchan Mines and the areas in ranges VIII and IX east of these properties. The northern and northeastern sectors of the band are intercalated with intrusive rocks. However, at the type locality and southwestward for four miles, the top of the unit is precisely defined by the base of a thin "horizon" of laminated chert and tuff which overlies porphyritic rhyolite and is overlain by pillowed dacitic lavas of the Wabassee Group. Elsewhere, no simple delimitation of the two groups could be devised. This is due to the lack of information on lithology and structure in the contact area but is also a result of local intercalation of the lithological types of the two groups. Thus the contact of the Wabassee Group and Lac Watson Group, as illustrated in Figure 2, is based mainly on gross changes in lithology.

Lithologic units

The main lithological types are rhyolitic rocks which differ in texture and in degree and type of alteration. These are: porphyritic rhyolite, spherulitic rhyolite, tuff and agglomerate, brecciated and silicified rhyolite, and chloritic rhyolite. The mafic volcanic rocks in the group are:"chloritized intermediate volcanic rock" and mafic lavas. Most of these rock types have indistinct or gradational contacts and it is rarely possible to delineate large continuous units of simple lithologic character.

Porphyritic rhyolite:- Porphyritic rhyolite forms the uppermost unit of part of the group in Galinée township and occurs elsewhere admixed with other rocks.

The only good surface exposures are those 2,000 feet east of the railroad in range IX, Galinée township. Outcrop surfaces have a light bleached color and exhibit hackly fractures. Primary volcanic structures are rare. Here and there a lamellar flowage pattern can be discerned. The rock, as seen on broken surfaces, has a very fine-grained lithoidal matrix, dark gray to green in color and speckled with vitreous, 1mm. quartz crystals. Most samples contain small stubby feldspar phenocrysts and they and the quartz grains constitute 10 to 20% of the rock.

In thin sections, the quartz phenocrysts are euhedral or subhedral and have embayed forms. The feldspar phenocrysts are mainly simply-twinned subhedral grains of alkali-feldspar and antiperthite. Micropegmatitic intergrowths of microperthite and quartz and a few small phenocrysts of albite are also present. The matrix consists of a microcrystalline intergrowth of quartz and feldspar with shreds and irregular clots of chlorite and zoisite. Tiny radial spherulites form part of the matrix and merge imperceptibly with the microcrystalline intergrowths. The disposition of the spherulites and the indistinct textural relations suggest that the matrix is a devitrified glass.

A chemical analysis of a relatively fresh sample indicates that the rock is soda-rich (Appendix B).

Spherulitic rhyolite and rhyodacite:- The spherulitic varieties are, in part, textural variations within massive lavas but also form thick distinctive units. Extensive units were seen one mile northwest of Watson lake, also along the east shore of the Allard river near New Hosco Mines and at intervals along ranges III and IV of Daniel and Isle-Dieu townships. At these localities the spherulitic rhyolite is considered to be the uppermost unit of the Lac Watson Group. However, identical rocks occur intercalated with the basal lavas of the Wabassee Group near Orchan Mines' property. Altered equivalents of these rocks are also common. The following descriptions represent the less-altered occurrences.

The spherulitic texture gives outcrop surfaces a distinctive grained or pebbled appearance. The rock, as seen on a fresh surface (Plate I-A), consists of closely packed, dull gray or vitreous spherulites with chloritic or sericite material in the interstices and small phenocrysts of feldspar and glassy quartz. The spherulites are radiating crystals of plagioclase, intergrown with cryptocrystalline quartz and feldspar; some have patches with vague microperthitic and myrmekitic textures, too fine to be adequately resolved by the microscope. The boundaries and interstices between the spherules are usually defined by a selvage of chlorite with lesser amounts of sericite, epidote, calcite, magnetite, leucoxene and pyrite and, in places, small tabular meta-blasts (?) of brown mica in the chlorite. Some schistose samples of the spherulitic rhyolite have sericitic instead of chloritic interstitial material and the spherulites, although macroscopically distinct, appear granulated and indistinct under the microscope.

The phenocrysts of quartz are less abundant than those in the porphyritic rhyolite. The feldspar phenocrysts are mainly albite and a few clouded simple twins of potash feldspar. Some of the feldspar phenocrysts form the nuclei of spherulites.

The mineral proportions of the rock are difficult to estimate because of the fine and complex texture. The quartz content is usually in the range of that of rhyolitic and dacitic rocks. As the spherulite rock is most commonly closely associated with typical rhyolite it was termed spherulitic rhyolite in the field.

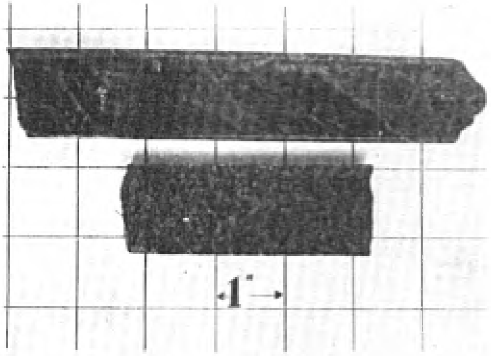
The chemical composition (Appendix B) of a fresh-appearing sample from a drill core 7,000 feet northwest of the shore of Watson lake has a high soda/potash ratio. This ratio and the petrographic aspect suggest a keratophyric affinity. The specimen approaches the chemical composition of rhyodacite rather than that of rhyolite.

Tuff and agglomerate:- Thin bands of fine to coarse pyroclastic materials occur throughout the group. These rocks are particularly susceptible to alteration and deformation and commonly are schistose and altered by silicification, chloritization and sericitization.

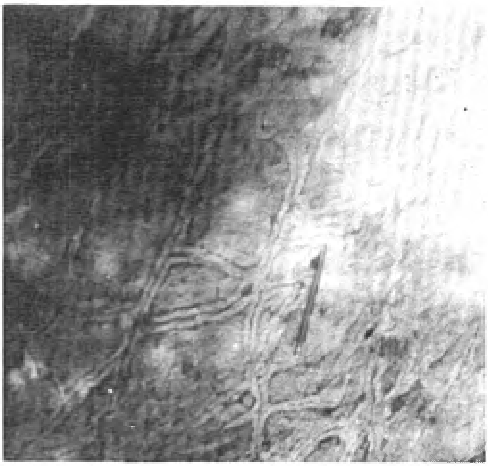
Their appearance is extremely variable. Most varieties are dark siliceous rocks characterized by rude bedding or banding. The clastic nature of the rock may be almost indiscernible on fresh surfaces but becomes accentuated on weathered surfaces.

PLATE I

LAC WATSON GROUP ROCKS



a) Silicified lapilli tuff (top.) Spherulitic rhyolite (bottom).



b) Silicified fractures in altered rhyolite north of Watson lake.

c) Irregularly shaped silicified zones in altered rhyolite. Range VIII, Galinée township.

d) Alteration nodules in chloritized rhyolite (dalmatianite?) east of Mattagami Lake mine.

Plate I-A illustrates a sample of lapilli tuff impregnated with secondary silica. Lithic fragments of quartz and feldspar, pumice and a few devitrified shards, outlined by films of iron oxide, can be seen in thin-section. These materials are compacted and welded together in the fashion of a pumiceous ignimbrite.

Commonly the tuffaceous deposits merge imperceptibly with compacted pumiceous rocks which mark the tops of rhyolite lavas, or serve as the matrix of coarse volcanic breccias. Examples may be seen in the outcrops in range III, Isle-Dieu township, 7,000 feet east of the Bell river and also in the area northeast of Watson lake.

The contact zone between the Wabassee Group and Lac Watson Group is usually marked by pyroclastic rocks and bedded chert. These will be described as units of the Wabassee Group.

Brecciated and silicified rhyolite:- Irregular zones of fractured and silicified rocks occur throughout the Lac Watson Group and are the predominant rock type in some areas. Typical exposures may be seen to the north and northwest of Watson lake and in the type area in range VIII, Galinée township. Some of these rocks retain the texture and general appearance of the less altered porphyritic and spherulitic rhyolites described previously, whereas others are so effectively altered that their antecedents are uncertain. For convenience, these rocks will be described collectively as brecciated and silicified rhyolite.

Outcrop surfaces have intricate relief patterns due to the protrusion of silicified structures. The fracture patterns, which also characterize these rocks, range in style from regular joint patterns, somewhat suggestive of columnar joints, to irregular breccia patterns. Most of these structures have developed in situ as there is no matrix material or other features to suggest that the rocks are primarily volcanic breccias. Some volcanic breccias, with blocks of rhyolite scattered through more comminuted material, are intercalated with the brecciated rhyolite.

The silicated zones usually follow some structure such as the regular joints illustrated in Plate I-B. Here the walls of the fractures are bleached and enriched in silica. The silicification is more extensive at the intersections of fractures and, in some outcrops, individual blocks assume round forms that might be mistaken for pillow structures. Elsewhere the pattern of silicified zones is complex (Plate I-C). Broken surface and drill core of these rocks have a nondescript mottled or veined appearance due to impregnations of dense gray or bluish gray silica. The silicated areas merge with darker material which, in most specimens, consists mainly of small irregular clots of chlorite disseminated throughout a network of siliceous material.

The rhyolitic nature of the rock, despite its altered aspect, is indicated by abundant phenocrysts of quartz and the local transitions into fresher rocks which are similar in appearance to the porphyritic and spherulitic rhyolite described previously.

The silica, as seen macroscopically, commonly has a distinctive cherty, opalescent appearance. It either replaces the rock or occurs as transecting veinlets. Thin sections show that the highly siliceous varieties of these rocks consist mainly of quartz and albite.

Chloritic rhyolite:- Rhiolitic rocks, characterized by a high content of chlorite, occur in a zone adjacent to the south flank of the Bell River complex and elsewhere on a more local scale, particularly near some of the ore deposits. All varieties of the rhyolitic rocks contain some chlorite, but "chloritic rhyolite" designates rocks that contain large amounts of this mineral.

Outcrop surfaces of these rocks are variegated brown and white and, characteristically, are pitted and etched to a delicate cellular pattern. On close examination of the surface, it may be seen that the main component of the rock is tiny white grains usually .2 to .5 mm. in diameter, resembling spherulites. On broken surfaces the rock is dark green, massive, and very fine grained. Vitreous "quartz-eyes" abound in most samples and have a disposition and abundance identical to the quartz phenocrysts of the rhyolites.

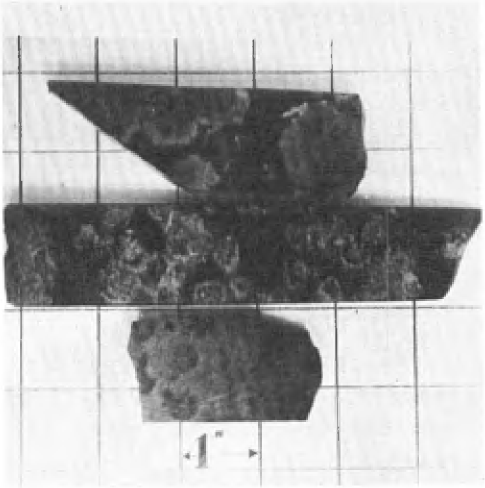
One facies of these rocks is particularly distinctive in that weathered surfaces have wart-like protuberances 3 to 30 mm. in diameter (Plate I-D). This is well displayed (indicated as "large spherules" on the map) in Galinée township a few hundred feet south of range-line VIII-IX and 4,000 and 8,500 feet east of the railroad tracks.

The "warts" on fresh surfaces are gray patches and in thin section appear to be an altered form of cordierite and muscovite, set in the typical matrix of the chloritic rhyolite. The rock resembles some of the "dalmatianites" of the Noranda district described by Wilson (1941, p. 67) and Walker (1930) that are considered to be highly metamorphosed rhyolites. Attempts made to confirm the presence of cordierite by X-ray diffraction were not successful.

Chloritized intermediate volcanic rock:- Dark green, massive, quartz-poor rocks outcrop and are intersected by drill-holes, at intervals, over a distance of eight miles in the south volcanic band. A liberal interpretation of the meager data suggests that these rocks are most abundant in an irregular zone, approximately 1,000 feet wide, which lies near the main mass of the Bell River complex. Smaller,irregular masses of these rocks occur elsewhere.

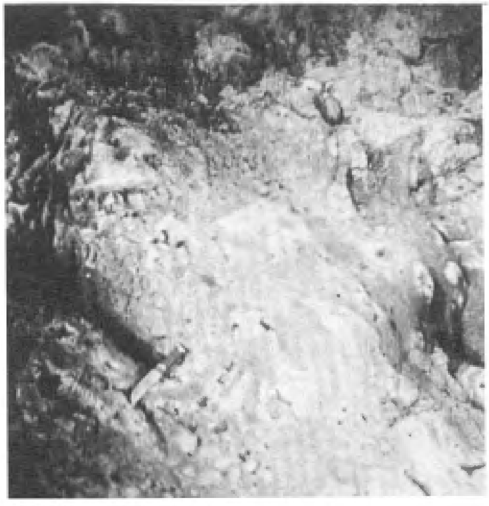
PLATE II

WABASSEE GROUP ROCKS



a) Variolitic structures in lava northeast of New Hosco mine. Upper specimen is from top of lava, in flow breccia, where the varioles appear to have been replaced by cherty silica.

b) Pillowed andesitic lava on shore of Matagami lake.



c) Mafic agglomerate near Inlet rapids.

d) Small fold in layered tuff on island in Matagami lake.

The rock is usually fine grained and structureless except for secondary features. In places, the texture has an ophitic aspect or the fine-grained rock grades into a granular gabbroic rock. Small vitreous "quartz-eyes" may become locally so abundant that the rock resembles the chloritic rhyolite. Amygdules filled with quartz and carbonate minerals are commonly present near the contacts and some pillow structures are suggested in drill cores by regularly spaced bands of chlorite.

The rock, as seen in thin section, is extremely altered. One specimen consists almost entirely of a mat of chlorite intergrown with small splotches of quartz. Laths of leucoxene and magnetite speckle the rock along with a few metablastic crystals of clear albite.

Alteration spots, analogous to the "warts" of the rhyolite, characterize the zone situated one mile east of Mattagami Lake Mines.

The general features of these rocks throughout the area suggest that they are altered lavas which are more mafic than the rhyolitic rocks. However, the lack of abundant volcanic structures (which characterize other mafic lavas in the area) indicates that some intrusive rocks may be present. And in fact similar rocks which occur as small,irregular masses at the Mattagami Lake mine are named "metadiabase".

The writer's opinion is that these rocks are mainly altered intermediate lavas with associated intrusions.

Mafic lavas (andesite-basalt):- Layers of mafic lava are intercalated with rhyolitic rocks along the north contact zone of the Lac Watson Group in the north volcanic band but none were seen south of the complex. The chloritized "intermediate volcanic rocks" described above are much more altered. The following descriptions are based mainly on examination of drill core at properties in the north band between those of New Hosco Mines, and Dumagami Mines Ltd.

The rocks have a dense lithoidal appearance which, near the interior of thick flows, grades to a fine-grained ophitic texture. The central parts of exceptionally thick flows are gabbroic, The presence of numerous amygdules, pillow selvages and interflow pyroclastic material establishes the extrusive nature of the rock. Where these features are absent, such as in the vicinity of the Bell river, the fact that lithoidal textures are maintained over widths of more than 50 feet indicates that the rock is lava,as sills with similar compositions and thicknesses invariably have only narrow marginal zones of lithoidal texture. However, narrow concordant intrusions of gabbro can seldom be distinguished with certainty from the lavas.

An interesting example of the difficulty in distinguishing lavas from intrusions may be seen in an island outcrop located in the Bell river, 2,500 feet north of range-line II-III. The outcrop lacks distinct lava structures but is uniformly fine grained and, from drill-hole information to the north, the rock becomes variolitic. There is high probability that the rock is a lava rather than an intrusion (and it is so indicated on Longley's map (1943). If so, the presence of xenoliths of anorthosite (Plate III-D), identical in appearance to the anorthosite in the interior of the Bell River complex, is disharmonious unless the lava activity accompanied the emplacement of the complex.

Wabassee Group

The volcanic assemblage here termed "Wabassee Group" underlies 50% of the area (Figure 2). It is characterized by thick flows of light-colored pillowed feldspathic lavas and contrasting dark mafic lavas. Abundant exposures of the feldspathic varieties are found along the Allard river and in the vicinity of Wabassee lake in Daniel township, whence the name was derived. Excellent exposures of the mafic varieties are scoured by wave and sand abrasion on the islands and shores of Matagami lake. Outcrops are scarce along the south volcanic band, particularly at the type-area of the Lac Watson Group but there are sufficient drill-holes to establish that the lava types at Wabassee lake and along the Allard river extend southeast across Galinée township and overlie the Lac Watson Group in its type area. Outcrops of the main rock types of the group may be seen along the Bell river, for 3,000 feet south and north of Inlet rapids.

Lithologic units

The group consists mainly of lavas that can be grouped for descriptive purposes into: dacitic varieties, andesite-basalt varieties and rhyolitic varieties. The other members are tuff, agglomerate and bedded cherty rocks (tuffite).

Dacitic lavas:- The term "dacitic" has been applied to varieties of light-colored feldspathic lavas, predominant in the west part of the area. In the eastern parts of the volcanic bands, they become intercalated with mafic lavas. Most of the lavas exhibit round, bulbous pillows whose rims are marked by a narrow selvage of pyroclastic material or a rind which is in places variolitic or spherulitic. Amygdules of quartz with rosettes of brown clinozoisite are another characteristic feature. Microscopic examination indicates that there is a range of compositions from sodic trachyte to dacite to rhyodacite.

In the sodic trachyte, small subhedral crystals and microlites of albite-oligoclase (and its micaceous and zoisitic alteration products) form 60 to 80% of the rock. These are arranged in felted or trachytic textures. Mafic minerals have been altered to irregular clots of chlorite, magnetite and epidote. Quartz is a minor component; usually less than 6% is visible under the microscope. Phenocrysts of oligoclase (Ab_{70}) are abundant in some samples.

The dacite lavas are similar in appearance to the sodic trachyte except that more quartz and dark minerals are present. A typical sample consists of cloudy, felted microlites of feldspar (mainly oligoclase) set in a cryptocrystalline matrix of light-colored and semi-opaque minerals. The only discernible mafic minerals are clots of epidote and chlorite and grains of clinozoisite. Carbonate minerals are scattered erratically through the rock. Quartz is intergrown with the matrix minerals and occurs also as rounded phenocrysts.

In a few places along the south volcanic band and also northeast of Wabassee lake, some of the dacitic lavas are particularly hard and contain abundant quartz phenocrysts. These lavas are probably rhyodacite. A contorted lens of rhyolite outcrops west of Dunlop bay.

A variety of variolitic lava outcrops at intervals along the north volcanic band, east of Allard river, near the east-west center line of Daniel township. The outcrop surfaces are a mass of protuberances 5 mm. to 30 mm. in diameter. In a drill core these were seen in stages of development from vague spots in dark green lava to concentric variolitic structures to distinct spheres of cherty material (Plate II-A). A thin-section of the cherty stage shows that the spheres are composed mainly of cryptocrystalline quartz with epidote. An X-ray diffraction pattern indicated a small amount of albite-oligoclase. The interstitial materials are shreds of strongly pleochroic chlorite.

Andesite-basalt:- The andesite-basalt lavas are intercalated with the dacitic flows throughout the area but form particularly thick and extensive units in the vicinity of Matagami lake.

Outcrops have brownish, relatively smooth surfaces in contrast to the hackly appearance of the dacitic rocks. The lavas range in color from black to green; in texture from dense lithoidal to fine-grained diabasic, even within single flow-units. Thick layers of ellipsoidal pillows are common (Plate II-B) and flow breccias, disrupted lava crusts and layers of tuff mark flow contacts. In the area southeast of Matagami lake the lavas are particularly massive, only locally pillowed or mixed with ejectamenta. Porphyritic varieties are common here and the rocks are difficult to distinguish from the ubiquitous gabbro sills.

Under the microscope some of these rocks retain primary crystalline, microlitic or interstitial textures; others appear to be composed mainly of devitrified and altered glass. Pervasive low-grade alteration has obliterated both original minerals and textures.

A porphyritic variety (from an outcrop east of the mouth of the Bell river) has a dark green, semi-opaque cryptocrystalline matrix. It is probably a devitrified glass as a few microlites are present and exhibit the "swallow-tail" form characteristic of skeleton crystals (Johannsen, 1948, p. 15). Euhedral and subhedral zoned andesine phenocrysts form 25% of the rock.

A sample from the interior part of a flow that outcrops on the largest island near the mouth of the Allard river has a chemical composition (Appendix B) between, or close to, those of "average basalt" and "average quartz basalt" (Barth, 1959, p. 69) except for the very low quantity of potash. The soda proportion is that of "average plateau basalt" (Rittman, 1962, p. 105), thus the rock is not spilitic. The normative feldspar is An_{55}.

<u>Tuff and agglomerate</u>:- Pyroclastic ejecta form narrow layers and irregular lenses and wedges between lavas, and in many places the thickness of these deposits exceeds several hundred feet. Fine-grained tuffaceous rocks are particularly abundant in northern Daniel township and, here, in places resemble bedded, waterlain sedimentary rocks. In most outcrops or drill core, the tuffaceous materials are so altered or schistose that only the layered aspect and the intercalation with lavas or coarser pyroclastic debris indicate the origin of the rock.

The tuffs are variable in composition and texture. Some layers resemble laminated black siltstone and graphitic slate. Most commonly, the layers are thicker or not bedded and vary in color from dark green to brownish green (Plate II-D). Lapilli tuffs are common. Narrow layers of chert and chertified tuff are intercalated with the pyroclastic materials.

The agglomerates are closely related in composition to their enclosing lavas. Mafic varieties with bombs and scoria, may be well preserved (Plate II-C). The pyroclastic rocks in the basal part of the Wabassee Group contain here and there a block of spherulitic rhyolite probably derived from the underlying Lac Watson Group.

The coarser agglomerates usually have angular fragments but, in places, a few rounded pebbles of lava are present. The southernmost of the exposures in range VI, Daniel township, immediately east of the Allard river, are not layered and contain blocks up to 40 cm. in size of rhyolite, dacite and chert embedded in a fairly even-grained groundmass of granule size. In the outcrops to the north, the groundmass is crudely sorted and contains rounded pebbles. This suggests that there has been some local reworking by fluvial agencies.

"Tuffite":- Laminated chert and other materials form thin horizons within the Wabassee Group and one of these marks the base of the group over a distance of six miles in Galinée township.

The rock type, although quantitatively insignificant, is of particular interest because of its unusual appearance (Plate IV), its stratigraphic continuity and the fact that certain layers are intimately associated with sulfide deposits.

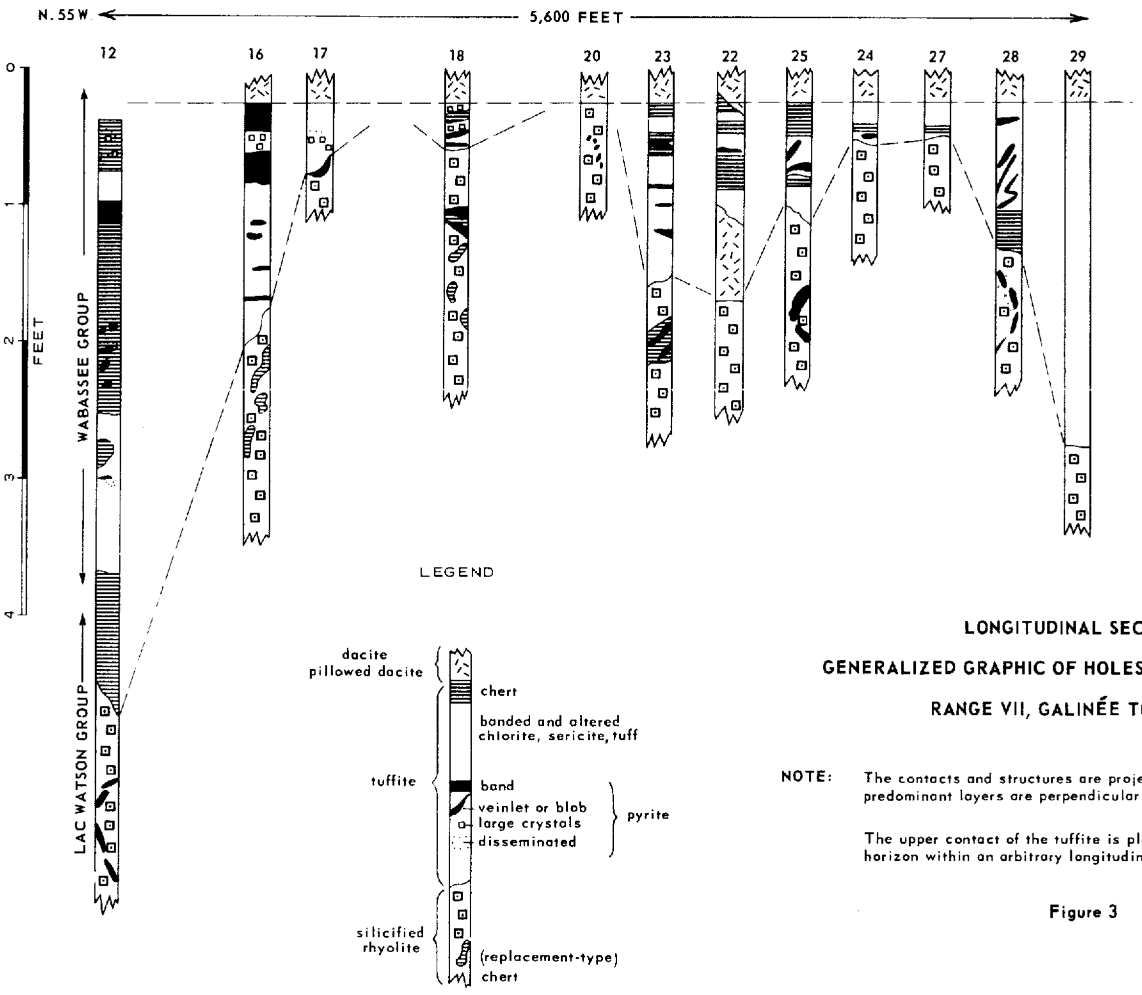
At the mines the rock is termed "tuffite" and a particular unit, known as the "key tuffite" or "KT" is the basal tuffite mentioned above. There are no outcrops of the typical rock. The descriptions are based mainly on 90 drill-core intersections, distributed throughout the area.

The general name "tuffite" has been applied to rocks composed of a mixture of fine-grained sedimentary and pyroclastic detritus. The term serves in the present instance although some components appear to be chemical sediments.

The tuffite has two main modes of occurrence: at the contacts between lavas and in intercalations with tuffaceous pyroclastic deposits. The "key tuffite" in the south volcanic band is similar to the other tuffite horizons except for its greater persistence. The general characteristics can be illustrated by graphic logs (Figure 3). The most notable features are: The thickness varies in a crudely systematic way and the layer pinches out in places; the banding in the rock is commonly discordant to the lower contact; in combination with the first feature, this indicates that the depositional surface was irregular; the rock is heterogeneous, and no consistent sequence of beds can be recognized (even in drill-holes a few feet apart); the rocks immediately below the tuffite are rhyolite, mottled and impregnated by blebs and veinlets of cryptocrystalline silica.

The tuffite layers within the thick deposits of pyroclastic rocks near the New Hosco, Radiore and Bell Channel sulfide deposits are commonly so disrupted as to form autoclastic breccia. Some agglomerate contains a few isolated angular fragments of laminated chert in addition to the lithic fragments that make up the bulk of the rock.

Individual tuffite beds range from a few inches to more than 15 feet in thickness. Most are less than 2 feet. The distinctive



LONGITUDINAL SECTION

GENERALIZED GRAPHIC OF HOLES THROUGH TUFFITE

RANGE VII, GALINÉE TOWNSHIP

NOTE: The contacts and structures are projected and reoriented so that the predominant layers are perpendicular to the trace of the drill hole

The upper contact of the tuffite is placed at an arbitrary reference horizon within an arbitrary longitudinal plane

Figure 3

D.N.R.Q. 1967 B-886

feature of the rock is its delicate lamination and layering which in some instances resembles a colloform banding (Plate IV-B) but, usually, even lamellae of .5 mm. are planar and continuous for several feet.

The main constituents of the lamellae or beds are chert, chlorite, sericite, semi-opaque crystocrystalline materials mixed with phyllo-silicates, altered very fine-grained tuffaceous material, and sulfides. Carbonate minerals and magnetite are abundant in some beds but are not characteristic components.

The chert layers consist of microcrystalline and cryptocrystalline sutured quartz grains which contain numerous inclusions and transecting shreds of chlorite, sericite and other crystallites. Variations in the amounts of these color the individual lamellae and beds different shades of gray and green. No clastic textures could be discerned.

Some layers are composed mainly of a soft light gray phyllo-silicate which, under the microscope, is seen as tiny shreds, resembling a clay mineral with an aggregate polarization and low birefringence. Diffractometer graphs and a chemical analysis (Appendix B, samples from Mattagami Lake Mines property) indicate that the phyllosilicate is sericite, perhaps soda-bearing or mixed with paragonite.

Pyrite and pyrrhotite, occurring as regular layers, small nodules and disseminations, are fundamental constituents of these rocks. Chalcopyrite and sphalerite, though commonly present in small amounts, usually occupy post-lithification structures such as fractures or narrow schisted zones. The disposition of these minerals can be discussed most pertinently in the descriptions of the sulfide deposits.

The general field relations indicate clearly that the tuffite units were deposited during volcanism. The discontinuities and erratic variations in the lithology of individual units indicate that they are not homogeneous stratigraphic "horizons" but coalescing deposits of polygenetic volcanic products which are particularly extensive along certain stratigraphic zones.

Sedimentation of silica is common in volcanic terrains, particularly those affected by thermal springs and fumarole activity. For instance in Iceland, silica sinter "--- makes up extensive deposits, flats or domes approaching 100,000 m^2 in area" (Barth, 1950, p. 113). Some of these deposits consist of regular layers of chert and clay, similar to some sections of the Matagami "tuffite". The cryptocrystalline texture, the opalescent appearance of the chert, and the colloform silica layers in the tuffite suggest that quartz was not the original crystallographic form. Amorphous or opalescent silica invert to alpha quartz, the only form ever observed in Precambrian rocks (Pettijohn, 1956, p. 437).

Some of the pyrite in these rocks has a bedded aspect and is folded (Plate IV-A). It may be indigenous to the volcanism as there are numerous recorded instances of the formation of pyrite in the volcanic environment. For example in Iceland, Barth (1950, p. 47) notes: "Pyrite forms a heavy secondary precipitate in a few acid springs --". Bernauer (Friedman, 1959, p. 279) describes the formation of iron sulfides in tuff around the crater of the island of Volcano. Markhinin (1961, p. 42) mentions the pyrite deposits exposed by erosion in the solfatara fields in the Kurile islands and Hegemann (1948) notes that extensive accumulations can form with submarine volcanism.

Some components of the tuffite thus appear from their disposition and lithologic character to be akin to deposits formed by thermal springs. Whether in fact they are related to sub-aerially deposited siliceous sinters and their associated alteration minerals or to an analegous subaqueous environment is uncertain.

Intrusions related to volcanism

Fine- to medium-grained rocks with intrusive contacts, but with the appearance of the various lava types, may be seen throughout the volcanic sequences. Examples of transgressive relations can be seen at Inlet rapids where sills of porphyritic andesite-basalt disrupt layers of agglomerate and pillowed lava. The petrography of the rocks is similar to that of the massive gabbroic portions of the thicker mafic lavas.

Several small intrusions of felsitic rocks are difficult to recognize where they intrude dacitic lavas. Many of the drill-holes along the south volcanic band transect homogeneous granular dacitic rocks intercalated with pillowed dacitic lavas, rhyolite and tuffite. Some of these granular rocks transgress the stratification. Dikes of porphyritic and spherulitic rhyolite have also been observed within the Lac Watson Group but are very rare within the Wabassee rocks.

Small dikes, similar in appearance to various members of the volcanic suite, were seen in several of the drill cores from the interior of the Bell River gabbroic complex (e.g. range IX, Galinée twp.). These are definitely dikes, quite readily distinguished from the altered inclusions of lava which have also been observed.

Correlation of volcanic sequences

The inherent irregularity of volcanic deposits and the limited exposures in the area inhibit any but the rudest stratigraphic correlations. However, a broad pattern in the distribution of lava types and sequences, combined with structural information, allow gross correlations; particularly the delineation of the Wabassee and Lac Watson groups' contact. The distribution of lava types is illustrated in Figure 2 and the general sequences at critical localities are indicated in Table 1.

The general sequence in the south volcanic band is well established as the structure is generally homoclinal. The tuffite in the Watson Lake section is considered to be the base of the Wabassee Group here as no dacitic lavas have been found below it. However some of the rhyolitic rocks, below the chert, are similar to the spherulitic units of the Wabassee Group at Mattagami Lake mine and thus a detailed correlation on the basis of lithology would be imperfect.

The Allard River sequence faces north and is part of the north volcanic band. The sequence can be correlated across an anticlinal axis with the south volcanic band.

East of the Allard river information is scanty but at several localities where drill-hole data are available, there is a more or less well-defined zone that marks the south limit of Wabassee-type rocks and the north limit of Watson-Lake-type rocks. Lavas of the two types are intercalated and structural relations are uncertain. Thus the indicated stratigraphic separation is based on the gross aspects of the lithology rather than the more precise distinctions that are possible elsewhere.

The Bell River sequence has thick mafic lavas. Similar lavas occur in the lower part of the Wabassee Group in the Véract section, across the Bell River complex, but not in the western part of the south volcanic band. The northern contact of the spherulitic rhyolite in the Bell River sequence could be considered to be the base of the Wabassee Group but, because of the possible structural complications, a direct correlation is uncertain.

Alteration and metamorphism of the volcanic rocks

The volcanic rocks exhibit alteration and metamorphism of diverse character and intensity as follows: 1) regional low-grade metamorphism; 2) schists in zones of dynamic metamorphism; 3) amphibolite-stage contact metamorphism; 4) zones of intense chloritization and spotted alteration rocks; 5) silicified rocks.

Table 1

Volcanic Sequences and Correlation*

	SOUTH VOLCANIC BAND			NORTH VOLCANIC BAND	
	Véract River	Mattagami Lake M.	Watson Lake	Allard River	Bell River
Wabassee Group	Pillowed dacitic lavas (± 6000) **		Mainly pillowed dacitic lavas and pyroclastic rocks. Some andesitic lavas and variolitic zones (+ 6000)	Folded basic lavas and pyroclastic rocks - - - - - - - - - - - Mainly pillowed dacitic lavas, variolitic horizon (± 6000)	Folded basic lavas and pyroclastic rocks - - - - - - - - - - - - Pillowed dacite (± 1000)
	Mainly andesitic lavas cherty tuff beds near base (± 1400)	(± 2800) spherulitic rhyodacite (± 600)			Mainly andesite, cherty tuffs to south. (± 5000)
	Pillowed dacitic lavas (± 500)	(± 900)			Spherulitic rhyolite (± 1000)
	Cherty tuffite (± 3)	(± 10)	Cherty tuffite (± 2)	Cherty tuffite tuff, agglomerate and lavas (± 1000)	Tuff, agglomerate cherty tuffite
Lac Watson Group	Porphyritic rhyolite, spherulitic rhyolite, chloritized and silicified volcanic rocks (+ 200)	(+ 3000)	Spherulitic rhyolite, rhyolite, silicified and schistose rhyolitic rocks (+ 2000)	Spherulitic rhyolite and rhyodacite (+ 800) ? ?	Spherulitic and porphyritic rhyolite and basic lavas (± 2000) ? ?
	Bell River Complex		Bell River Complex	Gabbro sills and dikes	Bell River Complex

* Location of sections on Figure 2.

** Order of true thickness or outcrop width in feet. Includes small intrusive masses.

In general, the Wabassee rocks are less extensively and less intensely altered than the Lac Watson Group. However, though their primary characteristics of texture and structure may be well preserved, the mafic minerals are converted to uralite, chlorite, epidote and magnetite, and feldspars are clouded with secondary minerals or replaced by saussurite. These minerals are characteristic of the greenschist facies of regional metamorphism but include also the products of deuteric and diverse hydrothermal processes.

Linear zones of foliate rocks occur along the flanks of the Bell River complex and in the north part of the area. These encompass narrow zones of schists composed of chlorite, sericite, talc, carbonate, quartz and feldspar. In part the schists represent fault zones and, as these trend parallel to fold axes, they reflect regional deformation.

The volcanic rocks along the margins of the granitic plutons in Isle-Dieu township are blackened and coarsened by amphibolitization. Some beds of fine-grained tuff are converted to mica schists. Amphibole hornfels occur at the Garon Lake Mines' property and these include cordierite-anthophyllite hornfels.

The fourth type of alteration has resulted in the conversion of large and small parts of the Lac Watson rocks to chloritic material and the development of the "chloritic rhyolite" and the spotted rocks (dalmatianite ?) described previously. In some instances, rocks with the textural appearance of rhyolite consist mainly of chlorite and quartz and are transected by vein-like masses of these minerals. Such extreme effects characterize some of the host rocks of the sulfide deposits.

The degree of chloritization is erratic but, on a broad scale, is spatially related to the margin of the Bell River complex. No specific attempt was made to determine whether there might be a progression of alteration effects towards the margin of the gabbro. However, volcanic rocks observed close to the south margin of the complex are extremely metamorphosed; chloritized rhyolitic rocks grade to mottled hornfels and chlorite-rich aplitic or granophyric material and then merge with gabbro that contains much occluded quartz.

Large inclusions of pillowed lava in the Bell River complex can be seen at Chenal rapids (Plate III-B) and, in these, the rock is completely reconstituted and splotched with large porphyroblastic clots of pyrobole.

The preliminary observations on the chloritized rocks and, in particular, the gradations of rhyolite to masses of chlorite indicate that considerable iron and magnesium have been added to these rocks.

Silicified rocks

Silicified structures and zones are common in the Lac Watson rocks, and their field relations and character are described in the section on "brecciated and silicified rhyolite". In general the silica is microcrystalline and cryptocrystalline quartz, with a cherty appearance, that impregnates the walls of ramifying fractures and brecciated materials or forms blobs or veinlets (Plate I). The zones of silicification commonly are stratigraphically limited; the apex being along the base of layers of cherty tuffite.

Limited microscopic observations indicate that the introduction of silica may also be associated with bleaching, albitization and the formation of secondary white micas. Commonly, but not invariably, the rocks contain abundant chlorite.

The structures that control the silicification do not appear to be related to regional deformation; evidence for this is the superposition of foliation and "tectonic" joints on the silicified structures, and some of the more regular patterns resemble columnar jointing (Plate I-B).

The relations outlined above suggest that the cherty type of silicification of the Lac Watson rocks is the imprint of large-scale hydrothermal processes during the volcanism. The hypothesis accounts for the association of chertified rocks and epigenetic silica with bedded chert and the stratigraphic circumstances. The sites and structural controls of the alterations correspond to openings that existed before the regional deformation and metamorphism. A survey of the literature indicates that there is a high probability that alteration of this type can be as extensive as that observed.

Environments of extrusion

The general disposition of the lavas and volcanic deposits give a few clues as to the conditions of eruption.

The Wabassee Group consists in large part of pillowed lavas interstratified with tuffaceous pyroclastic materials. Some sectors resemble truncated sections of strato-volcanoes. No eruptive vents could be identified although the abundance of bombs and coarse breccias throughout the area and the abrupt lateral variation in the compositions of the lavas suggests that there were several sources or centers of eruption.

Pillow structures are abundant. Some pillowed lavas appear to be local facies of more extensive flow units, merging laterally and across the dip with massive lava. The pillowed zones tend to occupy the upper parts of flow units.

As noted by Shrock (1948, p. 362), "Most geologists now seem to accept the opinion that pillows form in lavas ... which come into contact with marine or fresh waters. Extrusion need not be subaqueous necessarily, but apparently extraneous water must be present ...". Rittman (1962, p. 72) considers that true pillow lavas can form only under water.

Thus some of the Wabassee lavas were extruded in an aqueous environment. They are presumably not abyssal submarine lavas as there are abundant amygdules and evidences of explosive activity which seem incompatible with very high pressures.*

Evidence of erosion or aqueous sedimentation are scarce. A few of the tuffaceous deposits in the Wabassee Group may be water sorted, particularly those at Radiore Mines that are interstratified with iron formation.

Certain rhyolitic pyroclastic units to the west, near the Allard river and elsewhere, resemble welded tuffs and compacted pumiceous material. It is unlikely that these rocks could form under water as the components must have maintained a plastic state during lithification.

North and south of the boundaries of the area lavas do become intercalated with sedimentary rocks. Presumably these lavas were extruded in sedimentary basins.

The Lac Watson Group rocks have the petrographic character of lavas and locally are interstratified with volcanic pyroclastic material. But distinct flow or lava units are seldom discernible. In this respect they differ from those of the Wabassee Group. More recent volcanic rocks of the composition of the Lac Watson rocks tend to be extruded, not as simple lava units but in "endogeneous domes" such as those of Java (Rittman, 1962, p. 25). The heterogeneity and lack of distinguishable flow units in the Lac Watson rocks may reflect this form of extrusion.

The extrapolation of such skimpy date to indicate the general conditions of the volcanicity is somewhat subjective. The writer's opinion is that both sub-aerial and sub-aqueous eruptions occurred in transitory lacustrine or shallow-sea environments. During the eruptions, thermal waters permeated and altered the volcanic rocks, silicified zones near fractures, impregnated porous pyroclastic deposits and, in some localities,

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* Rittman (1962, p. 50) notes that below 2,000 m., hydrostatic pressure exceeds the critical pressures of water and considers that extrusion will be "a completely quiet process ..."

reached the top of the volcanic complex to contribute silica to sediments that became interbedded with tuffaceous materials. These tuffites are most extensive at the contact between the Lac Watson and Wabassee Groups. This contact marks a large-scale change in the nature and composition of the eruptions and one might conclude that the Lac Watson rhyolites mark the end of a volcanic cycle. If so, the earlier (presumably mafic) components of the cycle have not been identified.

It may be speculated that such a fundamental change, whatever its true nature, accompanied a temporary diminishment of extrusive activity. This hypothetical lull in lava activity could account for the relative areal extensiveness of tuffite and pyroclastic deposits along the top of the Lac Watson Group. Elsewhere in the volcanic section the thin beds of tuffite and pyroclastic deposits lack this stratigraphic continuity as they interfinger with lava units.

Intrusive Rocks

Most of the intrusive rocks fall within the following three divisions:

Older intrusions; the Bell River complex of gabbro and anorthosite and small intrusions of peridotite and quartz diabase;

Younger intrusions; granitic to dioritic masses and affiliated dikes;

Late diabase dikes.

Small dikes of diverse composition and affiliation are also numerous.

In general the "older intrusions" were deformed with the volcanic rocks, whereas the "younger intrusions" tend to transect the main tectonic structures and are probably syntectonic or post-tectonic. The diabase dikes transect all rocks and fold structures and, presumably, are Late Precambrian in age.

Older Intrusions

Bell River complex

An elongate pluton of layered gabbroic rocks underlies the central and eastern parts of the area. This is the western extremity of the Bell River complex (Figures 1 and 4).

The first evaluation of the complex was based on the reconnaissance mapping by Freeman (1939). The western part of the complex was mapped again by Freeman and Black (1944) and by Longley (1943). Black (1942) made a specific study and was the author of the 1944 report. Freeman concluded that the complex is a deformed lopolith with bilaterally symmetrical limbs of "basal norite" which enclosed a "banded zone" and an interior "gneissic cataclastic zone". Black (Freeman and Black, 1944) does not revive this terminology. Black (1942) showed that Freeman's first delineation and interpretation of the zones were incorrect and suggested that several folds are present.

The writer's description will be limited to 25% of the total area of the complex which is within the map-area. This is a critical sector as it encompasses both the "limbs" of the intrusion and the section along the Bell river which has provided most of the data discussed by previous workers. Hereinafter the term "complex" refers only to the sector mapped by the writer unless indicated otherwise.

Three spatial divisions of the complex can be made (Figure 4) and these also reflect differences in petrographic and structural features. The divisions are: marginal zones; core zone; apophyses and subsidiary intrusions. It should be noted that the disposition of the intrusions on the maps is based, in part, on detailed ground magnetometer surveys. The reliability of the extrapolations can be judged from the presence or absence of outcrops and drill-holes indicated on the detailed maps.

Marginal zones

The marginal zones consist of intricately layered rocks that mark the north and south margins of the complex but do not appear to encompass the western nose.

The north marginal zone is 6,000 feet wide at Chenal rapids and can be traced for three miles on either side of Chenal rapids. Its western extension merges with magnetite-rich apophyses. The eastern extension trends south of east and appears to truncate a westward-striking mass of crudely layered gabbros. This relation is well expressed by magnetometer data due to the presence of a band of magnetite in the layers contiguous to the exposures at Chenal rapids.

The south marginal zone is similar but wider. Only the north part lies within the map-area, in the southeast corner. There is no concrete evidence, in the few drill-holes, that the layered rocks extend along the southwest flank of the pluton, or around its western extremity.

The characteristic banded aspect is mainly the consequence of variation in the proportion of feldspar to ferromagnesian minerals between layers or lensoid masses, enhanced by variations in texture. The widths of layers range from that of a few crystals to over 80 feet. A rude super-layering, expressed by the predominance of anorthositic or gabbroic rocks over widths up to 800 feet, is discernible at

Chenal rapids. Individual layers may have sharp or gradational contacts and the mineral composition may be homogeneous or vary asymmetrically. Rhythmic layering is common. The layers at Chenal rapids are not significantly asymmetrical as compared with similar rocks described by Freeman and Black south of the map-area (1944, p. 11). An interesting rhythmic clot and layer structure was seen at the west foot of Chenal rapids (Plate III-A). In a few places sill-like masses of fine-grained gabbro and,more rarely, irregular masses of granulated anorthosite transgress or form septa between layers.

The petrography of the marginal zone rocks is so variable that only a cursory description is possible here. The well-layered rocks range in composition from anorthosite (90% altered plagioclase) to uralitized pyroxenite (80% ferromagnesian). The varieties gabbroic anorthosite and anorthositic gabbro are most common. The pyroxenitic rocks tend to form irregularly shaped clots and lenticles.

The anorthosite varies from chalk white to greenish gray. The greenish varieties are less altered and are readily overlooked when present with gabbro. The feldspar is saussuritized,though remnants of fresh plagioclase ranging from An_{43} to An_{78} are usually discernible. The ferromagnesian constituents are uralite, chlorite, epidote and accessory ilmenite and sulfides. Iron-bearing carbonate is abundant in some zones. The rocks are medium to coarse grained, in places pegmatitic. Usually, the feldspar is severely fractured and comminuted. The ferromagnesian minerals are interstitial and where there is an enrichment in pyrobole, the feldspar is poikilitically enclosed.

A sample of white anorthosite from a layer on the east bank of Chenal rapids was analyzed (Appendix B). The rock contains 5% uralite and chlorite and 2% calcite. The plagioclase is completely saussuritized except for a few remnants of andesine (An_{45}). The analysis corresponds closely to that of "average plutonic anorthosite" (Barth, 1959, p. 70). The oxide proportions of Na_2O and CaO are equivalent to normative feldspar of composition An_{60}.

The gabbroic layers are medium- to coarse-grained rocks containing mainly altered feldspar, the remainder being some combination of hornblende, uralite, bastite, serpentine, chlorite, quartz, titaniferous magnetite, ilmenite and sulfides. Hypersthene has been identified in a few of these rocks but remnants of clinopyroxene are much more common. The textures range from granitic to diabasic to poikilitic. Primary foliation marked by the orientation of feldspar laths is common.

Some layers, or sills, are relatively homogeneous fine-grained diabase. These also may have a subtle layered aspect. No attempt was made to discern crypto-layering, though this is probably present.

A layer of titaniferous magnetite and magnetite-rich gabbro crosses Chenal rapids and can be traced intermittently for more than three miles. Similar layers of magnetite-rich rock occur south of the map-area but appear less extensive. Samples of the Chenal rapids band contain traces of chromite (Appendix B).

The layered structures are common to many gabbroid complexes for which numerous hypotheses have been proposed. Barth (1959, p. 197) points out that none of these are satisfactory. There is general agreement that the crystal layers are a characteristic of thick stratiform intrusions. Thus, the layered structures in the Bell River complex which now dip steeply presumably have been tilted from an original near-horizontal attitude.

Core zone

The core zone of the complex is characterized by a lack of well-defined layering and a low content of magnetite and ferromagnesian silicates in the rocks, contrasting in these features with the marginal zones. The contact with the marginal zone is gradational.

The predominant rock type is a coarse-grained gabbroic anorthosite with pegmatitic masses of subhedral feldspar. These pegmatitic crystals are commonly 15 cm. long and merge with poikilitic intergrowths of anhedral plagioclase (Plate III-C) in a base of ferromagnesian material (bastite and uralite where determined).

The feldspars are opaque white and under the microscope are seen to be mainly pseudomorphic masses of saussurite. Some labradorite was found in one sample. Irregularly shaped zones of pegmatoid uralitized pyroxenite are mixed with the feldspathic rocks.

The rocks in general contain between 60 and 80% feldspar, or its alteration products, thus appearing more feldspathic than the gross composition of the layered marginal zones. Ilmenite and titaniferous magnetite are very minor constituents.

Apophyses and subsidiary intrusions

Numerous semi-concordant intrusions occur around the periphery of the main complex. As these have a distinct spatial relation to the complex (Figure 4) and are in large part petrographically similar, they are considered to be subsidiary intrusions.

The intrusions are sill-like but in places transect strata at low angles. The contacts are rarely observed in outcrop but in drill core are usually marked by fine-grained border-facies. Some thin sills contain a few amygdules and the rocks are not easily distinguished from the massive mafic lavas. Stratiform mineralogical layering is present in the thick sills north of Chenal rapids.

The rocks of the subsidiary intrusions are various types of gabbro, quartz gabbro, diorite and anorthositic gabbro. Primary minerals are so scarce that a precise petrographic classification is not possible.

The most common varieties are dark greenish-black, fine- to medium-grained rocks composed of saussuritized feldspar, uralite, hornblende, epidote, chlorite and accessory quartz, titaniferous magnetite, leucoxene, sulfides and apatite. The altered feldspar usually constitutes 40 to 60% of the rock, and the ferromagnesian alteration minerals are arranged in a sub-ophitic fashion. Some samples have up to 10% quartz and others contain pseudomorphic masses of serpentine after olivine and pyroxene.

Some of the rocks, mapped as gabbro, might be termed "gabbro-diorite" as the only fresh plagioclase observed (in one of three thin-sections) was An_{45}. The normative feldspar composition of a sample of medium-grained "gabbro" (Appendix B) resembles that of diorite. However, except for the oxide proportions of CaO and Na_2O, the composition is more similar to average "plutonic gabbro" (Barth 1959, p. 69).

A distinctive porphyritic gabbro forms individual dikes and local facies within equigranular intrusions. These are common only in the subsidiary intrusions to the south and west of the main complex. The rocks are characterized by numerous rounded white phenocrysts of feldspar* which in places become so abundant that the rock resembles a coarse-grained gabbroic anorthosite. The matrix is variable; in some samples it is diabasic and contains comminuted fragments of the phenocrysts.

The phenocrysts are less distinct under the microscope as they are completely altered to semi-opaque saussuritic material. The matrix contains less altered, strongly zoned plagioclase and secondary ferromagnesian minerals.

The comminuted aspect of the phenocrysts indicates that they are allothigenous. That is, they were carried and abraded within the gabbroic magma which formed the matrix. This and the resemblance of some of the dikes occurred during a differentiation of anorthositic components of the complex.

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* The apt term "polka-dot gabbro" is in general usage in the area.

Structure of the northwest part of the complex:

The unexposed areas of the complex leave broad avenues for speculation. An early interpretation was that the complex is a lopolith, as in the case of the Bushveldt and Stillwater complexes, folded into a tight syncline (Freeman 1939, p. 41). Black (1942) indicates that the gross structure is much more complicated and in a diagram shows seven hypothetical fold axes across a transverse section.

An evaluation of the structure should integrate: the disposition of the complex's margin in the structure of the volcanic rocks, the internal layering structures, the gross symmetry and asymmetry of the various zones, and the petrographic and petrogenetic features of the rocks.

An evaluation of the latter aspect will not be attempted here. It is the writer's opinion that there is not a close analogy between the petrography of this part of the complex with that of the basal sectors of the Stillwater and Bushveldt complexes. For example, no large volume of olivine-rich or ultrabasic rocks has been identified. There are similarities to the medial and upper parts of these complexes as described by Peoples (1933) and Hess (1960), and these correspond to the general scheme of basic complexes proposed by Buddington (1943, p. 123).

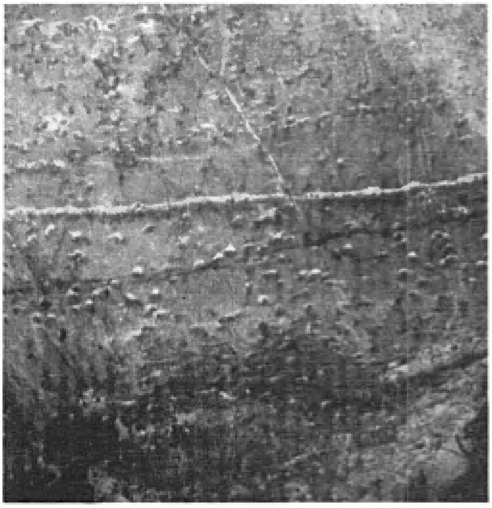
All observers of the Bell River complex agree that the intrusion has been folded. The problem is to determine the form of the fold or folds.

The field relations indicate that this part of the complex occupies an anticlinal structure and in this respect is akin to the Chibougamau anorthosite as described by Norman (1936, p. 772).

The main evidences are: the mineralogical layers at the margins of the complex dip steeply and are rudely parallel to the volcanic rocks, indicating that the complex has been tilted after differentiation. The volcanic sequence south of the complex dips moderately south and is upright. There is a similar but reversed volcanic sequence north of the nose of the complex. Thus, parts of the volcanic bands that encompass the complex are the limbs of one large asymmetrical anticline or north and south limbs of different anticlines. The rocks of the "marginal zone" are not repeated in the interior of the complex. This suggests only one major fold which would be coaxial with an anticline at the Allard river. The very few stratiform structures in the medial part of the core zone are oriented transverse to the layers in the marginal zone, as may be expected in the axial zone of a fold.

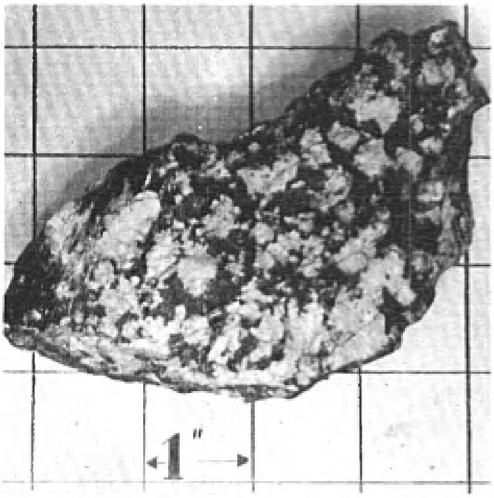
PLATE III

BELL RIVER COMPLEX ROCKS



a) Clots of pyrobole with feldspar "caps" in layered gabbro at Chenal rapids. Top of photograph is northward. Note dual layer of pyrobole (dark gray) and feldspar (white) and lack of clots to the north of it.

b) Metamorphosed inclusion of pillowed lava at Chenal rapids. The asymmetry suggests that the pillows face northward (toward bottom of photograph).



c) Poikilitic feldspar in altered pyroxene base at Bancroft island.

d) Xenolith of anorthosite in basalt or fine-grained gabbro north of Chenal rapids.

This interpretation must be qualified because of the possibility that subsidiary fold structures may not be recognized. It should also be noted that the layered zone at Chenal rapids has not been conclusively identified as either the original lower or upper part of the complex (on the assumption that these exist in simple form). If the "top" of the layered rocks here can be demonstrated to be southward (rather than northward as implied by the general interpretation) then there may be an unrecognized syncline, perhaps located north of Bancroft island.

Another complication is possible. Some of the subsidiary sills are multiple intrusions, as may be seen where chilled margins transect earlier injections (an example can be seen on the west bank of Bell river, opposite the sulfide mass). The apparent truncation of coarse gabbros by the layered marginal zone has been noted (p. 30). This, again, indicates the possibility that the complex is a composite intrusion; perhaps the emplacements of the subsidiary intrusions, marginal zones and core zone were sequential events.

The positions of the complex's margin in the volcanic sequence, the bilateral symmetry of the petrographic facies, and the internal structures of the plutonic rocks conform, in the simplest interpretation, to a large anticlinal structure.

Possible consanguinity of gabbros and the mafic lavas:- The recognition of the folded nature of the complex raises the question of its relation to the volcanic suite. There are petrographic similarities between the plutonic and mafic volcanic rocks but these have not been studied intensively or extensively enough to present definitive comparisons.

The margins of some of the gabbro sills in the south volcanic band are fine grained and locally amygdular. This suggests that they were intruded at a comparatively shallow depth. Mention has been made of possible xenoliths of anorthosite in lava (p. 17).

Longley (1943, p. 16) notes that "since some of the smaller presumed offshoots from the main body of gabbro are near the top of the volcanic series, their intrusion must have taken place toward,or after, the close of the period of volcanic activity ..." but he considers: "that the fact that the feldspars of the gabbro are more basic than those of the flows strongly suggests that the gabbro is not a differentiate of the magma that produced the flows". The writer would hesitate to assign any limitations on the basicity of the feldspars in the andesite-basalt lavas, but agrees that the general field relations are in accord with the first quotation and considers that the Bell River complex and mafic lavas were comagmatic.

Peridotite

Small intrusions of altered peridotite occur at Mattagami Lake Mines and two miles to the southwest. The peridotite at the mine has a synformal base of granular, black, serpentinized peridotite, rich in magnetite, which grades upward into a more feldspathic rock and gabbro. The chronological relation of the peridotite to the rocks of the Bell River complex is uncertain. No gabbro dikes were seen to cut the peridotite but it appears to have been folded and is transected by siliceous dikes.

Quartz diabase

A distinctive porphyritic diabasic sill or dike was transected in the center of Orchan Mines' property. Similar rocks have been intersected in drill-holes near the south end of Watson lake and also one mile west of this lake. The rock appears fresher than the ubiquitous gabbro of the Bell River complex but may be related. The intrusions are medium grained and the texture is distinctively diabasic. The upper and lower sectors contain subhedral feldspar phenocrysts. The equigranular part consists of saussuritized plagioclase, set in a base of uralitized colorless clinopyroxene with incipient alteration to serpentine, chlorite and clinozoisite, and splotches of myrmekitic quartz.

Younger Intrusions

Granite, granodiorite, quartz diorite, siliceous, feldspathic and mafic dikes

An elongate intrusion of granitic and dioritic rocks extends westward across ranges III and IV of Isle-Dieu township to the Bell river. Drill-holes in the eastern part of range III intersected typical pink biotite and hornblende granite and granodiorite. Similar rocks which outcrop near the Bell river contain lesser amounts of potash feldspar and quartz and were termed quartz diorite and granodiorite. These rocks may represent an apophysis of the Olga quartz-diorite batholith which intrudes the Bell River complex (Longley, 1943, p. 18). Rocks of granodioritic affinity also occur along the southwest margin of the complex in ranges IX and X, Galinée township.

The western extremity of an elongate pluton of granite, termed the Dunlop intrusion, outcrops around Dunlop bay in the northeast corner of the area. Within the map-area, it is mainly a massive, coarse-grained, pink granite. Syenitic and monzonitic facies and hybrid rocks occur along the south margin of the pluton. The Dunlop intrusion and allied rocks are younger than the main gabbro and diorite intrusions as the granitic rocks are relatively fresh and under-developed and their conjugate dikes cut the mafic rocks.

Small light-colored siliceous and feldspathic dikes were seen in many drill cores. Pink or gray sodic syenite porphyry dikes are most common. Less common gray diorite porphyry dikes cut the gabbroic rocks and tend to be emplaced in transverse fault or joint structures. Examples may be seen at Chenal rapids.

Miscellaneous mafic dikes of various ages and associations occur throughout the region. Their chronology is seldon determinable but they appear to be mainly congeners of the larger intrusions.

Black micaceous lamprophyres occur in the vicinity of Mattagami Lake Mines and elsewhere. A relatively fresh hornblende-oligoclase porphyry was transected in a drill-hole located west of New Hosco mine and similar dikes occur northwest of Watson lake and elsewhere.

Pink aplitic dikes and mottled hybrid aplitic rocks occur in the marginal parts of the Bell River complex. These rocks may be differentiates or contact effects of the gabbro rather than later intrusions.

Late Gabbro Dikes

Large dikes of coarse-grained quartz gabbro and diabase traverse the area in a northeast direction. The largest of these extends across the Allard river towards Matagami lake. The magnetometer data indicate that they have an *en échelon* arrangement.

As these cut all other intrusive rocks and orogenic structures in the area, and as they are similar in composition to other Late Precambrian dikes throughout the Shield, they are assigned to this age.

STRUCTURAL GEOLOGY

The predominant structural unit is a westward-plunging anticline whose axis crosses the Allard river in range IV and whose core is, in large part, considered to be occupied by the Bell River complex (Figure 2). North of this structure the volcanic rocks are folded along axes that trend eastward. Schist zones and transverse faults are abundant.

The folds, longitudinal faults and foliation are geometrically consistent and presumably are the imprint of one main period of deformation. The intensity of folding increases northwards.

Folds

The key to the main structure is found at the large bay in the Allard river where the south volcanic band coalesces with the more complexly folded north band. The pattern of lithologic units, in combination with top determinations on pillowed lavas, demonstrates that this is the axial zone of an anticline, which plunges west. It is probable that other, lower-order folds are present in this zone as it is difficult to correlate drill-hole data. Where lavas assume moderate or low dips, the asymmetry of their pillows becomes erratic or indistinct in horizontal plan, and their value as index of tops diminishes. This is the case in the vicinity of the Allard bay and is itself evidence for the axial zone of a fold. The position of the anticlinal axis on the map is approximately co-axial with the longitudinal symmetry axes of the Bell River complex.

The moderately dipping, homoclinal structure of the south volcanic band constitutes the south limb of the fold. Subsidiary structures, marked by deviations in the tuffite marker horizons, are present. A notable example is an asymmetrical anticline at Mattagami Lake Mines.

The north limb of the main anticline can be traced a few miles eastward and then merges with more complex folds of the north volcanic band. Outcrops are so scarce that the scattered top determinations only indicate that several fold axes must be present. The syncline in Matagami lake is better defined as a tight fold probably plunging east. The northwestern extremity of the area is the northern limb of an anticline as graded beds in the tuffs here face north.

Faults and Schist Zones

Faults, marked by breccia, gouge, or zones of intensely schisted and crumpled rock, are commonly transected by drill-holes but it is seldom possible to define the fault plane attitudes or extensions. The faults can be grouped into two general types: longitudinal faults marked by schist zones, and transverse (or oblique) faults.

Schist zones

Carbonatized schist zones, up to 100 feet wide, were intersected by drilling between the wide bay of Allard river in range IV and Watson Lake. These probably mark longitudinal fault zones.

Intricate faults marked by intensely crumpled schists transect many outcrops in Matagami lake. The main ruptures are oriented N.75°E. and a particularly schistose zone extends along the south shore of Matagami lake in Isle-Dieu township. To judge from the heterogeneity in the geometry of small-scale structures, the "movement-picture" is complicated. In general, the schist zones are parallel to fold axes and presumably have developed during the folding.

The longitudinal schist zones and faults at Matagami lake probably persist westward as similar schists occur in ranges VI and VII, Daniel township. It is suspected from little direct evidence that a fault extends across Wabassee lake and eastward, across the inlets in Allard river.

Transverse faults

Transverse faults are probably numerous as they are present in all sectors where the geology is known in detail. The strikes are usually between N.15°W. and N.15°E. Notable examples are found one mile north of Chenal rapids where segments of the stratified rocks are displaced short distances northward and southward. The most easterly of these faults passes beside an outcrop of gabbro in which an east-striking schistosity is crumpled and offset by closely spaced fractures oriented N.10°W. The other assumed faults in this area are marked by topographic scarps and valleys. Large transverse faults, assumed to underlie Dunlop bay and Matagami lake, offset the contacts of the Dunlop pluton and fold axes.

The best examples of transverse fault systems are those described in connection with the sulfide deposits such as at Orchan Mines.

Foliation and Joints

Secondary foliation or schistose fabrics are not pronounced, except near longitudinal faults. Development of the foliation is largely conditioned by the rock type.

The dacitic lavas of the Wabassee Group are brittle and have tended to fracture in an intricate pattern. The mafic lavas, pyroclastic rocks and chloritized rocks may be extremely fissile. Those which underlie Matagami lake and the area to the west have an incipient to pronounced schistosity that trends eastward, rudely parallel to fold axes.

The rocks along the margins of the granitic plutons, Isle-Dieu township, are markedly foliate and, where amphibolitized, assume a gneissose fabric.

Regular joints are present in the more massive intrusive rocks. Those of the Bell River complex include a system of oblique joints whose acute angles face toward the longitudinal symmetry axis of the complex. Other sets have diverse orientations, commonly parallel to primary foliation or layering.

ECONOMIC GEOLOGY

DESCRIPTIONS OF DEPOSITS*

Introduction

The main metallic deposits which have been found in the area consist of 12 more or less discrete concentrations of sphalerite and chalcopyrite and several zones of more dispersed sulfides. Three of the sulfide masses are being mined at present. The main deposits are listed below.

Matagami Sulfide Masses

		Approximate tonnage in millions of tons of ore-grade
SOUTH BAND	Mattagami Lake Mines Ltd.*	
	Main orebody	21.0
	No. 2 orebody	2.0
	Orchan Mines Ltd.*	
	Nos. 1, 2 and 3 orebodies	4.6
	Bell Allard Mines Ltd.	0.3
	Consolidated Mining and Smelting Co. of Can.	(less than 0.1)
NORTH BAND	New Hosco Mines Ltd.*	3.4
	Radiore Uranium Mines Ltd.	
	"A" deposit	0.3
	"E" deposit	0.1
	Bell Channel Mines Ltd. No. 1	0.1
	Garon Lake Mines Ltd.	0.3

* Producers

Small zones of chalcopyrite are widespread and occurrences of bismuth, molybdenite, gold and silver have also been found.

The sulfide masses are heterogeneous mixtures of pyrite, pyrrhotite, sphalerite, chalcopyrite, magnetite, and non-metallic minerals associated with metallized rocks. The smallest contains a few thousand tons, the largest more than 20 million tons.

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* Pertinent parts of this section have been revised by the writer so as to include data available in September 1965.

Even a cursory examination of the disposition of the deposits in the framework of the general geology (Figure 2) reveals several circumstances of interest: each deposit lies near the periphery of the Bell River complex and each is within a restricted stratigraphic zone between the Wabassee Group and the Lac Watson Group.

The deposits are of the type generally referred to as "massive replacements". Preliminary geothermometric studies (summarized in a later section) indicate that the sulfides have crystallized in a temperature range above 425°C.

In general, each deposit has been studied by the following method. Several drill-holes throughout the deposit were logged and all the available company data were reviewed. A section across the deposit was then chosen to represent the general nature of the deposit and studied in more detail. Then it was possible to meld the company data, available at that time, with the direct observations and the general geology. Particular attention was directed toward the morphology and boundaries of the sulfide masses and their relations to lithology, stratigraphy, dikes and structure; the host rock of the sulfides; the macroscopic character of the ores - their texture, mineral association and spatial heterogeneity; the nature and degree of alteration within and close to the metallized zones; the interplay of these features.

Copper-zinc Deposits

Mattagami Lake Mines Ltd.

Mattagami Lake Mines' property, Mining Concession No.458, is located two miles southeast of Watson lake. The main deposit was discovered in June 1957 when a drill-hole, collared over a combined electromagnetic and magnetic anomaly, entered massive sphalerite. A four-compartment shaft has been sunk to 1,185 feet near the main orebody and production from a mill, rated at 3,500 tons per day, started in October, 1963.

The writer is indebted to Mattagami Lake Mines for permission to examine the mine data and workings and to the several persons who aided the writer in his observations. R. Hallum, and G. Kier, mine geologists at the time of the writer's examinations, and Dr. R. Miller of Noranda Exploration, oriented the writer towards significant features and provided much useful information.

The geologic maps of the property, except in the immediate vicinity of the main orebody, (Figure 5) are based mainly on the writer's extrapolation of data from the extensive exploration drilling done by the

Mattagami Syndicate. The salient features of the deposits are projected to a horizon approximately 350 feet below the land surface.

General geology

The contact between the Lac Watson Group rhyolites and the overlying Wabassee Group lavas has been traced for a distance of more than 4,000 feet in the south part of the property. This contact strikes northwest and dips moderately to the southwest except in the vicinity of local warps and asymmetrical flexures. The main intrusive rocks are gabbroic sills and dikes, congeners of the Bell River complex. A differentiated peridotite intrusion underlies the central part of the property.

Two distinct masses of zinc and copper ore have been discovered: the "main orebody" and the "No. 2 orebody" 1,200 feet southeast of the first. A zone carrying nickel and copper minerals, probably not related to the copper-zinc orebodies, lies adjacent to the peridotite complex.

The geologic succession is as follows:

(7) lamprophyre dikes
(6) feldspathic and siliceous dikes ("acid dikes")
(5) peridotitic complex ("peridotite, feldspathic peridotite, olivine gabbro")
(4) porphyritic gabbro and gabbro ("polka-dot gabbro") (related to Bell River complex)
(3) "metadiabase"
(2) volcanic rocks:

  (a) Wabassee Group: andesite, dacite, spherulitic rhyolite and rhyodacite, pyroclastic rocks, tuffite beds. ("basic, intermediate and acid metavolcanics, tuffite and metasediments")

  (b) Lac Watson Group: porphyritic rhyolite, spherulitic rhyolite, chloritic rhyolite, silicified and brecciated rhyolite. ("porphyritic and spherulitic metarhyolite, acid volcanics")

Note: a) Names in quotation marks are nomenclature used at the mine.
b) Age relations between unit 4 and unit 5 are uncertain.
c) Some lamprophyric dikes are related to unit 4 and 5.
d) Unit 3 is in part related to unit 4 but may include earlier intrusive rocks.

Volcanic rocks

The lithologic sequence across the south part of the property (and part of Orchan Mines property which adjoins to the south) follows:

WABASSEE GROUP

andesite-basalt lavas and porphyritic andesite	± 250'
(gabbro sill, 140')	
pillowed andesite	± 130'
(diabase sill ± 350')	
pillowed dacite	± 50'
"upper" tuffite and tuff	± 40'
(porphyritic gabbro ± 100')	
andesite-basalt	± 150'
spherulitic rhyolite and rhyodacite	± 550'
(porphyritic gabbro ± 80')	
pillowed dacitic lavas, massive dacitic lavas, tuffite	± 500'
"key" tuffite	± 10'

LAC WATSON GROUP

rhyolite, silicified rhyolite, highly altered siliceous rocks	± 1000'

The lavas of the Wabassee Group are typical of the general lithologic types already described and the property is a type locality for the Lac Watson Group. The basal lava unit of the Wabassee Group is a thick layer of pillowed and massive dacite lavas which overlies the basal or "key tuffite" which in turn overlies rhyolitic rocks of the Lac Watson Group.

The "key tuffite" is usually less than 10 feet thick and exhibits the general lithological features described previously, except in the vicinity of the orebodies where the sulfide content increases. Other less continuous tuffite layers occur above the "key tuffite", interstratified with pillowed dacite and the andesitic lava units.

The rhyolitic rocks of the Lac Watson Group include the porphyritic rhyolite variety, the fine-grained, altered, spherulitic variety, the chloritic type, and finally the silicified and brecciated facies. In the vicinity of the ore deposits these rocks are intensely chloritized but are characterized by numerous vitreous quartz "eyes".

Massive rocks, identical in appearance to the pillowed dacitic lavas, occur throughout the dacitic and rhyolitic lava units. They may grade into dacite and have lava structures but may also occur as dikes which transgress the contacts of the lavas.

Intrusive rocks - The main intrusive rocks are: gabbroic sills and dikes, a peridotite complex, and siliceous, feldspathic and lamprophyric dikes.

The most common rock type of the gabbroic intrusions is a distinctive porphyritic gabbro known as "polka dot gabbro", because of its rounded phenocrysts of saussuritized feldspar. Some of these intrusions are deformed in folds; notable examples are the arcuate patterns of the porphyritic gabbro located northwest of the main orebody (see N.W. Galinée map). These reflect an anticlinal structure which plunges northwest.

Extremely altered drak green rocks with, in places, a vague ophitic texture are termed "metadiabase" at the mine. An irregular mass of these rocks occurs south of the main orebody. The mine geologists consider these rocks (in part at least) to be basic intrusions, older than the porphyritic gabbro.

A differentiated pluton of serpentinized peridotite and gabbro lies adjacent to the north flank of the orebody. A section across the complex has been explored by drill-holes and, within this section, the pluton has a synformal trough 1,050 feet below the land-surface. The southwest flank of the peridotite has an irregular contact which dips northeast cutting across volcanic units. The basal zone of the pluton consists of serpentinized peridotite which grades upward into feldspathic peridotite and thence to serpentinized gabbro. The company data indicate that these differentiated zones extend upwards along the flanks of the intrusion and, in effect, conform to a synclinal structure. These relations suggest that the intrusion may have been a slightly discordant, tabular mass which has been folded into a synclinal structure. There is a lesser possibility that the intrusion has the form of a concentrically differentiated plug or pipe.

The age relation between the peridotite and porphyritic gabbro is uncertain. No gabbro dikes were seen within the peridotite. Narrow ultrabasic lamprophyres have been reported to intrude the gabbro and some porphyritic gabbro sills terminate abruptly near the southwest contact of the peridotite. These data suggest that the porphyritic gabbro was emplaced before the peridotite and that both gabbro and peridotite were intruded before (or during) the folding of the lavas.

Swarms of small felsitic dikes transect the volcanic rocks and orebodies and are particularly abundant near folds. There are many varieties: the most common are fine to medium-grained light-colored rocks that can be referred to collectively as feldspathic and siliceous dikes. They include rhyolite porphyry, gray biotite-feldspar porphyry and pinkish feldspar porphyry. Many of these dikes occupy post-ore faults and intrude the gabbro. One extends over 800 feet through the orebody, in a northwest direction.

Trap dikes and biotite and hornblende lamprophyres are common, particularly within the orebodies. Some dikes of this group are schistose and serpentinized and related to the peridotite intrusion. Others may be older or much younger.

Structure - The stratiform lavas, except near the small folds, dip 20 to 40 degrees southwest and, in accord with the general homoclinal structure of the rocks of the south volcanic band, are upright.

The main fold structures are an anticline which envelops the main orebody, a complementary assumed synclinal structure occupied by the ultrabasic rocks, and small flexures at the No. 2 orebody and near the south boundary of the property. The anticline is asymmetrical and plunges an average of 30 degrees northwest. The axial plane dips steeply. The southwest contact of the peridotite lies within the northeast limb of the anticline and dips moderately to steeply northeast (Figure 5), more or less discordant to the stratification of the volcanic rocks.

The peridotite appears to occupy a syncline but in a discordant fashion. The consequence of this interpretation would be important because the "key tuffite" marker-horizon, which appears to be cut off by the lower peridotite contact, may re-appear above the peridotite. If the peridotite mass plunges northwest, as the fold structures do, then the extension of the tuffite would be north of its established position at the main orebody.

A zone of intensely schistose and altered rocks up to 100 feet wide extends along the axial zone of the main anticline and orebody, dips 80 degrees to the north and trends approximately S.80°E. The structure could not be traced eastward from the orebody. The mine geologists have noted that the intensely schistose rocks terminate near the contact of the ore and the overlying dacitic lavas but that the zone extends downwards to the limit of exploration. These schists contain ore minerals and are discussed in a later section. No offset has been observed along this structure and the abrupt termination suggests that it is not a major fault.

Post-ore faults that offset ore-contacts and dislocate parts of the orebody are marked by narrow zones of gouge, schist or breccia or a relatively regular fracture surface. Most of these are oriented N.30°W., north, or east.

Orebodies

The ores are heterogeneous mixtures of pyrite, pyrrhotite, magnetite, non-metallic minerals and variable amounts of sphalerite and chalcopyrite. Reserves in the main orebody to a depth of 750 feet are calculated (December 1964) to be 18,860,820 tons of ore which contains 10.8% zinc, 0.70% copper and 0.014 ounce of gold per ton and 1.15 ounces of silver per ton. The No. 2 orebody is estimated to contain 2,000,000 tons with 12.86% zinc, 0.86% copper, and 0.013 ounce of gold and 0.99 ounce of silver per ton.

Form of deposit and relations to structures, host rocks and dikes - Both orebodies are confined to the top of the Lac Watson Group; both mark loci of small folds and are similar in composition. More information is available for the larger and only it will be described in detail.

The deposit occupies an anticline and plunges, with the fold, in a northwest direction (Figure 5). Tha main part of the orebody is a continuous mass of sulfides. The maximum dimensions occur near the surface where the horizontal width is approximately 500 feet in a northeast direction, 700 feet in a northwest direction and 200 to over 400 feet in the vertical dimension. Down the plunge, the anticlinal limbs become more open and near the 750-foot level the main sulfide mass assumes a warped tabular form with a vertical dimension of the order of 40 feet. The crest of the orebody, above the 550-foot level, plunges 25° at N.45°W. and then steepens to 35°,and at depth the plunge-direction appears to curve to the west. The down-plunge dimension of the sulfide mass exceeds 1,700 feet.

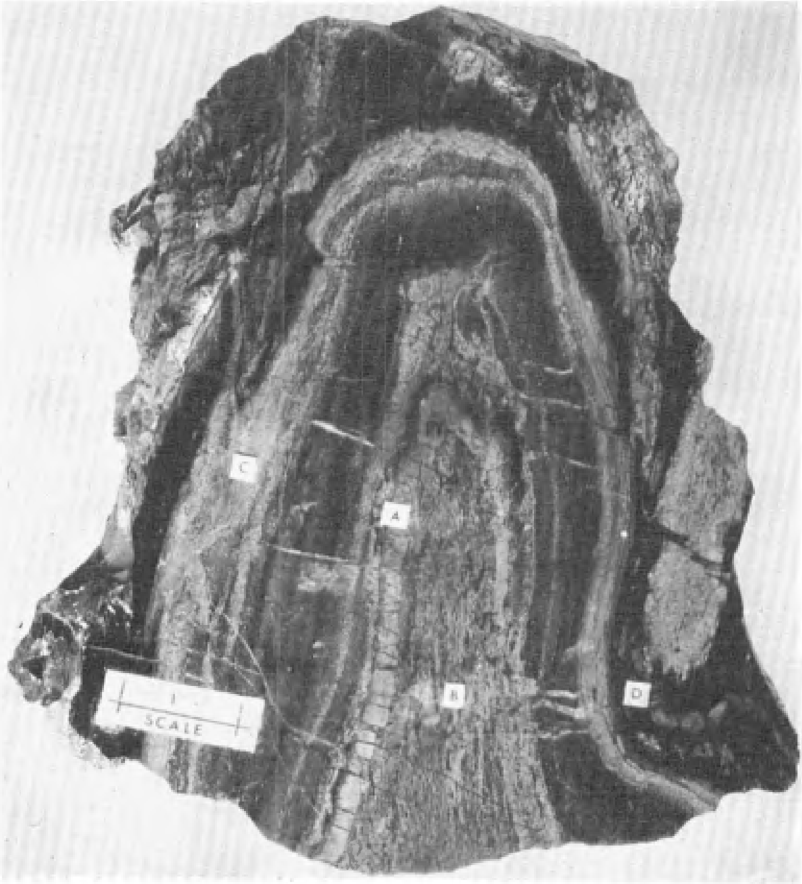
The upper ore limit is sharply delineated by a band of tuffite overlain by typical intermediate lavas of the Wabassee Group. Locally, these are chloritized and contain a few veinlets or stringers of sulfides. Several ore-shoots breach the tuffite-lava contact and extend a short distance upward into the dacitic lavas, particularly above the crest of the orebody. However, the prevailing relation is that the upper contact of the ore is concordant to the base of the Wabassee Group lava.

A contrasting relation occurs along the basal limits. The lower part of the orebody (above the 550-foot level at least) becomes intercalated with highly altered rocks and the sulfides become more dispersed, forming irregular lenses, veinlets and disseminations within a chloritic gangue. The dispersed sulfides extend downward along irregular shear and breccia zones into chloritic rhyolite.

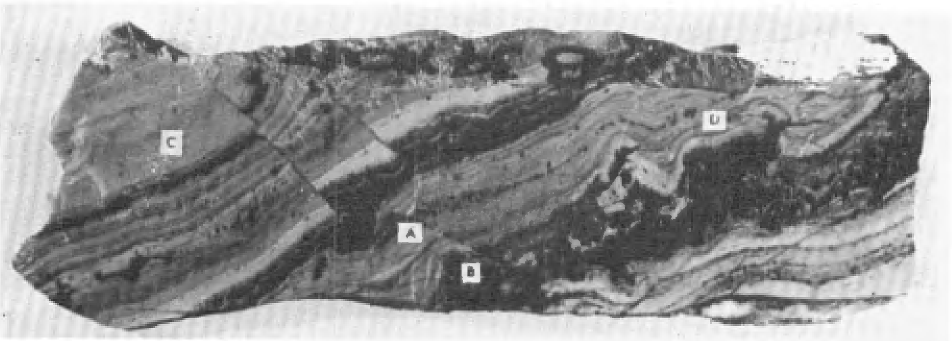
The sulfides, as seen in cross-section, appear to replace part of the top of the rhyolitic rocks,and the base of the tuffite merges

PLATE IV

"KEY TUFFITE", MATTAGAMI LAKE MINES



a) Dragfold in sulfides and "key tuffite", Mattagami Lake Mines. Sulfides (light tones), chlorite (black), impure chert (gray medial layer). Note tension fractures in pyrite bed "A", boudin of pyrite at D in chlorite, foliate pyrrhotite at B and massive pyrrhotite at C.



b) "Key tuffite", Mattagami Lake Mines. Pyrrhotine and pyrite with a minor amount of chlorite (black), sericite and chert lamellae (gray). Note intricate crenulations localized near layers of sulfides, flowage of sulfides into fracture (A) and apparent piercement (B).

with the sulfide mass. In most sections the lateral extremities of the sulfide mass are contiguous to the tuffite and in some sectors the tuffite is unusually thick where adjacent to the ore. Remnants of extremely chloritized rhyolite and tuffite are found throughout the ore and these are considered to be the main host rocks.

The southwest flank of the peridotite complex abuts against the ore in the upper levels but diverges away at depth, leaving a septum of altered volcanic rocks.

Numerous dikes traverse the ore zone. Some of these, particularly the siliceous and younger lamprophyre varieties,must have intruded the ore as the dikes have regular chilled contacts and in some instances occupy post-ore faults.

Small, extremely altered, chloritic dikes are pre-ore in age. These have fretted contacts and in places have been segmented into aligned tabular masses by the sulfides.

Several porphyritic gabbro dikes appear to transect the sulfide mass. These are subsidiary intrusions of the folded Bell River complex and their contorted aspect indicates that they were also folded with the volcanic rocks. Jenney states (1961, p. 747): "In the Mattagami Lake-Orchan mineralized area, this intrusive takes the form of both sills and dikes, the sills appear to be conformably overlying orebodies in places and the dikes definitely cut orebodies elsewhere." No specific instance of the cutting relation is cited.

These dikes seldom contain sulfide minerals except for disseminated pyrite and pyrrhotite,and the contacts between gabbro and sulfides are usually distinct. A large dike of porphyritic gabbro extends across the ore zone in a northwest direction on the 350-foot level and was observed in contact with the ore in the main crosscut. The north (hanging-wall) contact is sharply defined and is fine-grained or "chilled" adjacent to ore. The interior of the dike is composed of typical porphyritic gabbro. Near the footwall contact, the rock becomes schistose and the footwall contact is indistinct. A few discontinuous veinlets of sphalerite and pyrite and sulfide-bearing quartz veinlets occupy irregular fractures in the dike in a fashion which indicates that they have been emplaced after the dike consolidated. However small angular masses of sulfides resembling inclusions also occur within the dike.

Thus evidences of the relative age relations between dike and ore are somewhat in conflict: the dike-like contacts suggest that the dikes are intrusive into the ore rather than (for example) isolated by a complete replacement of the country rock; but the veinlets of ore minerals in the dike suggest that the dikes are pre-ore.

The problem of this age relation is important in evaluating the relation of ore emplacement to the regional tectonics. Thus, if the gabbro was intruded into the ore, it signifies that the ore was emplaced before (or at an early stage of) the development of folds.

In view of the importance of these relations it would be desirable to make more extensive observations. However the writer's opinion is in accord with that of Jenney (1961, p. 747) and the mine geologists (verbal communication) who believe that some of the dikes intrude the ore.

Ore types and distribution - The main metallic minerals, in order of decreasing abundance are: pyrite, sphalerite, pyrrhotite, magnetite and chalcopyrite. These usually constitute approximately 60% of the ore. The proportions and textures of the main metallic minerals vary locally and on a larger scale throughout the deposit. The main ore-types observed by the writer can be characterized as follows:

1) tuffite ore
2) banded, layered, foliated and massive sphalerite-pyrite ore
3) magnetite-pyrite-pyrrhotite ore and metallized zones
4) metallized schist and breccia

These ore-types have spatial distributions of variable distinctiveness. Most of the ore is of type 2 and occurs mainly in the upper and lateral extremities of the mineralized rocks. "Type 3" ores are relatively poor in zinc and copper and the most extensive sectors of this type occur below "type 2" and, in part, form the base of the sulfide mass. "Type 4" sulfides occur in a large irregular zone under the orebody and as lenticular zones that extend into the sulfide mass. "Type 1" ore is the sulfide-bearing tuffite which occurs along the top and sides of the sulfide mass. Most of these ore-types are transitional one to the other and in some sectors they are so intimately admixed that no simple division is possible. However these sub-divisions represent distinctive mineral assemblages with characteristic structural or textural features and will serve as a basis for describing the various facies of the ores.

1) Tuffite ore

The "key tuffite" at the Mattagami Lake Mines deposit delineates the top and sides of the deposit. Pyrite and pyrrhotite are everywhere present and usually sphalerite is abundant enough to provide ore. The base of the tuffite merges with the "type 2" sphalerite ore. The transition is commonly marked by a disruption of the tuffite layers and the mixing of fragments of cherty tuffite with massive sulfides.

The tuffite sulfides are markedly contorted (Plate IV) and evidence of recrystallization can be seen in diagnostic specimens (Plate V). There is no doubt that the sulfides are deformed. The secondary structures in the samples, where studied, are geometrically consistent with the larger structures of the deposit.

Not all sulfides in the tuffite are arranged in bedding layers; much of the base metal sulfides are distributed as veinlets. For example, veins of coarse sphalerite may transect delicate layers of very fine sphalerite. Veining relations such as this are usually interpreted as representing different stages of metallization but, in the present instance, the veining could also be due to a redistribution of sulfides rather than sequential periods of metallization.

In general, much of the pyrite and of the pyrrhotite in the tuffite occupies bedding structures and conforms to the local deformation structures.

Pyrite and small amounts of other sulfides are components of the tuffite deposits throughout the area and probably were formed with the rock. Thus the spatial proximity of the bulk of the base metals to the tuffite-sulfides could conceivably be fortuitous. A specific study would be required to demonstrate or disprove a consanguinity of the sulfides of the tuffite and those of the ore mass.

2) Banded, layered, foliate and massive sphalerite-pyrite ores

The predominant sulfides in the upper and lateral extremities of the sulfide mass are sphalerite and pyrite characterized by banded and layered structures and a high zinc tenor. Small amounts of chalcopyrite and pyrrhotite are present, either disseminated or as splotches and veinlets.

The banded aspect is due to layers and lenses with different amounts of gangue, pyrite and sphalerite; some bands are essentially monomineralic. The thicknesses of the bands are usually between 2 and 20 mm. Other planar features, such as layers of nodular pyrite, variations in crystallinity, and layers of chloritic and sericitic material contribute to the banded aspect; where these are particularly regular (Plate VI-A) the ore may be termed "layered" rather than "banded". The banding or layering is generally parallel to the upper contact of the oremass. That is, it dips at low angles near the crest of the orebody and dips steeply along the limb zones.

The main gangue minerals are quartz, chlorite and sericite with minor amounts of carbonate, the same minerals which constitute the wall rocks. Particularly notable are small angular masses of cryptocrystalline and microcrystalline quartz, remnants of the tuffite.

The sulfides are generally very fine-grained granular aggregates and the pyrite, in particular, is usually dense and microcrystalline. Discrete idioblastic crystals and masses of medium-grained pyrite are also common. In polished sections the dense pyrite layers (when etched) show a fine mosaic texture. The sphalerite and coarser pyrite form mutual intergrowths of very fine to medium-grained crystals. The sphalerite crystals contain tiny blebs of pyrrhotite and usually chalcopyrite, both distributed in the random fashion of exsolution textures. In some samples containing cherty inclusions, the sphalerite penetrates and partly replaces the boundaries of the chert.

Some sphalerite-pyrite ore has a more or less pronounced foliate fabric, analogous in general appearance to gneissic textures in silicate rocks. This variety is most common in the interior of the ore mass, and, in part, is disposed as steeply dipping shoots adjacent to the vertical schist zones. The mineralogy and gangue are similar to those of the banded ores. The texture is due to folia of host material and schlieren-like streaks of pyrite and sphalerite of different purity and crystallinity. In some samples, elongated nodules and irregular or tabular fragments (Plate VII-A) of microcrystalline pyrite are set in a pyrite-sphalerite matrix. These forms of pyrite are a characteristic of the layered ore-type but,within the foliate ore, they appear fractured, displaced, and healed with sphalerite. In one instance (on the 350-foot level) the foliation of the ore appears to be superimposed on a layered fabric.

Minor amounts of pyrrhotite and chalcopyrite occur within the pyrite-sphalerite ore but are particularly abundant near or within masses of chlorite and highly chloritized material that are intercalated with the sulfides. Much of the chalcopyrite occurs as small splotches and irregular stringers within chlorite or massive sphalerite and pyrite. Invariably, chalcopyrite-rich zones are enriched also in pyrrhotite. The chalcopyrite in one polished section (Plate VII-B) appears transected by chlorite flakes.

The vein-like nature of chalcopyrite and pyrrhotite and the lack of admixture with pyrite and sphalerite indicates that the copper has been introduced into the sphalerite-pyrite mixtures. Some chalcopyrite is an integral part of the sphalerite as it occurs in exsolved form.

3) Magnetite-pyrite-pyrrhotite ore

Pyrite, magnetite and pyrrhotite with minor amounts of sphalerite and chalcopyrite form large discrete masses in the basal and interior parts of the sulfide body (Figure 5). Typical samples (Plate VI, C-D) have deformation fabrics. Veins of magnetite may impregnate the pyrite. Pyrrhotite is enriched along the contacts between pyrite and magnetite and some may be a reaction product.

4) metallized schist and breccia

The fourth general type of sulfides are those dispersed through the altered country rocks below and within the main mass of sulfides. The host rocks are chlorite schists, serpentine-talc (chlorite) schists and chloritized, silicified and brecciated rhyolitic rocks. Miller (verbal communication) considers that the metallized zone "mushrooms" below the sulfide mass and narrows at depth.

The metallic minerals are those found in the orebody except that there is commonly a predominance of chalcopyrite over sphalerite where these are present together. The sulfides in the chloritic schists occur as narrow stringers parallel to the foliation planes, as isolated blebs or along fractures across the schistosity. There is a distinct association of chalcopyrite, pyrrhotite and highly chloritized rocks. The silicified rhyolitic rocks, at depth, contain mainly pyrite, disseminated or in the form of veinlets.

Alteration -

The wall-rocks adjacent to and within the metallized zone are variably altered. The extensiveness or spatial relation of alteration phenomena to the ore masses is known only in general terms. The pattern is asymmetrical, the rocks below the ore masses, or below the key tuffite, being intensely altered in contrast to the rocks above.

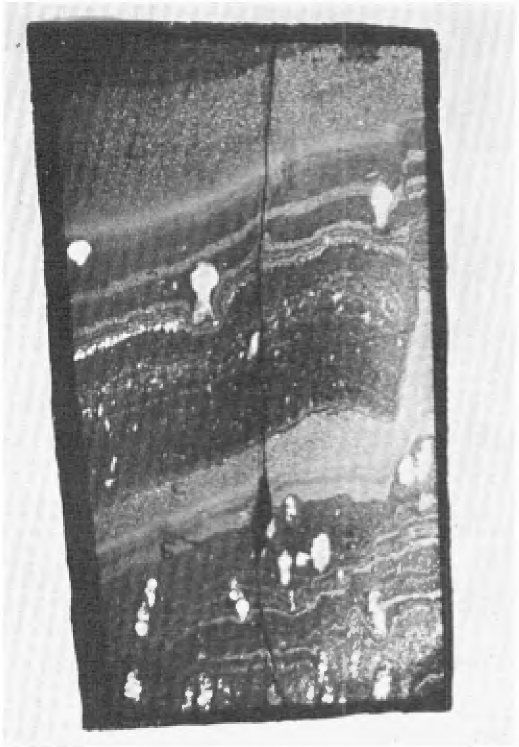
The most pronounced effect is chloritization. In places, there has been a conversion of sectors of the rhyolitic rocks to masses of chloritic material. Sericitized material is common in the metallized tuffite and within the sphalerite ores in general. Carbonate minerals are locally abundant, either disseminated, or in veinlets which transect chloritized rocks and sulfides. Silicification of Lac Watson Group rhyolites is marked by mottling and the presence of cherty blobs and veinlets. In some sectors, this silicification is particularly intense and the chertified rocks have been referred to as "opalite" at the mine.

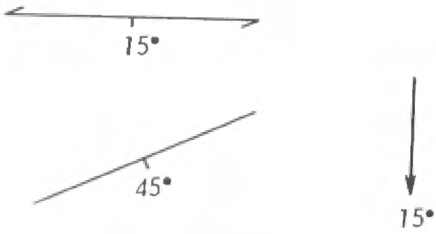
Talc and serpentine schists are found along steeply dipping structures, below and within the sulfide mass.

Genetic relations between the different facets of the alteration and the metallization are not clear. Chloritized zones and "opalite" rocks, without associated sulfides, are not uncommon in the Lac Watson rocks. The effects near the ores are much more pronounced. The magnesian-rich schists are unusual and perhaps may be related to the peridotite intrusion.

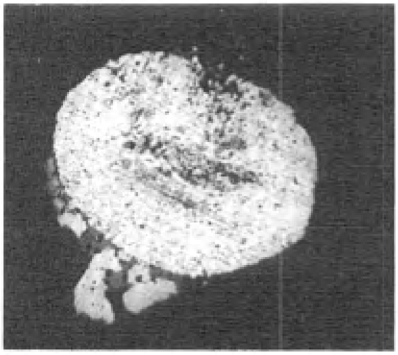
PLATE V

NODULES AND LAMELLAE OF SULFIDES IN TUFFITE, MATTAGAMI LAKE MINES

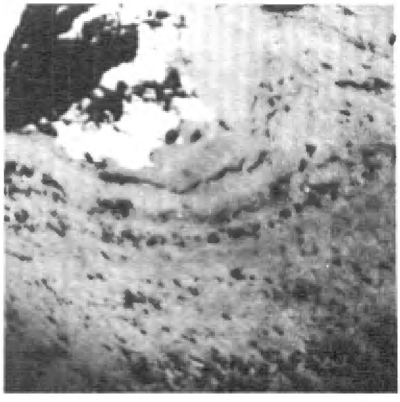




a) Laminated sericite (gray) and sphalerite (light gray bands) with pyrite spheroids (white). White flecks are coarser crystals of sphalerite. Orientation of beds, cleavage and long axes of spheroids is given above and details in lower photographs. (reflected light, x 1.3).



b) Pyrite spheroid with recrystallized sphalerite, pyrrhotite and quartz in "shadow zone" coincident with long axis of spheroid and superimposed cleavage. Longest axis of ellipse is intermediate axis of spheroid. (reflected light x 16, slightly etched)



c) Crenulation in lamellae of sericite (gray). Pyrite and sphalerite grains (black) tend to be elongated left to right, parallel to the superimposed cleavage. (transmitted light, x 20)

Summary

The ore masses underlie the base of lava of the Wabassee Group. The upper ore boundary is concordant and sharply defined by a tuffite bed, whereas the basal limit of the main ore mass is less distinct and in places has the form of discordant shoots which extend downwards into a zone of dispersed sulfides.

Several spatially-zoned ore-types can be recognized in the main orebody. Concentrated sphalerite occurs along the upper parts of the sulfide mass, and the basal sectors are, in part, barren magnetite, pyrite and pyrrhotite.

Deformation structures and textures are present in much of the ore. These are most readily observed in the "tuffite ore" where sulfides are folded.

The ore masses are enclosed by fold structures, dislocated by numerous post-ore faults and appear to be transected by gabbro of the Bell River complex and other intrusive rocks.

Orchan Mines Ltd.

Orchan Mines holds Mining Concession No. 460, in range IX, Galinée township, one mile southeast of the Mattagami Lake Mines main deposit. The most northerly of three sulfide masses, the "No. 1 zone", was discovered in 1958 by drilling an electromagnetic anomaly. The exploration work has been described by Latulippe (1962). A three-compartment shaft was sunk to 1,654 feet and production from the "No. 2" and No. 3 orebodies started in October, 1963. The rate of milling is approximately 1,000 tons a day.

The writer is indebted to Orchan Mines for granting access to the mine data and to the mine geologist in 1963, Nels Vollo, and to Dr. R. Miller, Noranda Exploration, for the information and discussion they provided. The geology shown in the vicinity of the sulfide mass (Figure 5) is based on the underground plans and sections. Elsewhere, the relations are established less precisely, mainly by the writer's projections of data from surface drill-holes.

General geology

The basal part of the Wabassee Group and the top part of the Lac Watson Group extend southeast across the property and are intruded by gabbro and several varieties of siliceous dikes. The general geologic sequence is equivalent to that given for the Mattagami Lake Mines property. The lava and sill units dip moderately to steeply southwest and are complexly dislocated by faults.

The general lithologic sequence across a medial part of the metallized zone is as follows:

Wabassee Group

- spherulitic rhyodacite
- dacite lava
- tuffite layer (discontinuous)
- spherulitic rhyolite and porphyritic rhyolite (± 800')
- tuffite layer (discontinuous)
- pillowed dacite
- rhyolite, spherulitic rhyolite

- pillowed and massive dacite (± 300')
- key tuffite (± 10')

Lac Watson Group

- rhyolite, altered rhyolite (± 800')

The Lac Watson rocks are massive, gray and gray-green, porphyritic rhyolites which grade into dark green chloritized varieties and mottled, silicified rhyolite with a fractured or brecciated aspect. The Wabassee rocks are mainly dacitic and rhyolitic lavas. The dacitic unit that forms the base of the group can be correlated with the dacite at Mattagami Lake Mines.

The spherulitic siliceous lavas above this dacite are particularly distinctive. In places the rock is composed entirely of tiny to large (1 cm.) spherulites of altered feldspar and quartz surrounded by shreds of chlorite. This texture persists over widths of 40 feet and then merges gradually with massive or porphyritic rhyolite. Layers of typical cherty tuffite at Mattagami Lake Mines occur along lava contacts.

The intrusive rocks in the vicinity of the metallized zone are "metadiabase", porphyritic gabbro, and feldspathic dikes. Slightly transgressive dikes of "metadiabase" and porphyritic gabbro extend along the hanging-wall volcanic rocks. A dike of the porphyritic "polka-dot" gabbro cuts across the lavas west of the sulfide masses (Figure 5) and extends, with a low dip, across the top of the sulfide mass. A similar intrusion occurs below the sulfide masses.

Masses of dark green, fine- to medium-grained rocks are termed "metadiabase" at the mine and appear to be chloritized and saussuritized intrusions. Considerable quartz is present in some altered facies of these and the dikes are not easily distinguished from some varieties of chloritized rhyolite.

Small dikes of diverse composition and age occur throughout the lavas. Many of these, except for their dike-cutting relationship, are indistinguishable from the lavas. The youngest siliceous dikes are gray feldspar porphyry.

Structure

The lavas dip moderately to steeply southwest. The flatter dips are usually in the upper part of the explored sector. Open flexures can be discerned in some areas but it is difficult to distinguish between changes in strike and dip and offsets due to faults.

Three sets of faults have been recognized. The earliest faults are expressed by vertical schist zones that trend east (faults a_1, a_2, a_3, Figure 6). A southeast fault (b) is cut by a reverse oblique (?) fault (c) that strikes north and dips east. The net slip along this fault may be approximately 600 feet. A fault oriented northeast (d) is exposed underground and is reported to displace the north-striking fault (c). The faults are marked by narrow schist, breccia or gouge zones or relatively clean fracture planes.

Orebodies

Form and relations to host rocks and structure:- Three sulfide masses are disposed along and beneath the "key" tuffite horizon. The upper contact of "No. 2 orebody", illustrated in Figure 5, extends along the tuffite apexing near the 350-foot level. Below this, the ore is a steeply dipping lensoid mass intercalated with chloritic schists. The "No. 1 orebody" is 900 feet north of "No. 2 orebody" and extends to surface. As No. 2 orebody, it lies near a schistose fault zone. The "No. 3 orebody" is the largest sulfide mass and apexes 850 feet below surface with a similar setting.

Thus, the upper contacts of the sulfides are generally concordant and delimited by the tuffite contact. However, masses of sulfides extend downwards as steep shoots, intercalated with the chloritic schists that mark the earlier fault zones. The dacitic lavas above the ore masses are less schisted and contain minor amounts of disseminated sulfides.

Some warped structures near the ore zones are indicated by distortions of the tuffite horizon. In particular, the "No. 1 orebody" may lie within a small anticlinal flexure. Contortions also occur near the "No. 2 orebody".

The sulfide bodies lie adjacent to intensely schistose rocks which, at the No. 2 orebody at least, mark a fault zone. It is readily apparent that the sulfide masses also occur near the intersection of transverse faults with the schist zones (Figure 6). However, the north fault (c) appears to form the west wall of the "No. 2 orebody" and the east wall of the "No. 3 orebody". If the tuffite horizon in the various fault blocks were "reconnected" by movements equivalent to the strike offsets the vertical projections of the "No. 2 and No. 3 orebodies" coalesce. These relations suggest that the north-south fault has dislocated the two orebodies. Confirmation of this hypothesis was provided by R. Miller (verbal communication) who noted that the grades and the ore types of the two orebodies match where they are adjacent to the fault. Thus considerable movement has occurred along the north-south fault (and later northeast fault) after the emplacement of the sulfide masses.

The ores

The three sulfide masses are similar in mineralogy and tenor. At the start of production the company estimated that they contained 4,600,000 tons with 12.41%.zinc; 1.29% copper and 0.015 ounce of gold and 1.29 ounces of silver per ton. The following descriptions are based mainly on drill cores from the "No. 2 orebody". The average relative proportions of sulfides, as estimated in three drill cores through the sulfide mass, were: pyrite (60%), sphalerite (20%), pyrrhotite (10%), chalcopyrite (5%), magnetite (5%). The sulfide mass as a whole contains 10 to 30% of non-metallic minerals and the relative proportions of the various sulfide minerals vary extremely.

Several general types of ore can be distinguished in drill core. These are intimately mixed as large- or small-scale zones. The ore varieties are in most respects analogous to those of the Mattagami Lake mine but have less distinct spatial relations. Some of these mixtures are so variable over short distances that no simple classification is applicable. The main types are:

1) tuffite sulfides
2) sphalerite-pyrite ore
3) chalcopyrite-pyrrhotite ore
4) pyrite-pyrrhotite-magnetite ore
5) metallized schist and breccia

1) The "key" tuffite contains pyrite, pyrrhotite and minor sphalerite and chalcopyrite in the vicinity of the mine and large amounts of these minerals near the sulfide masses.

The tuffite above the No. 2 orebody consists of lamellae and beds of chert, argillaceous material, and layers of sericite or chlorite-rich materials. Pyrite is present as regular microcrystalline layers, irregular masses and veinlets; nodular forms are particularly distinctive.

Sphalerite and chalcopyrite usually occupy microstructures or appear to have replaced some part of the tuffite. Some sphalerite occurs as very fine disseminated grains that tint some layers of chert a reddish brown. It is apparent, even in drill core, that the bedding structures in the tuffite are plicated and offset by numerous microfaults. The pyrite layers also exhibit deformation structures.

2) Sphalerite and pyrite form the predominant ore-type and the highest grade zinc ore usually occurs along the upper part of the mass. The most common ore is fine- to medium-grained, dark reddish-brown sphalerite intergrown with pyrite and intercalated with irregular lenticules of pyrite, which give the sulfide aggregate a foliate texture. Some zones have a banded structure due to layers or lenses of different crystallinity and composition.

The gangue is composed mainly of quartz, chlorite, sericite and fine-grained, semi-opaque material. Partially replaced masses and fragments of tuffite and chlorite are intercalated with the ores and in some sections, near the tops of the ore masses, abundant small fragments of chert, fine-grained pyrite and nodular pyrite are included in the sphalerite-pyrite mixtures.

Chalcopyrite and small amounts of pyrrhotite and magnetite occur erratically through the sphalerite and pyrite. Some of the chalcopyrite occupies stringers that transect and replace sphalerite. Polished sections show that small amounts of chalcopyrite are also a fundamental component of the ore-type as small exsolved blebs, disseminated through sphalerite.

3) Zones of barren sulfides or low-grade ore, characterized by the assemblage pyrite-magnetite-pyrrhotite, are mixed with the other sulfides. They consist typically of very fine-grained pyrite transected by crude veins of magnetite. Pyrrhotite is disseminated through the magnetite and in some samples appears to have formed from pyrite along the magnetite veins.

4) Chalcopyrite and pyrrhotite are enriched in some sectors and form a more or less distinct type of metallization. The chalcopyrite occurs as irregular splotches or is finely disseminated throughout other sulfides or through masses of black chlorite which otherwise contain only minor amounts of sulfides. In some high-grade copper ore the chalcopyrite has replaced sphalerite (Plate VIII-B).

5) Dispersed sulfides are present in the altered rocks adjacent to, and below the sulfide masses. The host rocks include chloritic and talcose schists and chloritized and silicified brecciated rocks. The sulfides are disposed along foliation planes and fractures and disseminated

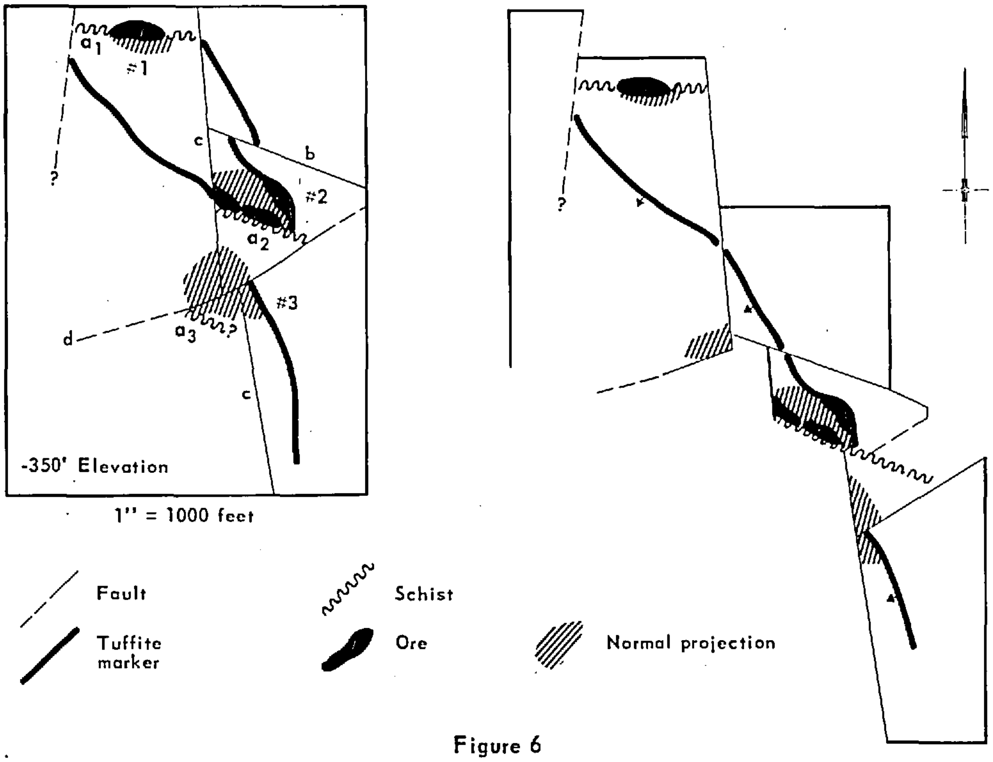


Figure 6

FAULT SYSTEM AND STRIKE-SEPARATION

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throughout the rocks. The sulfides in these rocks are similar to those in the massive ores and, in some sectors, may form lenses of ore-grade material.

Alteration:- The volcanic rocks bear the imprint of broad-scale alteration peculiar to the Lac Watson Group. There is a pronounced increase in the degree of chloritization and silicification in the vicinity of the metallized rocks, particularly below the sulfide masses and along the schistose and brecciated zones. Large and small masses of altered wall-rock, included in the ore, consist mainly of chlorite, speckled with grains of quartz, and are probably extremely chloritized rhyolite. Remnants of mottled silica-rich rock are also found in the sulfides along with the remnants of tuffite. Small amounts of carbonate minerals occur with the altered host rocks. Some carbonatization occurred subsequent to the alteration described above, since veinlets of iron-bearing carbonate cut the altered rocks and the sulfides.

Summary

Masses of sulfides extend along steeply plunging zones of structural disturbance and apex near the base of a relatively massive lava unit. Parts of the sulfide masses extend laterally along the "key" tuffite. An asymmetrical zone of dispersed sulfides and chloritized and silicified rock envelops the lower parts of the sulfide masses.

Several distinct sulfide assemblages can be recognized. The main ore-type consists of sphalerite and pyrite. Some of the sulfides are deformed and transverse faults have segmented the metallized zones.

Bell Allard Mines Ltd.

The Bell Allard deposit is located in range VIII, Galinée township, 8,200 feet east of the main road. It was discovered by Newmont Mining Company in 1957 and subsequently acquired by Orchan Mines. A brief description of the deposit has been given by Latulippe (1962). More than 20,000 feet of drilling had been done up to June 1962, the time of the writer's examination.

The general geological interpretation is based on the writer's logs of 20 drill-holes and the company's geophysical data and drill logs up to 1960. The more recent drill-hole data were not available at the time of writing. The writer appreciates the cooperation and information provided by Nels Vollo, resident geologist.

General geology

The sulfide deposit occupies the contact between the Wabassee Group and the Lac Watson Group. The stratigraphic sequence in the vicinity of the deposit is as follows:

Wabassee Group
Dacite, andesite, spherulitic rhyodacite, tuffite (± 1000')
pillowed dacitic lava (± 500 ft.)
tuffite (± 10 ft.)

Lac Watson Group
Rhyolite, porphyritic rhyolite, chloritized, brecciated rhyolite
(+ 500 ft.)

The main intrusions near the deposit are large tabular masses of gabbro extending along the rhyolitic rocks of the footwall. Numerous small dikes of felsite and rhyolite porphyry intrude the volcanic rocks.

The stratiform units dip approximately 50 degrees southwest and are slightly warped to a dip of 35 degrees near the sulfide deposit. A dextral transverse fault, south of the deposit, is assumed to offset the tuffite contact westward. The most notable deformation structure is a zone of brecciated, silicified and chloritized rhyolite located below the sulfide mass.

Sulfide deposit

The sulfides form a lenticular mass intercalated with tuffite and lavas. The zone is approximately 400 feet long, 1 to 80 feet thick, and extends 300 feet down the dip of the tuffite contact. Dispersed sulfides occur below the sulfide mass (Figure 5).

The hanging-wall is dacitic lava which has an abrupt contact against sulfides. The footwall or base of the sulfide mass and intercalated tuffite lies on chloritized and metallized rhyolite. The lateral extremities of the sulfide lens thin gradually and, in adjoining drill-holes, appear to have merged with tuffite which contains disseminated sulfides and layers of pyrite.

The relative proportions of sulfides in six drill-hole intersections were estimated as follows: pyrite (55%), pyrrhotite (18%), sphalerite (17%), chalcopyrite (5%), magnetite (5%). These constitute 50 to 80% of the sulfide lens and 10 to 25% of the rocks in the zone of dispersed sulfides. In 1964 the company estimated that the deposit contained 148,800 tons containing 16.44% zinc, 1.34% copper and 1.48 ounces of silver per ton.

In a polished sample, the sphalerite was seen to be intergrown with anhedral grains of pyrite and in places to replace and impregnate the margins of fine-grained, fractured pyrite. Blebs of pyrrhotite occur within individual crystals of sphalerite. Microcrystalline magnetite, in the forms of angular inclusions and bands, is mixed with some of the pyrite.

The main gangue material consists of embayed remnants of cherty quartz. Quartz and shreds and clots of chlorite are also disseminated through the sulfides, and in some samples carbonate minerals are abundant.

The layers of tuffite which are intercalated with the sulfide lens contain the characteristic layers of microcrystalline pyrite and nodular pyrite, magnetite and irregular bands or veins of pyrite, pyrrhotite and sphalerite. In some drill core the tuffite and its layered sulfides become progressively fractured, disorganized and in part incorporated in the sulfide lens.

Chalcopyrite occurs as erratic small stringers and disseminations in the other sulfides but is particularly enriched in chlorite-rich host rocks.

The altered rhyolite below the sulfide mass contains similar sulfides: as narrow bands along fracture structures and as disseminations through the rock. At depth the sulfides diminish and are mainly pyrite.

Consolidated Mining and Smelting Co. of Canada

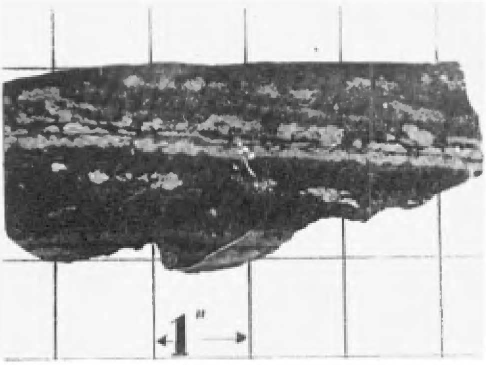
The Cominco deposit is located in range VI, Galinée township, 700 feet east of Véract river. Several thousand feet of drilling had been done in the vicinity of a small mass of sulfides between 1959 and 1962.

The contact between altered rhyolite of the Lac Watson Group and dacitic lavas of the Wabassee Group bears N.60°W., and dips 40° to 60° south, across the property. The dacitic lavas are overlain by andesite-basalt flows and gabbroic sills. Rocks of both groups are readily correlated with volcanic units that extend at least three miles northwest, to a type area. The contact between the rhyolite and overlying dacite is, in some holes, marked by a layer of tuffite or brecciated chert and chloritic material.

The small mass of pyrite, sphalerite, chalcopyrite and pyrrhotite is 150 feet below the tuffite contact, within schistose, chloritized rhyolite. The best drill intersection contained 3.8% copper, 1.0% zinc and minor amounts of gold and silver over a core length of 26 feet.

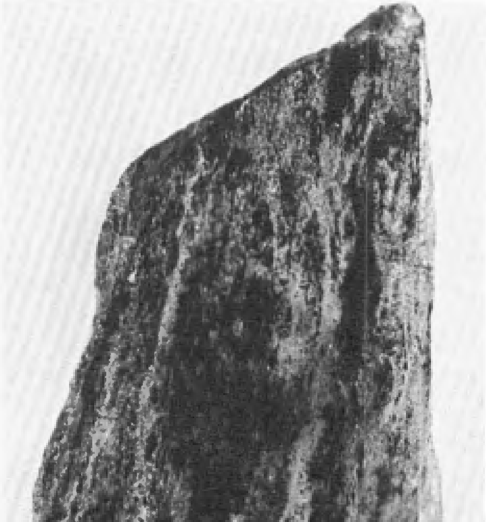
PLATE VI

SULFIDE FABRICS



a) Layered-type sphalerite ore. Microcrystalline pyrite (light gray) in layers and blobs, sphalerite-pyrite intergrowth (gray), chlorite (block), Mattagami Lake Mines.

b) Layered-type sphalerite ore, Bell Channel Mines deposit.



c) Foliate magnetite-pyrite-pyrrhotite. Chlorite folia (black) are intercalated with the sulfides. Compare with sector "B" plate IVa. (Mattagami Lake Mines, x1).

d) Brecciated pyrite with veinlets of magnetite (black). (Mattagami Lake Mines, x1).

The tuffite shown southwest of the sulfide mass (Figure 5) contains up to 4% sphalerite and traces of chalcopyrite.

Other narrow bands of pyrite occur in a chloritized and sheared zone in the mafic lavas above the sulfide mass. The structure enclosing this pyrite appears to dip steeply south.

New Hosco Mines

The New Hosco Mines deposit is located on the west bank of the Allard river in range IV, Daniel township. The discovery was made in July 1958 when the company drilled a combined electromagnetic and magnetic anomaly. In 1963, after extensive surface drilling, a shaft was sunk to a depth of 1,060 feet. Production started in 1963 and the ore is milled at Orchan mines' property at a rate of 900 tons per day.

At present (1965), copper ore is extracted from what is known as the A orebody of the north zone which lies north of the shaft. Considerable exploration and development work is being done at the 990-foot level on a newly discovered "south zone".

The following description is based mainly on the writer's logs of 19 surface holes, and some of the company's drill logs, geologic plans and sections concerning the "north zone". Development openings on the first and second levels were examined.

The geology shown on Figure 5 is based mainly on the pre-production drill-holes but includes some recent information from Nels Vollo, the mine geologist in 1963. The writer appreciates this and other information from the mine staff. W.J. Hosking, president, kindly furnished the writer with the core from one of the first holes.

Abstracts and short descriptions of the deposit have been given by Graham (1960) and Latulippe (1962).

General geology

The deposit lies within a thick lens of pyroclastic rocks near the confluence of the north and south volcanic bands. The structural and stratigraphic relations are imperfectly known in the general area of the deposit and are probably unusually complex. The general interpretation is that lithologic units of the Lac Watson and Wabasse groups interfinger, are intruded by gabbro, and have been folded into a large anticline and subsidiary folds which plunge west. The deposit lies in the north limb of the main anticline.

The lithologic sequence from north to south in the vicinity of the deposit is as follows:

Wabassee Group

pillowed dacitic lavas	(+ 2000 ft.)
andesitic lavas and tuffs	(± 300 ft.)
coarse and fine tuffs, chert and agglomerate	(± 350 ft.)
andesitic lava	(± 100 ft.)
(gabbro intrusion)	

Lac Watson Group

spherulitic rhyolite, intermediate volcanic rocks	(+ 1000 ft.)

The spherulitic rhyolite outcrops along the river. The texture is well displayed on weathered surfaces and the rock is typical of the schistose, sericitized variety of the spherulitic rhyolite of the Lac Watson Group. North of the gabbro intrusion (Figure 5), a dark green chloritized lava pinches out along the gabbro contact and, further to the west, becomes intercalated with other volcanic units. The main pyroclastic unit forms the host rocks. These are extremely altered to secondary minerals and the primary characteristics are not well preserved. The members are predominantly massive and bedded tuffs colored various shades of gray and green. The tuffs range in texture from shaly rocks to lapilli tuff. The upper and lower parts of the unit are interbedded with layers of laminated cherty tuffite.

The original components of the tuffaceous rocks near the orebody, except for some siliceous shards and fragments, have been variably replaced by manganiferous ferro-dolomite, chlorite and silica. Some sectors are chlorite schists with interspersed fragments of chert, considered to be, in part, autoclastic breccias.

Narrow intersections of siliceous spherulitic rocks were seen in several drill cores.

The pyroclastic unit is overlain by massive, porphyritic and variolitic andesite lavas which underlie a thick assemblage of pillowed dacitic lavas. An outcrop of these, in which pillows face northwards, can be seen 3,000 feet northwest of the orebody.

The main intrusions in the vicinity of the deposit are sills and dikes of gabbro, small dioritic and trap dikes and a few dikes of quartz-feldspar porphyry. The freshest (and probably youngest) rock is a small dike of hornblende lamprophyre which was transected in a drill-hole west of the deposit.

Large gabbro intrusions lying to the south and east of the ore zone are petrographically similar and may be one continuous intrusion now disrupted by faults. The typical rock is massive, medium-grained, greenish black altered gabbro, composed of saussuritized feldspar, uralite, pyroxene and chlorite. Epidote, titaniferous magnetite and flecks of leucoxene are abundant in some places.

The north contact of this gabbro in the footwall of the deposit dips northwest (Figure 5). The presumed south contact of the intrusion has been intersected 1,000 feet south of the north contact. However, the intervening area has not been explored and may not all be gabbro.

Small sills and dikes of altered gabbroic and dioritic rocks and porphyritic gabbro are abundant. In the vicinity of the ore mass, there are a few siliceous dikes which are younger than the mafic intrusions.

Structure:- The volcanic rocks in the north part of the property strike N.80°E. and dip and face north. West of the metallized zone the dip flattens and the strike swings southward. The assumed position of the Allard anticline's axis is approximately 3,000 feet south of the ore zone. Between the axis and the ore zone the structure is not well established. The apparent complications in the distribution of the lithologic units may be due to small subsidiary folds which plunge westward.

Schist zones and fracturing and brecciation indicate that faults have disrupted the volcanic and intrusive rocks in the vicinity of the metallized zone. Numerous small faults are visible underground.

The pyroclastic units are erratically schistose, particularly to the south, along their footwall. The schistosity is pronounced in the altered pyroclastic rocks probably because of their incompetency. Bands of intensely schisted rocks in the hanging-wall lavas probably represent longitudinal faults.

Important transverse faults are indicated on the company plans. The main dislocations are interpreted to be anastomozing faults which trend northwest, truncate the east end of the metallized zone and offset the gabbro intrusions. Along the north part of this fault zone the horizontal offset may be more than 200 feet, east-side-south.

Orebodies

The ores are heterogeneous mixtures of sphalerite, chalcopyrite, iron sulfides and non-metallic minerals. Before the start of production the company estimated that the deposit contained 2,187,000 tons averaging 2.70% copper, 958,000 tons averaging 7.96% zinc and a possible 269,000 tons averaging 2.19% copper. Development work in the south zone has encountered a separate copper-zinc ore zone near the 990-foot level that will increase the total tonnage.

Form and relations to host rocks, structure and intrusive rocks:- The general zone of metallized rock is confined to the pyroclastic unit and is 200 to 300 feet wide, 1,000 feet long and more than 1,000 feet in depth. The ores occur as lensoid masses that follow a west-plunging zone within the general zone of metallization (Figure 5).

The sulfides are distinctly zoned as to quantity and quality. The main components are: the "A" copper ore zone which occupies the upper medial part of the metallized zone; the zinc ore zones which occur along the north flank of the "A" zone and as a discrete zone to the north; conjugate and separate masses of nearly barren pyrite and magnetite which envelop and interfinger with the flanks and lateral extremities of the copper ores. Magnetite is enriched in the footwall of the "A" ore zone.

The upper or "A" ore zone is 10 to 180 feet wide and 400 feet long near the eroded surface. The vertical thickness of the main copper ore is approximately 200 feet. The base or footwall is concave in section above the apex of a protuberance of the gabbro intrusion and this configuration continues down a slight plunge to the west and then the zone swings southward in accord with a small asymmetrical fold.

A "south zone" of copper ore (not shown on Figure 5) is being explored from the 990-level and appears to be similar in composition to the other ores. The pyroclastic host is either a large inclusion or re-entrant separated from the "A" zone by the footwall gabbro.

The main part of the sulfides, both in dispersed and concentrated forms, is confined to the coarse-grained pyroclastic unit that is termed "pea agglomerate" or "lapilli tuff" at the mine. This is overlain by bedded tuffs and tuffite and the base of these units usually marks the north margin of the sulfides. The contact of the sulfides (but not necessarily the ore) is sharply defined and conformable to the layered rocks.

The footwall of the northern metallized zone is less distinct. The sulfides become progressively sparser and the ores grade into the footwall zone of magnetite and disseminated pyrite. The extremities of the lenses of ore narrow and become intercalated with barren pyrite.

The "A" ore zone has a spatial relation to the protuberance of gabbro below the thickest part of the "A" ore zone. The structural relation has been considered to have influenced the emplacement of the ore.

However, considering the occurrence of the south zone, within the gabbro, the protrusion may not have been an important factor; conceivably, the intrusion may have invaded parts of a once continuous metallized zone.

The relative ages of the main gabbro intrusions and metallization are not established. The contact of the gabbro within the footwall of the sulfide zone is distinct, generally fine grained for a few feet from the contact, and the gabbro contains only sparse amounts of pyrite and pyrrhotite. Minor amounts of chalcopyrite, disseminated or in veinlets, have been noted in a few places where small shears and fractures transect the gabbro.

Small fine-grained altered mafic dikes and a few gabbro dikes were observed in the metallized zone. Many of these trend northwest, dip northward and have well-defined contacts with either massive or disseminated ores. Some of the very altered dikes have indistinct contacts and in places become segmented by re-entrants of sulfides. These latter dikes have been disrupted and partly replaced by the sulfides. There appear to be at least two sets of mafic dikes, one of which is pre-ore and the other post-ore in age.

The main deformation structures near the deposit are the longitudinal schist zones and assumed transverse faults. The most schisted rocks observed by the writer are in the incompetent chloritized pyroclastic rocks in the footwall of the "A" ore zone and in the fault zones that transect the lavas in the hanging-wall. The schists in the hanging-wall contain no sulfides. The sectors of schisted rocks below the massive sulfides are not notably metallized when compared with the less deformed coarse tuff.

The main transverse fault zone is assumed to pass close to the east limit of the "A" orebody at the surface and appears to have disrupted the sulfide zone.

The ores:- The ores are 30 to 90% metallic minerals. The relative proportions were estimated in drill cores across a medial part of the metallized zone as follows: pyrite (70%), pyrrhotite (10%), sphalerite (4%), chalcopyrite (6%), magnetite (10%).

Pyrite, the main component, occurs disseminated or concentrated, with or without appreciable ore minerals. The main types may be referred to as "speckled pyrite", massive pyrite, tuffite-pyrite.

The "speckled type" is a distinctive and extensive type of metallization found in the coarse tuff. The amounts of pyrite vary and reflect a progressive replacement of the host rocks. This conclusion is based on the observation of transitions from tuff with fine specks of pyrite disseminated through the finer matrix to almost pure granular aggregates of pyrite with isolated remnants of siliceous lithic fragments. The even dispersion of sulfide grains suggests that the texture of the rock determined the sites of replacement.

Masses of fine-grained pyrite are mixed with the base metal sulfides and intercalated with fine-grained tuffs along with particularly dense pyrite having a layered appearance.

The pyrite in the tuffite is arranged in regular beds and irregular masses. In thin section and polished section the bedded pyrite is seen to be disseminated as, commonly, spherical grains through certain layers of microcrystalline quartz along with larger nodules and aggregates of automorphic crystals.

The ore-grade sulfides are either predominantly copper ore or zinc ore and, as noted, these form distinct zones within the pyritized rocks.

The zinc ores consist of sphalerite and pyrite with altered host rock, chlorite, carbonate minerals and silica. The ores are banded or foliated due to the alignment of streaks of the components. The sphalerite invades the fine-grained type of pyrite with caries-type boundaries and as veinlets that extend into the pyrite and in places leave "islands" of the host. A common characteristic of the sphalerite is the presence of inter-granular and intra-granular blebs of chalcopyrite exsolved from the sphalerite.

The chalcopyrite-rich ores are associated with pyritized rocks. The distribution is irregular; high-grade sections alternate with barren pyrite. Pyrrhotite, in the few places where it is abundant, is associated with chalcopyrite. Some chalcopyrite occurs as isolated splotches with milky quartz. Polished sections indicate that some chalcopyrite was introduced subsequent to most of the other sulfides and cherty silica (Plate VIII-C).

Magnetite is abundant along the footwall of the metallized zone and forms veins within pyrite in a few places in the "A" ore zone. In the footwall zone the magnetite occurs in small blotches, disseminated through highly chloritized tuff and chlorite schist. Small amounts of chalcopyrite occur around the boundaries of the magnetite splotches and disseminated in the chloritized host. Large automorphic crystals of pyrite occur within some of the magnetite.

The gangue of the ores is mainly remnants of the host rocks and various amounts of silica and carbonate. The carbonate occurs as aggregates of yellowish brown dolomite with lesser amounts of calcite or, more rarely, as narrow sections of laminated carbonate. Veins of sphalerite transect the carbonates mentioned above and are transected by later veins of quartz and carbonate minerals.

Summary

Dispersed and concentrated sulfides are disposed along a thick unit of schistose pyroclastic rocks. The sulfides have impregnated and replaced certain facies of the rock, notably the coarser pyroclastic materials. Layers of chert and fine tuff tend to delimit the metallized zones. The pyroclastic host is sandwiched between lavas and underlain by a large intrusion of gabbro which, in places, protrudes into the metallized zone.

Sphalerite is enriched along the north flank of the deposit and scarce in the interior copper ore zones. Magnetite is enriched in the footwall of the ore zones. Some of the pyrite is intricately shattered and replaced by the ore-sulfides. Chalcopyrite occurs as exsolution blebs in the sphalerite and as later veinlets and replacement material.

Faults and schist zones transect the volcanic rocks. No spatial connection between the distribution of sulfides and the fault structures was recognized. Post-ore fault movements have occurred. The host rocks have been altered near the ores mainly by chloritization, silicification and carbonatization.

Radiore Uranium Mines "A" Deposit

The Radiore Uranium Mines "A" deposit is located one mile west of the Bell river, in range IV, Isle-Dieu township. It was discovered in 1959 by drilling a combined electromagnetic and magnetic anomaly and delimited with 35 drill-holes.*

The geologic description and maps are based on the writer's logs of 12 holes and a study of the company data available in 1963. The general interpretation follows that of the company geologists.

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* During 1964 and 1965 the company drilled some 22 holes in the western part of the property, an area 4 miles west of Bell river in range IV, Isle-Dieu township. Projections of these holes from the company drill logs are shown on the map. The holes explored a 5,000-foot interval of intercalated gabbro, pillowed lava, pyroclastic rocks and rhyolite which mark the contact zone between the Wabassee and Lac Watson groups. Numerous stringers and small lenses of chalcopyrite and pyrite were found along the zone.

General geology

A volcanic sequence, complicated because of many lateral and cross-strike variations in lithology, strikes N.80°W., dips nearly vertically and probably faces to the north. Four more or less distinct volcanic units, which are tentatively correlated with the basal deposits of the Wabassee Group, can be recognized (Figure 5). These are from north to south:

pillowed dacitic lavas (+ 200 ft.)
interbedded siliceous and mafic lavas and
 pyroclastic rocks (± 200 ft.)
andesitic lava (60 - 100 ft.)
layered tuff, breccia and tuffite (ore host) (± 150')
\- - - - - - - - - - - -
gabbro

The uppermost lava units are typical of the Wabassee Group lavas. The lithology of the second unit is variable. Within the interval that was drilled, it consists of fine-bedded green, gray and brownish tuffs intercalated with spherulitic rhyodacite. The western part of the unit contains considerable volcanic agglomerate whereas to the east the main lithologic type is spherulitic rhyolite or rhyodacite. These rocks and the underlying andesitic lava are carbonatized and chloritized.

The fourth unit, the ore host, consists of diverse volcanic pyroclastic rocks, breccias and stratified tuffaceous deposits intercalated with narrow layers of laminated cherty tuffite and magnetite iron formation. These rocks are moderately to intensely altered and deformed to breccias and chloritic schists.

A gabbro dike, approximately 200 feet thick, cuts the stratiform volcanic rocks at a low angle. Its interior part is a medium to coarse-grained rock with a sub-ophitic texture. The dark minerals are converted to chlorite and epidote but the feldspar in one thin section was relatively fresh andesite-labradorite. The magnetometer data indicate that this gabbro is the eastern extremity of a subsidiary intrusion of the Bell River complex.

Several narrow felsitic and rhyolitic dikes also cut the volcanic rocks and metallized zone. These are difficult to correlate in drill-holes as large fragments of similar-appearing rocks are also distributed throughout the pyroclastic rocks.

Sulfide deposit

The deposit consists of a tabular-lensoid mass of sulfides and a conjugate zone of dispersed sulfides to the south. The main mass is 550 feet in length and extends to a depth of 250 feet; the thickness varies between 5 to 30 feet. The zone of dispersed sulfides is approximately 60 feet wide and extends beyond the lateral limits of the sulfide mass.

The sulfides encompass and impregnate chlorite schist, massive chloritic material, tuffite and chert breccia. The north contact of the sulfide zone is abrupt and marked, in places, by a layer of chert or chert breccia. Minor amounts of sulfides are present in the northern tuffs and in fractures and around pillows in the lavas. The south limit of the concentrated sulfides is not distinct, as is the north, but there is an abrupt transition to more dispersed sulfides.

The western end of the sulfide mass (Figure 5) abuts against the discordant gabbro contact. To the east and at depth the deposit thins and the sulfides occur as several narrow massive bands, adjacent to layers of tuffite and chert breccia. Similar rocks and sulfides occur to the west of the sulfide mass but separated from it by the gabbro intrusion. These relations indicate that the gabbro has intruded the metallized zone.

The average of the estimated relative proportions of metallic minerals in seven drill-hole intersections are: pyrite (65%), pyrrhotite (16%), sphalerite (11%), magnetite (10%), chalcopyrite (3%). Minor amounts of galena, bismuthinite, native gold and native silver (?) have been seen. The bismuthinite occurs as delicate crystals within massive chalcopyrite. The other minor minerals are usually associated with quartz-carbonate veins which cut the other sulfides.

The company estimates that the main sulfide mass contains 236,000 tons grading 5.76% zinc, 0.78% copper, and 0.018 ounce of gold and 0.90 ounce of silver per ton. An adjacent copper zone, noted above, contains approximately 36,000 tons grading 1.89% copper, 0.19% zinc and 0.032 ounce of gold and 0.17 ounce of silver per ton.

Four main mineral associations and dispositions can be recognized:

sphalerite - pyrite assemblage
chalcopyrite - pyrrhotite association
pyrite - magnetite assemblage
disseminated and veinlet sulfides

The sphalerite-pyrite assemblage is the main component. It forms the northernmost part of the metallized zone, and has a sharply defined northern contact against cherty layers or brecciated chert of the tuffite type. The gangue materials are mainly remnants and intercalations of the host rocks, silica-rich fragments, chert and clots of chlorite. The sulfides are banded due to variations in the amounts and crystallinity of the sphalerite, pyrite and gangue. The fine-grained sulfides may exhibit a regular lamination. The pyrite occurs as fine to medium-grained aggregates of subhedral crystals, as discrete idioblastic cubes (disseminated through gangue) and as microcrystalline, monomineralic layers. The sphalerite is usually admixed with pyrite and, in some places, pyrrhotite and chalcopyrite. Monomineralic intersections of coarse sphalerite are also common. Much of the fine-grained sulfides are fractured or brecciated. A polished sample of these consisted of irregular layers of shattered pyrite, invaded and in part replaced by sphalerite which contains tiny blebs of exsolution-type chalcopyrite and pyrrhotite.

The second variety of sulfides is characterized by the assemblage pyrrhotite-chalcopyrite, either in concentrated or disseminated forms. This pyrrhotite and chalcopyrite appear to be consanguineous as they are intimately mixed and truncate the fabric of the other sulfides. The characteristic host or alteration product associated with the copper metallization is a chlorite rock with tiny grains of vitreous quartz and splotches of opalescent silica. The sulfides in the brittle sectors of these rocks tend to impregnate and replace the walls of ramifying fractures (Plate VII-D). The pyrrhotite-chalcopyrite zones are most common in the footwall (south) of the pyrite-sphalerite zone.

The third component of the sulfide mass consists mainly of pyrite and magnetite, with or without base-metal sulfides. The magnetite occurs as laminated "iron formation" and as veins mixed with splotches and lenses of pyrite; both varieties contain low amounts of manganese and a trace of titanium.* In a polished sample, the magnetite appears interstitial to quartz grains and is partly replaced by chalcopyrite (Plate VIII-A).

The fourth form of metallization is the dispersed sulfides along the footwall and lateral extremities of the sulfide mass. The host rocks are the altered pyroclastic rocks and chloritic schists and chert-chlorite breccias. The predominant sulfide is pyrite and it occurs as narrow massive lenses or bands, as disseminated grains, and as veinlets along fractures. The quantity in the host rock varies from 10 to 25%. Minor amounts of sphalerite and chalcopyrite occur as irregular stringers that cut across the rock foliation, as isolated elongated blebs, and as

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* X-ray fluorescence analysis by writer.

slickensided films along foliation planes. In one sector there is considerable enrichment in chalcopyrite and pyrrhotite.

Alteration:- The alteration effects are diverse and complicated. Three main processes have occurred; chloritization, silicification and carbonatization. Abundant chlorite occurs in the rocks adjacent to the metallized zone and eastward and westward to the limits of the drilled area, and masses of chlorite are intercalated with the sulfides. Carbonatized zones occur throughout the host rocks and are particularly abundant in the lavas and pyroclastic rocks to the north of the sulfides. Veins and irregular masses of opalescent silica transect the host rocks and are cut by fracture-fillings of iron-bearing carbonate and quartz which contain pyrite and, in one place, visible gold.

Structural relations

The main structural features are illustrated in Figure 5. The most schistose rocks occur between the sulfide mass and the gabbro sill. The foliation is oriented parallel to stratiform features and, if the schist zones were extended westward, they would intersect the gabbro. However, no pronounced foliation was seen in the intersections of the gabbro. This discontinuity, and the erratic nature of the schistosity in general, suggest that the foliation has developed locally as a consequence of the incompetent nature of the pyroclastic rocks.

A transverse fault (or faults), oriented northwest, cuts the medial part of the sulfide zone. The fault is marked by gouge and breccia and appears to offset the west part of the sulfide mass to the north. West of the fault zone the inclined contacts dip north,whereas east of the fault zone they dip south. Thus some rotational movement has occurred.

Summary

The sulfides are closely associated with tuffite, bedded pyroclastic rocks and magnetite "iron formation" that occur near the base of the Wabassee Group lavas. The distribution of sulfide minerals is quantitatively and qualitatively asymmetrical. Zinc-rich massive sulfides occur in the north part,whereas disseminated or veinlet-type sulfides and zones of copper-enrichment occur in the south part of the metallized zone. Considerable hydrothermal-type alteration products are present. The wallrocks are, in places, schistose and contorted, however the contacts of the massive sulfides are marked mainly by lithologic discontinuities rather than structural features.

Bell Channel Mines Ltd. (No. 1 Deposit)

The Bell Channel Mines Ltd. deposit is situated in range III, on the Bell River. It was discovered by an electromagnetic survey and, during 1960 and 1961, 21 holes were drilled by Radiore Uranium Mines Ltd. and it held an option on the property.

The general geology is derived from the writer's drill logs and the company sections and logs. Section "3+00E" (Figure 5) is based on the writer's logs.

General geology

The deposit lies within stratified tuffaceous rocks and agglomerate, adjacent to the south contact of a subsidiary intrusion of the Bell River complex. The volcanic rocks strike east and are steeply inclined. The sequence, from north to south, is as follows:

gabbro intrusion
- - - - - - - - - -
layered tuffs, breccia and cherty tuffite (± 80 ft.)
rhyolite and mafic lavas (± 100 ft.)
andesite-basalt lavas (+ 200 ft.)

The southern unit consists of very fine-grained rocks that, locally, have ophitic and porphyritic textures and zones of amygdules and varioles. The second unit consists of siliceous and mafic lavas. The siliceous varieties include aphanitic rhyolites, porphyritic rhyolite and spherulitic facies. The mafic varieties are similar to those in the third unit except that they are intercalated with tuff and breccia.

The third unit is the sulfide host and consists of bedded tuffaceous rocks, laminated cherty tuffite layers and volcanic breccias. Near the sulfide mass the host rocks are markedly altered and the cherty layers become fragmented and strewn through a schistose chloritic base. Layers or large fragments of siliceous spherulitic volcanic rock are intercalated with the tuffs and tuffite.

A gabbro intrusion extends along the north edge of the volcanic units. The intrusion is grossly conformable and its south contact has a steep, irregular dip. The south part is a medium- to coarse-grained uralite-epidote-saussurite rock, derived from gabbro. A rude mineralogic layering can be discerned. On an island near the deposit, an outcrop shows the dip to be 80 degrees north.

A few small dikes of dark gabbroic rocks cut the volcanic units, and narrow felsite dikes were seen in a few drill cores.

Sulfide deposit

Form and relations to host and wall rocks:- The sulfides occur as a more or less massive lens adjacent to a zone of disseminated and veinlet-type sulfides. The lens dips steeply south, has a lateral extent of 300 feet, a depth of 260 feet and in the medial part is 40 to 60 feet wide. The conjugate zone of dispersed sulfides is 30 to 40 feet wide.

The host rock is the tuffite and layered tuffaceous rocks as remnants of these occur throughout the metallized zone. The north flank of the lens abuts against the gabbro contact except at depth, and,to the east, where there is an intervening zone of agglomeratic rock with disseminated sulfides. The south margin of the sulfide lens merges abruptly with the zone of dispersed sulfides.

The contacts between the metallized volcanic rocks and the gabbro are, in general, quite distinct and the gabbro contains no significant amount of sulfides. In places the sulfide-gabbro contact is schistose and the relations blurred. The south contact of the gabbro is nearly vertical at depth but,near the surface, gabbro overlies the up-dip extension of the sulfide zone. In fact, the zone apexes beneath an outcrop of gabbro on an island. These relations are attributed to a transverse fault along which a segment of the gabbro is offset over the sulfides as both are brecciated and slickensided here.

The sulfides:- The sulfide assemblages range from massive pyrrhotite and massive pyrite to mixtures of these with sphalerite and chalcopyrite. The deposit has a stratiform zoning; pyrrhotite is strongly enriched in the north flank of the sulfide mass,whereas the south flank and the adjoining zone of dispersed sulfides are enriched in pyrite. Concentrations of chalcopyrite occur in the south part of the metallized zone. The sphalerite is usually mixed with pyrite and is concentrated in the medial and south part of the deposit.

The relative proportions of metallic minerals across the whole metallized zone were estimated for six drill-holes as follows: pyrite (47%), pyrrhotite (35%), chalcopyrite (6%), sphalerite (2%) and magnetite (10%). The company estimates that the deposit contains approximately 100,000 tons grading 1.95% copper and 0.57*% zinc.

The pyrite has a variable habit. It occurs commonly as monomineralic bands of subhedral crystals intercalated with layers of the host rocks. Some microcrystalline pyrite is interlayered with pyrite

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* Some zones were not assayed for Zn.

nodules and sphalerite (Plate VI-B). Where siliceous breccia is the predominant host rock the pyrite is disposed along microfractures and disseminated through the chloritic component. The schists contain bands of pyrite and disseminated idioblastic crystals. Much of the pyrite is shattered and, in places, healed with other sulfides. The sphalerite, where present, is intimately admixed with the pyrite. The pyrite and pyrrhotite mixtures are massive, foliated, or banded. In places the pyrite forms porphyroblastic (?) crystals in a fine matrix of pyrrhotite or (rarely) magnetite. The chalcopyrite is usually in the form of monomineralic blobs and stringers or distributed throughout a pyrrhotite host. Masses of black chlorite and chlorite schist are the most common gangue materials. In the sheared rocks, the chalcopyrite may be localized in narrow cross-fractures that transect the foliation but most commonly it is smeared along the foliation planes.

Alteration:- Veinlets of cherty silica and zones of silicified material permeate the host rocks. The tuffs and schistose rocks contain abundant sericite material and chlorite and small metablasts of actinolite are visible in some of the darker quartzose rocks. Masses of chlorite with scattered small grains of quartz are admixed with the sulfides. This material represents the extreme alteration of the host rock. A minor amount of carbonatization and silicification is associated with veinlets of quartz and carbonate which transect the other alteration products.

Summary

The sulfides are confined to the northern edge of stratified volcanic deposits. The sulfide masses and the minerals within them have an asymmetrical distribution; the massive types occur along the north part of a zone of dispersed sulfides.

A gabbro intrusion forms part of the wall rocks on one side of the metallized zone.

The host rocks of the deposit are complexly fractured and sheared and considerable post-sulfide deformation has occurred.

Bell Channel Mines Ltd."No 4 Zone"

The Bell Channel Mines Ltd. "No 4 zone" is located one mile northeast of Chenal rapids and east of the Bell Channel Mines Ltd. "No 1 deposit".

The deposit was discovered by an electromagnetic survey in 1961 after the property was optioned by Radiore Uranium Mines Ltd. Six holes were drilled by Radiore. Dumagami Mines Ltd. drilled the eastern extension of the host rocks on its property in 1962.

Interbedded and intertonguing mafic lavas and pyroclastic rocks strike N.70°E. and dip vertically or steeply south. Gabbro dikes truncate, at a low angle, the north and south part of the volcanic assemblage.

A serpentinized schist zone, probably a longitudinal fault zone, lies south of the metallized zone, and an assumed transverse fault, oriented N.30°W., displaces the host rocks and gabbro dikes in the west part of the explored area.

The sulfides are pyrite, pyrrhotite, chalcopyrite, sphalerite and magnetite dispersed throughout a zone approximately 100 feet wide, 1,000 feet long and intersected to a depth of 700 feet. The total amount of sulfides in intersections of this zone ranges between 10 and 35%. Some contain up to 1% copper and 1% zinc.

The sulfides occur as veinlets, as irregular bands along foliation planes, and as disseminated blotches. The main host rocks are chloritized layered tuffs and agglomeratic tuff. Narrow veinlets of all the sulfides also traverse massive mafic lava.

Some of the most concentrated sulfides consist of pyrite and sphalerite closely associated with cherty silicified rock. The chalcopyrite is usually mixed with pyrrhotite or pyrrhotite and pyrite. The magnetite occurs as irregular small bands and lenses and occasionally in veinlets.

Radiore Uranium Mines Ltd. "East deposit"

The Radiore "East" deposit is located in range II, Isle-Dieu township, two and one half miles east of Chenal rapids. The deposit was indicated by an electromagnetic survey in 1961 and explored by 38 drillholes. The writer is indebted to the company and its resident geologist, M. Woakes, for their information. The geology shown on the map is a simplified version of that derived by Woakes. Section "5+00E" (Figure 5) was constructed from the writer's logs.

General geology

The sulfide deposit lies in stratified volcanic rocks enclosed within the north margin of the Bell River complex. The volcanic units are vertical and strike N.80°E. The sequence from north to south is:

gabbro and quartz diorite
- - - - - - - - - - - - - -
andesitic lava (± 100 ft.)
altered tuff, rhyolitic breccia, agglomerate, layered
  silica rock (tuffite ?) (± 80 ft.)
andesitic lavas (+ 150 ft.)

The lavas are dark green to greenish black rocks similar to other andesitic lavas but unusually cohesive due to an incipient amphibolitization. Narrow tuff layers and flow breccia are intercalated.

The central unit, the host rock, consists of three main rock-types; siliceous breccia, chloritic and biotitic schists and laminated and brecciated silica rocks. The siliceous breccia consists of fragments of cherty or porcellaneous quartz, rhyolite and other quartzo-feldspathic and chloritic materials, set in a dark chloritic matrix. The texture of the rock is complicated but resembles that of an agglomerate whose primary fabric has been brecciated, disorganized and blurred by alteration.

The chloritic schists are composed of varying amounts of chlorite, brown mica, sericite, quartz and semi-opaque materials. They are layered and, presumably, derived from stratified tuffs. The brown mica is at an incipient stage of development from chlorite in most samples but, in some instances, forms monomineralic layers, a few inches thick, of tiny flakes which give the rock a peculiar sheen.

The third rock type is also a breccia but, unlike the others, is composed mainly of irregular fragments of cryptocrystalline quartz and other cherty material. A laminated or bedding structure is visible in a few of these fragments. The matrix material of the breccia is chlorite and sericite. In some samples these are partly altered to brown mica. The breccia fragments resemble tuffite and narrow sections of layered tuffite were seen in one drill core.

Gabbro, cut by numerous dikes of quartz diorite, forms the north wall of the volcanic rocks and small dikes of gabbro intrude the pyroclastic unit at depth. The gabbro is a medium-grained uralitic rock with the vague crystal layering common in the Bell River complex gabbros. Felsitic and siliceous dikes also transect the gabbro.

Sulfide deposit

Form and relations to host rocks, structure and intrusive rocks:- The sulfide mass is lensoid, approximately 400 feet long, 250 feet deep and 5 to 30 feet thick. The upper part of the north contact of the sulfides (Figure 5) is sharply defined by the contact of the lava unit. At depth, where the sulfide zone diverges from the lava contact, the sulfides become more disperse. The south flank of the sulfide mass merges with a zone of dispersed sulfides, 10 to 25 feet thick. A few streaks and veinlets of pyrite are present in small structures in the lavas, but, except for these, the sulfides are confined to the north part of the pyroclastic unit.

The asymmetry in the distribution of sulfides appears to be related to the interplay of lithology and small structures. Thus the main concentration of sulfides is along the north part of the pyroclastic deposit, against the relatively massive lava unit. The breccias south of the massive sulfides become progressively less metallized away from the lava contact.

A small felsitic dike transects the massive sulfides in one drill-hole. The dike has sharply defined, chilled contacts against the sulfides and is not metallized. Another dike of porphyritic gabbro cuts the metallized zone at depth.

The volcanic rocks that enclose the deposit cannot extend, with their present strike, much more than a thousand feet. There is a possibility that the strike may change and that the volcanic rocks extend westward as a septum between apophyses of gabbro. It is more probable that the host rocks and sulfides form a large inclusion, engulfed in the gabbroic rocks.

The sulfides:- The approximate relative proportions of metallic minerals are: pyrite (60%), pyrrhotite (25%), chalcopyrite (7%), sphalerite (4%), magnetite (5%). The company estimates the deposit at 100,000 tons containing 2.61% copper, 1.35% zinc and minor amounts of gold and silver.

The metallic minerals are distinctively zoned across the thickness of the deposit; the south part is enriched with pyrrhotite, the medial part with pyrite, and magnetite is concentrated along the north flank of the lens. No pronounced zonation of copper and zinc was noted although the copper is usually associated with pyrrhotitic zones and the sphalerite is always in pyrite-rich zones. The gangue is mainly remnants of the pyroclastic host. Silica-rich fragments are particularly distinct. A few fibers of aluminous anthophyllite were noted on a fracture surface of massive pyrrhotite.

The sulfides are massive, regularly layered, or have foliate textures. Most of the pyrite is in medium-grained subhedral aggregates. Irregular streaks and fragments of microcrystalline pyrite are present in some sectors, particularly in the layered types of sulfides. The pyrrhotite is variable in habit; disposed as structureless masses; intergrowths with pyrite and chalcopyrite; and as veinlets and networks in gangue. A distinctive "porphyritic pyrite" texture was noted in places. This is due to subhedral (pyritohedral) crystals of pyrite up to 2 cm. wide, scattered through a pyrrhotite base. The pyrite crystals have mutual interference boundaries and occur within both massive and disseminated pyrrhotite. These are probably porphyroblasts. The chalcopyrite forms intricate networks in fractures and is disseminated in the interstitial material of the siliceous breccias. Chloritic zones within the massive sulfides are commonly enriched in chalcopyrite. The sphalerite is invariably mixed with pyrite.

Alteration and metamorphism:- The predominant alteration products are chlorite, silica and brown mica. Chlorite is an ubiquitous component of all the volcanic rocks and occurs in concentrated form as bands and irregular clots in the host rocks. Considerable silica has been introduced into the volcanic breccias which contain veins of porcellaneous and cherty silica. Silica also impregnates and accentuates the margins of lithic fragments. It is notable that some of the silicified rocks are intricately brecciated and thus the silicification predates a time of deformation. The brown mica is probably biotite and has developed from a pre-existing alteration product -- the chlorite. The mafic lavas are slightly amphibolitized.

Garon Lake Mines

The Garon Lake Mines deposit is located in range III, Isle-Dieu township, two and one quarter miles east of the Bell river. The sulfides were indicated by an airborne electromagnetic survey in 1956 and explored by 15 drill-holes. The exploration work and geological setting have been described by Joklik (1960) and Latulippe (1961).

General geology

The deposit is within highly metamorphosed volcanic rocks that lie between the north margin of the Bell River complex and an intrusion of granitic rocks. The strata dip steeply north and strike N.70°W. Two gross lithologic units can be distinguished; a band of amphibolitized lavas 100 to 150 feet thick and a band of bedded rocks approximately 300 feet thick. The latter unit is south of the first and can be traced over 2,000 feet along strike.

The amphibolitized lavas are massive and foliate, very fine grained, with varying amounts of feldspar, biotite and quartz. In places, porphyroblastic aggregates of hornblende coarsen the texture. The occasional narrow layer of pyroclastic material and amygdular zones indicate that the rocks were lavas.

The second unit, the host rock of the sulfides, is composed of schists and layered foliate hornfelsic rocks consisting mainly of quartz and smaller amounts of amphibole, biotite, muscovite, feldspar and chlorite. Weathered surfaces occasionally display a fine to coarse fragmental or agglomeratic texture that is not apparent on fresh surfaces. Near the sulfide zone, the rocks are mainly fine-grained maculose hornfelsic rocks and schists, quartzite, dark mottled chloritic rocks and cordierite-anthophyllite hornfels. Fresh cordierite does not appear to be abundant although some samples of the maculose hornfels and mottled chlorite rocks contain pinite aggregates, fibrous amphibole of the anthophyllite-gedrite series and masses of fine tremolite. The quartzite is a compact mass of sutured and granulose quartz, almost pure or with minor amounts of muscovite, biotite, green hornblende, epidote, fresh oligoclase and sulfides. One sample contained small porphyroblasts of red garnet.

The general composition and appearance of the layered unit and the intercalation with volcanic rocks indicates that the host rocks are metamorphosed pyroclastic rocks, analogous to the less altered bands of these rocks a mile to the west. It is probable that the quartz-mica (hornblende) schists are derived from siliceous tuff and other pyroclastic materials. The fine-grained quartzites resemble a recrystallized chert; analogous to the cherty rocks common in the stratified pyroclastic rocks of the area.

Dikes of massive and gneissose feldspar-amphibole rock transect the volcanic rocks. The massive varieties have a crystalloblastic texture and some samples contain minor amounts of magnetite, biotite and quartz. A sill of the feldspar-amphibole rock, south of the volcanic rocks, appears to be contiguous to gabbro of the Bell River complex.

A few dikes of aplite, gray lamprophyre and quartz diorite cut the other rocks.

The south contact of the granitic intrusion is probably marked by the limit of a magnetic low, located 1,000 feet north of the metallized zone. The pronounced contact metamorphism of the volcanic and gabbroic rocks can be ascribed to this intrusion.

The sulfide zone

The sulfides occur in a conformable tabular zone which dips steeply north and strikes eastward. Drill-holes intersect the sulfides over a strike-interval of 1,100 feet, and to a depth of 250 feet at the western extremity and 700 feet at the eastern extremity. The widths are between 5 and 25 feet. The thicker intersections correlate with a warp in the host rocks that bulges southward and plunges to the east.

The deposit consists of massive and dispersed sulfides. Most intersections contain more than 50% sulfide. The approximate relative mineral proportions in five intersections were estimated as: pyrrhotite (65%), pyrite (20%), chalcopyrite (6%), magnetite (6%) and sphalerite (3%). The company estimates that the deposit has approximately 290,000 tons containing 2.12% copper. The average tenors of other metals were not reported.

The sulfides are crudely banded and foliated. Pyrrhotite and pyrite occur as mixtures and as nearly monomineralic bands. Some pyrite has a porphyritic or porphyroblastic aspect; subhedral crystals, up to 5 mm. in diameter, are set in a fine-grained matrix of pyrrhotite or pyrrhotite and gangue. Nodular forms of pyrite are present in some layers of massive sulfides.

Sphalerite is enriched in pyrite sections and is intimately intergrown with pyrite and pyrrhotite. Microscopic blebs of pyrrhotite and chalcopyrite and pyrite are scattered through the sphalerite crystals. Some of the chalcopyrite occurs as isolated patches or irregular stringers in the other sulfides.

The gangue is composed predominantly of inclusions and remnants of the wall-rock. Fibrous orthorhombic amphibole is present along some fracture surfaces and intergrown with sulfides. It is notable that some black monoclinic amphibole occurs in narrow veinlets that cut massive sulfides.

Alteration and metamorphism:- Some aspects of the metamorphic nature of the rocks have been noted above. Joklik (1960) discusses cordieritic alteration in two of the four drill-holes he described and, after considering local relations, states (p. 349): "The zone of alteration therefore plunges conformably with the massive sulfides". He also notes, (p. 351): "The extent of alteration of the rock is generally proportionate to its content of sulfides". These relations are not pronounced in the subsequent drill-holes and the magnesian silicates appear to be a local facies of the amphibolitic aureole of the granite intrusion, rather than alteration associated with metallization. The apparent relation between the "magnesian alteration" and the metallization is possibly indirect: the cordieritic rocks formed from chloritized wall-rocks.

Daniel Mining Co. Ltd.

The southeast corner of a large block of claims held by Daniel Mining Co. Ltd. is located in range VII, Daniel township, east of Gouault (McIvor) river. Airborne surveys led to the discovery of a sulfide zone which was drilled in 1959.

The sulfides are chalcopyrite, sphalerite, pyrite, and pyrrhotite, dispersed in altered pyroclastic rocks. The zone is 5 to 30 feet wide and 300 feet long. Drill intersections had tenors ranging from 0.4 to 2.6% copper, 1.2 to 1.8% zinc and small quantities of gold and silver.

The structure is complicated. Of several possible interpretations, the writer considers that the zone may plunge southeast, along the base of a gabbro intrusion, which dips northeast.

New Calumet Mines Ltd. (Bosada Syndicate)

New Calumet Mines hold a group of claims, centered 5,000 feet northwest of Watson lake, in Daniel township. Diamond drill-holes in this area intersected veinlets and disseminations of sphalerite and chalcopyrite in dacite, rhyolite and chert.

Near Matagami Townsite

A hole drilled by Mattagami Syndicate, approximately 3,000 feet east of the north-south center-line of Isle-Dieu township, and 200 feet north of the road, intersected gabbro and anorthosite with disseminated chalcopyrite.

South of Chenal Rapids

Veinlets of chalcopyrite and quartz occur in a gabbro outcrop located on the east bank of the Bell river, 5,000 feet south of Chenal rapids.

Galinée-Mattagami Mines

Veins of chalcopyrite in chloritized volcanic rock are exposed in a trench located 8,000 feet west of the center line of Galinée township and 200 feet south of range-line IX-X. A gabbro outcrop located 1,000 feet at S.30°E. from the trench has narrow quartz veins with chalcopyrite (Ingham, 1958, p. 20).

Bracemac Mines Ltd.

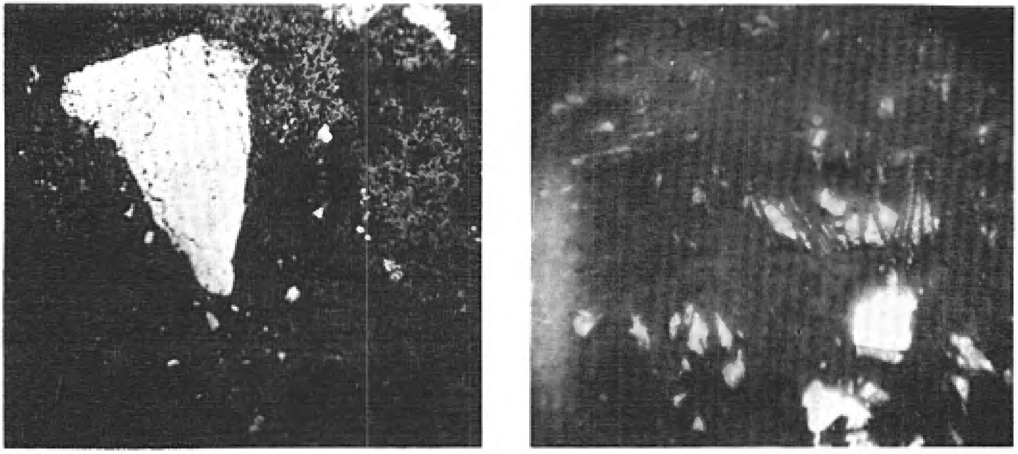
Small amounts of sphalerite and chalcopyrite were noted in drill-holes by Ventures Exploration Ltd. in places along a 5,000-foot interval of the contact between the Wabassee Group and Lac Watson Group near the railway in range VII, Galinée township.

Gold and Silver

Small quantities of gold and silver (aside from those associated with the sulfide masses) occur in a few quartz veins and schist zones. The more interesting occurrences known to the writer are described below.

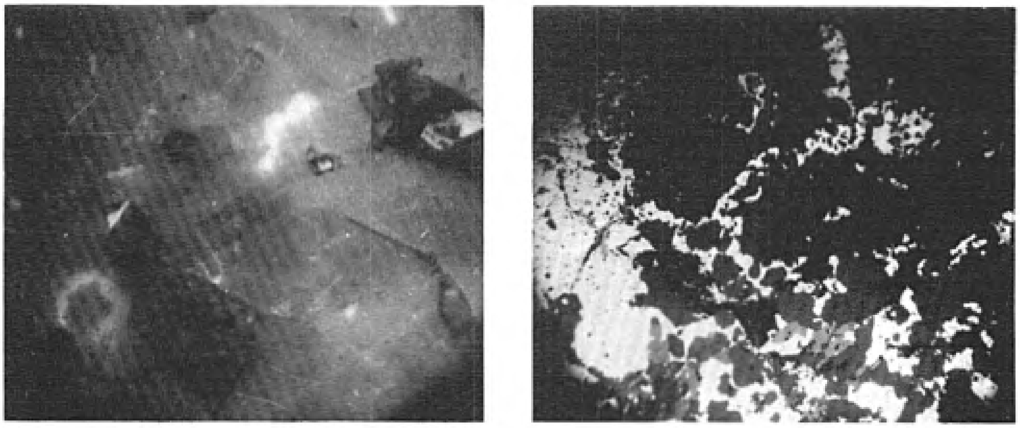
PLATE VII

MICROSCOPIC NATURE OF ORES



a) Fragment of pyrite in sphalerite and gangue. Mattagami lake (x 14).

b) Chalcopyrite transected (?) by shreds of chlorite, Mattagami lake (x 200).



c) Polysynthetic twins in sphalerite, Mattagami lake (x 250).

d) Network of pyrrhotite and chalcopyrite in opalescent silica, Radiore (x 27).

Northern Quebec Explorers Ltd.

This company holds a large block of claims which extend westward from the south tip of Dunlop bay. On claims 110206, No. 2, and 110209, No. 1, a set of steep fractures, oriented northwest, has been exposed by extensive stripping and trenching.

The fractures are filled with auriferous quartz and pyrite and, locally, small amounts of a bismuth mineral (bismuth telluride?). More than 16 fractures occur over an east-west interval of 800 feet; some have been traced several hundred feet along strike.

The veins are usually approximately 2 inches wide, occasionally swelling to 6 inches.

Assays of selected samples taken by the writer are as follows: 0.153 ounce of gold per ton, 0.378 ounce of silver per ton; 0.089 ounce of gold per ton; 34.440 ounces of gold per ton, 1.1% bismuth, and 0.00% molybdenum.

The last sample was gossanized pyrite and quartz from what is known as the Roland vein.

Daering Explorers Corp.

A hole drilled by Daering in 1958, located beside range-line III-IV, 8,400 feet east of the north-south center line of Daniel township intersected a brecciated fault zone under the river. A select sample of pyritic quartz from the fault zone, which was taken by the writer, contained 0.466 ounce of gold per ton.

Magado Mines Ltd.

A drill-hole by Dome Exploration in 1959, located 5,100 feet west of the north-south center-line of Galinée township, and 2,000 feet south of range-line VIII-IX, was reported by the company to have intersected a vein of quartz and chalcopyrite which assayed 0.20 ounce of gold per ton over a length of 1.2 feet.

Molybdenite

A few flecks of molybdenite and chalcopyrite in an aplitic dike are exposed in a trench located in Isle-Dieu township, 1,200 feet south of the end of the small bay and 5,000 feet west of the entry into Dunlop bay.

COMPARISON OF THE SULFIDE MASSES

The peculiarities of each of the main sulfide masses described in the previous section are outweighed by the general consistencies in disposition, composition and morphology. These primal relations indicate that the deposits formed under similar geologic conditions.

The main events in the geologic history of the area have been volcanism, accompanied or followed by the intrusion of gabbroic rocks, and then orogeny and the emplacement of the granitic rocks. That is, the geologic environments peculiar to the volcanism, or the main deformation, or later metamorphism by the granites were not repeated in time. This suggests a premise: the sulfide masses were emplaced during one stage of the geologic history of the region and consequently during one interval of time.

In the delimitation of this stage and time the following relations are of particular importance: the nature and stratigraphic disposition of the metallization; the spatial and chronological relations of the deposits to the main mass of the Bell River complex and related intrusions; the relations of the sulfide masses to deformation structures. Analyses of these relations lead to the conclusion that the sulfide masses were emplaced at high temperature, during a certain stage of the volcanism, at or very close to the top of the existing volcanic pile.

Gross mineral and metal compositions of deposits

All the deposits contain pyrite, pyrrhotite, magnetite, sphalerite and chalcopyrite. Some contain small amounts of galena, free gold, silver (?), bismuth and bismuthinite. Semi-quantitative evaluations of relative sulfide volumes, in what are considered to be representative sections of the main deposits, are indicated in Figures 7a and 7b*. The proportion of pyrite - pyrrhotite is roughly the same in five deposits but less in the Bell Allard, Mattagami Lake and Orchan deposits. The decrease corresponds to an increase in sphalerite. The amounts of pyrrhotite are higher in the north band deposits except at New Hosco deposit. The Garon Lake orebody is strongly discordant, although the base metal content of the deposit is similar to that of the other deposits. There is a general antithetic relation between chalcopyrite and sphalerite.

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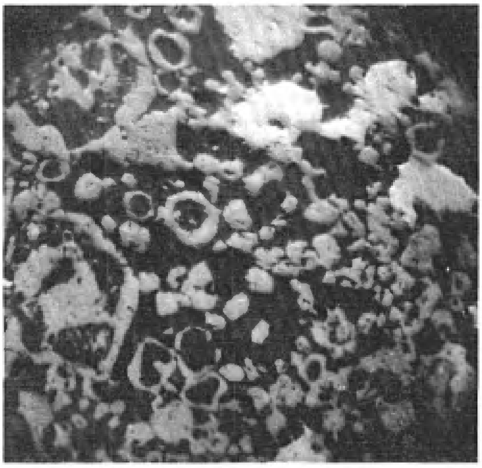
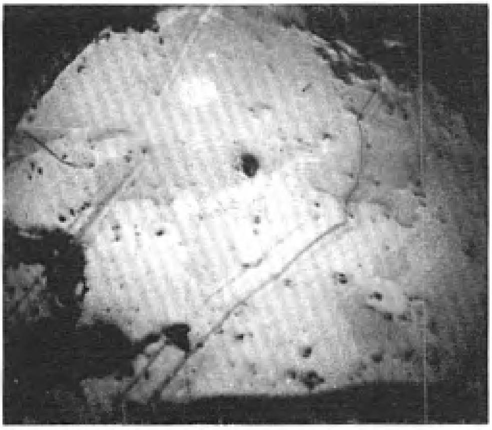
* The chalcopyrite and sphalerite are calculated from assays, and the sphalerite is assumed to contain 12% Fe. No correction made for specific gravity.

PLATE VIII

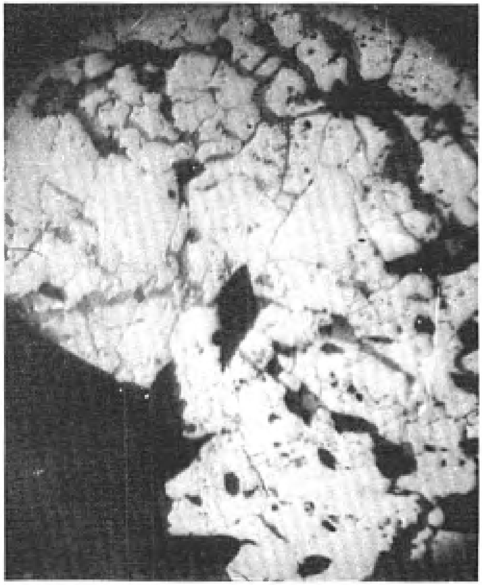
MICROSCOPIC NATURE OF ORES



a) Magnetite interstitial to quartz grains and replaced by chalcopyrite, Radiore (x 100).



b) Sphalerite (gray) replaced by chalcopyrite (light gray), Orchan (x 50).



c) Fractured pyrite (white) with ramifying veins of chalcopyrite, New Hosco (x 100).

The association of chalcopyrite with pyrrhotite was noted at most deposits. However, the gross amounts of pyrrhotite are not proportional to the copper tenor. The larger amount of pyrrhotite in the metamorphosed host rocks of the Garon Lake deposit is noteworthy.

The amounts of zinc and copper vary within and between the deposits. The Zn/Cu ratios range from 0.3 to 18.8 (Figures 7a and 7b). The smaller deposits and the larger New Hosco deposit are enriched with copper. There is also a general inverse relation between the amounts of copper and zinc.

Ore Types and Distribution

The deposits exhibit a broad spectrum of mineral associations and modes of occurrence. However, general types of ore and metallized rock can be distinguished on the basis of the predominant metallic minerals and fabric. The term "ore-type" will be applied although specific examples may not be "ore" or in an "orebody" in the strict sense of these terms. The following ore-types are the main components of the larger deposits: 1) tuffite sulfides 2) metallized schist, breccia and coarse pyroclastic rocks 3) pyrite-magnetite-pyrrhotite mixtures 4) pyrite-sphalerite ore 5) chalcopyrite ore.

1) Tuffite sulfides

The sulfides within the layered tuffite are of particular interest, not primarily because of the quantity of base metals, but because of the relations between the sulfides, bedding, and deformation structures and the close spatial relation of tuffite beds to the margins of many of the sulfide masses.

The more detailed observations were made at Mattagami Lake mine. The general relations observed there are also discernible in drill cores from the other deposits, notably the Mattagami Lake Mine No. 2, Orchan, Bell Allard, New Hosco, Radiore "A" and Bell Channel. The lithologic and stratigraphic nature of the tuffite has been described (p.20), and the conclusion has been drawn that some components of the tuffite may be thermal spring deposits interbedded with pyroclastic materials.

In general the sulfides in the tuffite occur as regular layers of pyrite and pyrrhotite along bedding structures. Some pyrite and pyrrhotite transgress the bedding structures and replace sectors of the rock. There is evidence (e.g. Plate IV) that sulfide layers were deformed during the regional folding.

As sulfur and iron are common in the assumed volcanic environment, the circumstantial evidence suggests that some of the tuffite sulfides were formed by surface or near-surface volcanic processes. Such sulfides are ubiquitous components of tuffite throughout the region and are not necessarily co-genetic with the sulfide masses.

Chalcopyrite and sphalerite in the tuffite generally occupy micro-fractures or appear to replace fine-grained pyrite or pyrrhotite. Some sphalerite does occur as fine lamellae, concordant to bedding. Evidence that local recrystallization of sphalerite has occurred in accord with a superimposed foliate fabric can be seen in diagnostic specimens (e.g. Plate V). Thus some sphalerite in the tuffite also appears to have been deformed.

Tuffite is an important host for the ores as partially replaced remnants occur throughout many of the deposits. The tuffite layers are generally thicker in the vicinity of the main deposits in the south volcanic band. However the "tuffite sulfides" (recognizable as such) are a small amount of the total sulfides and the general thickness of the contiguous tuffite bands is of the order of 10 to 20% of the total thickness of the sulfide masses.

2) Metallized schist, breccia and coarse pyroclastic rocks

Zones of dispersed sulfides underlie most of the deposits. Some of the zones in the south band have considerable vertical extent. The north band deposits dip nearly vertically, but,south of the sulfide masses, the pyroclastic units are impregnated with disseminated or vein-type sulfides. Parts of these zones contain considerable copper and are discussed under the chalcopyrite ore-type.

The type of metallization contrasts with the layered type of sulfides in the tuffite and indicates that the dispersed sulfides have been introduced into the rock, that is, they are epigenetic.

3) Pyrite-magnetite-pyrrhotite mixtures

The third general ore-type contains abundant magnetite, pyrite and usually pyrrhotite. Copper and zinc are also present but much of the material is essentially barren. Extensive sectors of the basal parts of the Mattagami Lake and New Hosco deposits consist of this material and small and large masses occur throughout the other deposits.

The magnetite occurs as monomineralic masses or is admixed with pyrite or pyrrhotite. Brecciaform and foliate textures are common. Large automorphic crystals of pyrite have formed in magnetite and pyrrhotite in most of the deposits. These appear to be porphyroblasts.

In general, the magnetite found throughout the sulfide masses may be polygenetic. In some places it occurs as epigenetic veinlets but, elsewhere, (Radiore "A", Bell Allard) it is in a laminated form, akin to "iron formation". Both varieties (in six samples which were analyzed by X-ray fluorescence) are non-titaniferous and, therefore, different from that in adjoining gabbro intrusions.

4) Pyrite-sphalerite ore type

Sphalerite is the main ore sulfide and, in combination with pyrite, forms large parts of the sulfide masses. The ores are layered or banded, crudely foliated, or featureless massive sulfides. The sphalerite is a dark reddish-black or brown variety and usually contains more than 12% FeS in solid solution. Most crystals contain tiny blebs of pyrrhotite that have the form and distribution characteristic (Edwards, 1954, p. 69) of exsolution. Evidence of exsolution is also found in the lack of pyrrhotite outside the sphalerite grains.

The sphalerite has various boundary relations with pyrite. In several samples the sphalerite has invaded fractures in fine-grained pyrite and has partially replaced this mineral but, in general, the sphalerite is intergrown with pyrite in a homogeneous fashion or occurs in monomineralic bands.

The fabrics commonly appear disordered; veinlets or irregular clots of pure sphalerite truncate foliated sphalerite-pyrite-chlorite mixtures, or breccia-like fragments of fine-grained pyrite are strewn through the ore. Some of these fabric elements resemble those of deformed rocks.

As sphalerite responds to deformation by twinning (Buerger, 1928), 12 samples from the New Hosco, Mattagami Lake, Orchan and Radiore deposits were studied to determine if this was true of the Matagami sphalerites. Eleven of the samples did exhibit polysynthetic twinning (Plate VII-C) but, as noted by Bastin (1950, p. 73), this might develop incidently to mild internal stresses rather than external stresses. It is perhaps significant that the one sample that did not exhibit pronounced twinning was of a well-layered variety of pyrite and sphalerite (Plate VI-A).

Small amounts of chalcopyrite, pyrrhotite and magnetite are mixed with the sphalerite-pyrite ores. Some of the chalcopyrite is a fundamental component of the sphalerite-pyrite ore as it is present as exsolution-type blebs (Buerger, 1934) in all the deposits. But much of the chalcopyrite was introduced into sphalerite ore.

5) Chalcopyrite ores

Zones within the sulfide deposits are enriched with copper. At some deposits these zones form spatially distinct ore masses such as the dispersed sulfides at Radiore "A" deposit or the concentrated sulfides of "A" orebody at the New Hosco mine.

The general characteristics are: The amount of chalcopyrite is independant of the total sulfide content as some sectors, rich in chalcopyrite, contain only minor amounts of other sulfides. Ores rich in copper are also enriched in pyrrhotite. The host rocks of the more dispersed sulfides are converted almost completely to chlorite and the characteristic form of chalcopyrite is as irregular blotches and veinlets in this host. Where the chloritic rocks are markedly schistose, the chalcopyrite becomes smeared out along the folia of the schist.

In all samples of chalcopyrite-rich ores that were examined microscopically, the chalcopyrite transects or appears to have replaced the other materials such as chert, pyrite, sphalerite and magnetite.

The prevalent characteristic of the copper mineralization is its tendency to be dissociated from the other sulfides, both on the scale of hand samples and within the metallized zones.

Paragenetic relations

No one deposit has been studied in sufficient detail to establish complete paragenetic relations. The pervasive deformation textures that characterize some of the ores is a factor to consider in interpreting paragenetic evidences. The following gross relations are apparent in most deposits:

1) The earliest sulfide is dense, more or less barren pyrite that is shattered and invaded by other sulfides.

2) The bulk of the sphalerite is intimately mixed with pyrite and contains minor amounts of chalcopyrite. These minerals appear to have formed contemporaneously.

3) Some chalcopyrite has been introduced subsequent to the sphalerite.

4) There has been local remobilization of the more plastic sulfides and fracturing and reorganization of the brittle minerals.

Zonation of ore-types

The sections of the larger deposits which were examined by the writer have a distinct zonation of the metallic minerals which in part follows a stratiform pattern.

The most pronounced feature is the concentration of sphalerite in the upper or hanging-wall sides of the metallized zones at New Hosco, Mattagami Lake and Radiore "A" deposits. Coincident with this is the enrichment of chalcopyrite along the basal parts and magnetite in the footwall of the ores.

Pyrite or pyrrhotite are commonly enriched in well defined to crude stratiform zones.

Temperatures of Crystallization

An attempt was made to estimate the minimum temperatures of crystallization on the deposits by the use of the sphalerite and pyrrhotite geothermometers.

Sphalerite geothermometer

The sphalerite geothermometer utilized the iron content of sphalerite which, as a solid solution, may be proportional to the temperature of crystallization (Kullerud, 1953).*

Samples were analysed by a mutual standard X-ray fluorescence technique which, as applied, has an estimated error of ± 4% of the contained iron.

The apparent temperatures of crystallization and the nature of the samples are presented in Table 2. Some samples were from intimate intergrowths of sphalerite and pyrite and the high apparent temperatures are probably due to contamination and are not significant. Aside from these, the range of apparent temperatures between 12 samples from six deposits is 425° to 615° ± 15°. The difference in apparent temperature of four samples from the New Hosco deposit is 153°C., 37 degrees less than the range between the six deposits. All these apparent minimum temperatures are uncorrected for pressure.

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* Details of the sulfide phase relations and applications as a geothermometer are available in the publications of Kullerud (1953, 1956, 1959), Skinner (1958), Rose (1961) and Sims and Barton (1961).

Table 2. Results from Sphalerite Geothermometer

Deposit Sample No.	Nature of mineral assemblage po(pyrrhotite) py (pyrite) cp (chalcopyrite) sp (sphalerite) sp^p (+ blebs of pyrrhotite) sp^c (+ blebs of chalcopyrite)		wt.% FeS in sample ± 0.5%	apparent temperature in °C.
	Macro	Micro		
Bell Allard				
Ba28-775	sp+py+cp	sp^p	12.8	450
Orchan Mine				
103-666	sp+py+cp+magnetite	sp^c	18.2(17.2)[a]	580(555)
Mattagami Lake Mine				
Md	sp+po+cp	sp^{pc}	14.9(14.8)[a]	501(500)
Md (2nd sample)	sp+po+cp	sp^{pc}	14.7	496
Me	sp+py	sp^p	14.3	486
Mop	sp+py+cp	sp^p	15.5	520
New Hosco Mine				
H20-485	sp+py	sp^c	19.2(19.3)[a]	605
H20-485 (2nd sample)	sp+py	sp^c	19.6(19.5)[a]	615
Ha	sp	sp^p	13.5	470
H20-464	sp+py	sp^c	13.2	462
Radiore U. "A" deposit				
R11-166	sp+py	sp^{pc}	11.9(11.3)[a]	425(415)
Bell Channel No. 1 deposit				
BC2-253	sp+py	Intimate intergrowth sp^p+py	"23.8"[b]	"695"[b]
Radiore U. "E" deposit				
EE7-163	sp+po+cp+py	Much po in sp	"16.7"[b] (12.2)	"545"(435)
Garon Lake Mines				
G8-288	sp+po+cp+py	Sample unsatisfactory, intimate intergrowth	"27.0"[b]	"755"[b]
G8-288			"27.0"[b]	"755"[b]

Note: a (----) Result after magnetic portion removed
b "----" Possible contamination in sample

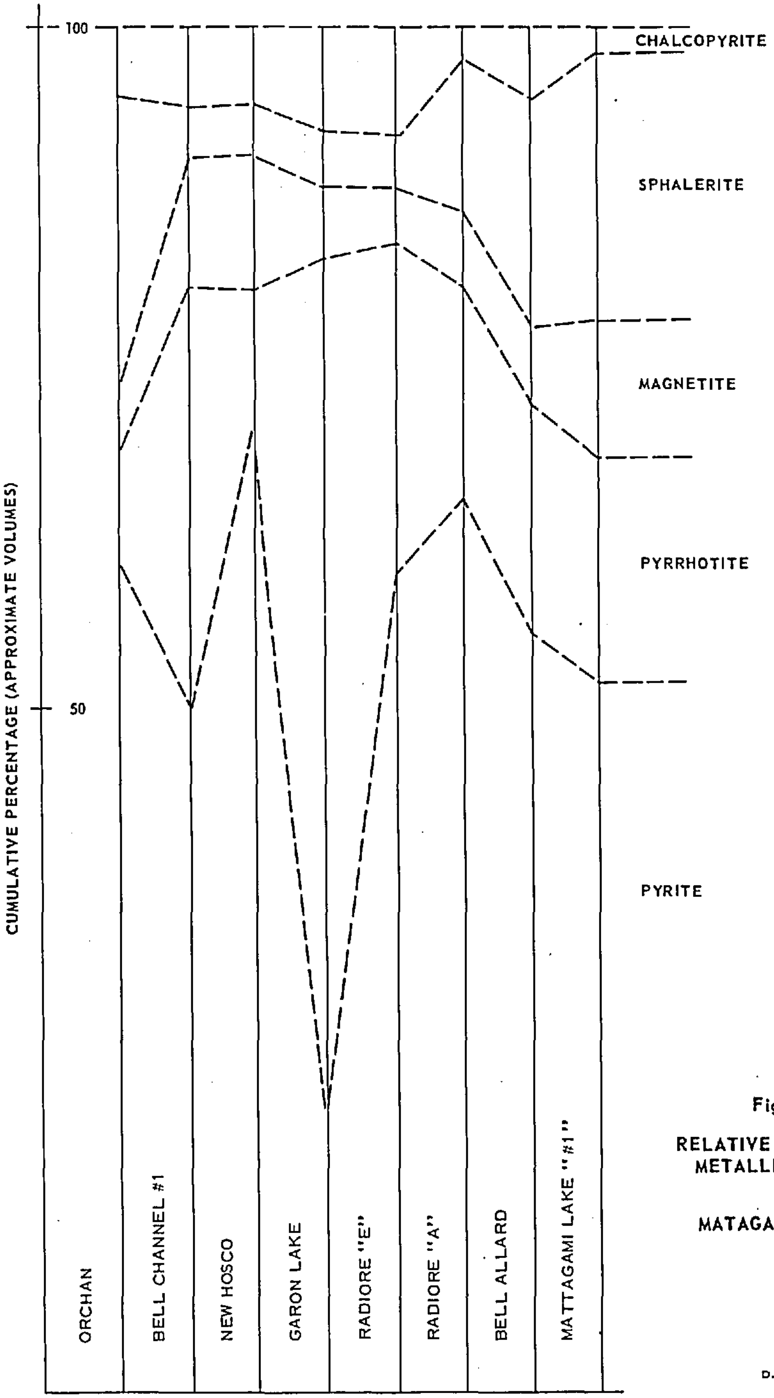
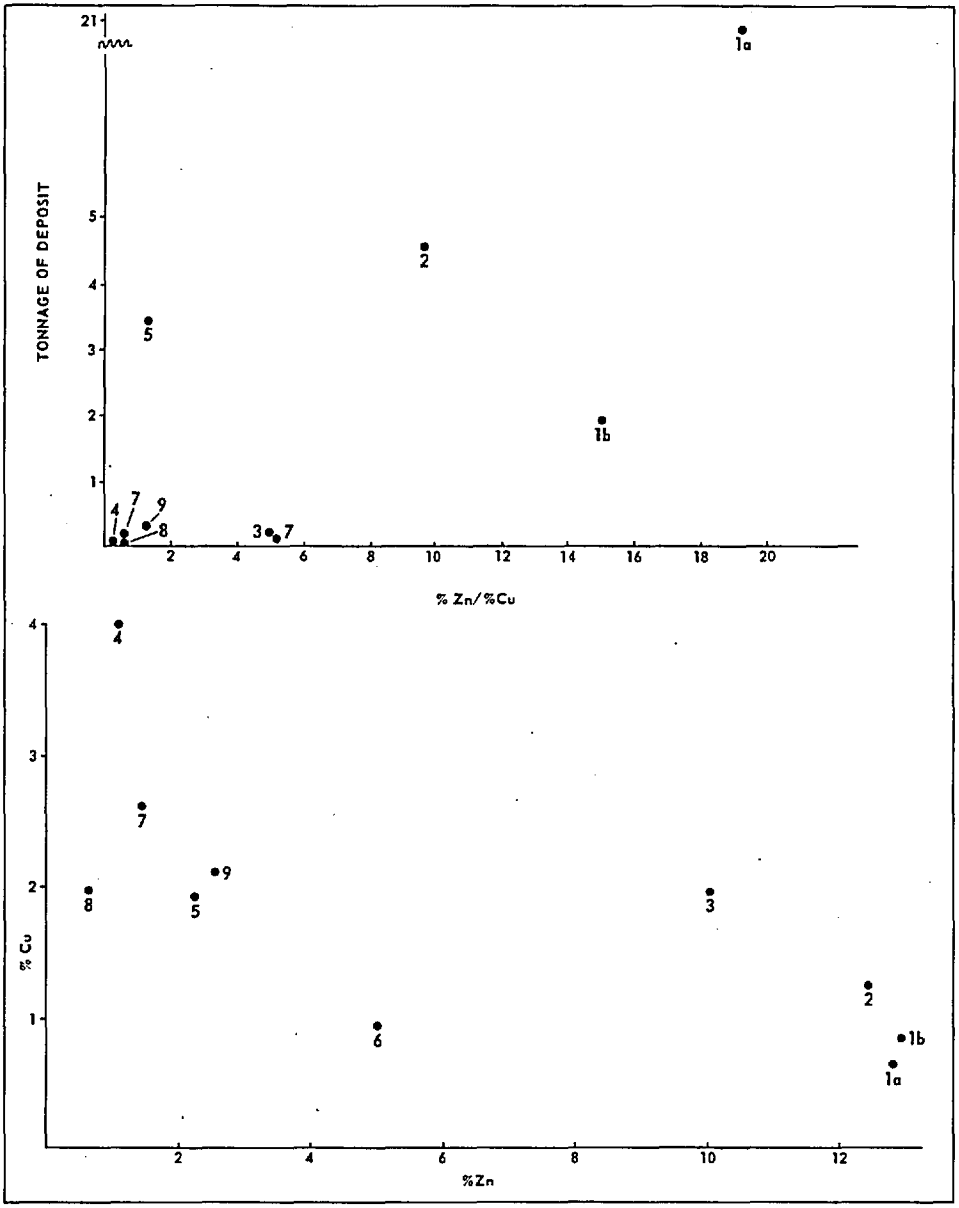


Figure 7a

RELATIVE PROPORTIONS
METALLIC MINERALS

MATAGAMI DEPOSITS

D.N.R.Q. 1967 B-666



D.N.R.Q. 1967 B-886

Figure 7b — METAL RATIOS, MATAGAMI DEPOSITS

(1a, 1b) Mattagami Lake Mines, (2) average of 3 Orchan deposits, (3) Bell Allard, (4) Cons. Mng. & Smelting, (5) New Hosco, (6) Radiore "A", (7) Radiore "E", (8) Bell Channel ≈1, (9) Garon Lake

Pyrrhotite geothermometer

The iron deficiency of hexagonal pyrrhotite, in equilibrium with pyrite, may be proportional to the temperature of crystallization (Arnold 1956). An X-ray diffraction technique was used to determine the $(10\bar{1}2)$ d-spacings of pyrrhotite, which are related to the iron deficiency of the mineral (Arnold and Reichen, 1962).

The date on 13 samples are presented in Table 3. The peaks in most samples were moderately broad though symmetrical. These could not be significantly improved by varying the analytical technique. It is possible that there is a narrow range of d-spacings within individual samples.

The iron contents range from 46.46 to 46.82 ± .23%. This is equivalent to apparent temperatures between 514° and 444° ± 46°C.

Significance of results

The range of apparent temperatures from the pyrrhotite geothermometer (444° to 514°C) falls within the range determined with the sphalerite geothermometer (425° - 615°C). The similarity of the ranges suggests that the results are meaningful in some way. The apparent temperatures are probably best considered as gross minimum temperatures as suggested by Rose (1961, p. 367), particularly as most of the sphalerite samples came from pyrite-sphalerite assemblages, rather than the more diagnostic pyrrhotite-sphalerite assemblage.

Thus the data would indicate that the various sulfide masses have crystallized (or recrystallized) in a similar temperature range, which extended perhaps to over 600°C. The genetic significance of these apparently high temperatures is uncertain. They are not unusual, however, as similar values (400 - 600°C.) have been reported for the several dozen massive sulfide deposits that have been investigated elsewhere by the same methods. The simplest interpretation, in the context of present knowledge, is that the temperatures approximate those attained during the formation of the sulfide masses.

Disposition of Sulfides in Volcanic Rocks

Stratigraphic and lithologic relations

The close spatial relation of the main deposits to the top of the Lac Watson Group is readily apparent (Figure 2). The most consistent relations occur in Galinée township where the upper limits of six sulfide masses are delimited by the "key" tuffite or base of the Wabassee lavas. Along the north volcanic band the stratigraphy is more

Table 3. Results from Pyrrhotite Geothermometer

Deposit Sample	Mineral assemblage po (pyrrhotite) cp (chalcopyrite) py (pyrite)	$d(10\bar{1}2)$	Iron content in % +other minerals ± 0.23%	Apparent temperature C° ± 46°C.
Cons. M.and S. 6-735	po+cp+py	2.0575	46.59	488
Mattagami Lake Mine				
K62	po+py	2.0580	46.63	480
M2-550L	po+py+magnetite	2.0582	46.64	480
Mc	po+sphalerite	2.0600	46.79	450
Orchan M.				
103-561.0	po+cp+py	2.0559	46.46	514
103-561.1	po+cp+py	2.0566	46.52	502
Radiore M. "A"				
R11-172	po+cp	2.0574	46.58	492
R2-270	po	2.0591	46.72	464
Bell Channel No. 1				
BC2-237		2.0584	46.66	474
Bell Channel No. 4				
B30-367	po+py+cp	2.0600	46.79	450
Radiore M. "E"				
EE17-333	po+py ("porphyroblastic" pyrite)	2.0562	46.48	510
Garon Lake M.				
G2-286	po+py	2.0582	46.64	476
G2-280	po+py	2.0602	46.82	444

Alpha quartz used as internal standard. Following values used for the (200) spacing. $d_{Ka} = 2.1274$, $2\theta_{ka} = 42.490°$, $2\theta_{Ka1} = 42.454°$ (Cu radiation) complicated. However, the New Hosco deposit underlies north-facing Wabassee lavas and outcrops of spherulitic rhyolite of the Lac Watson Group occur south of the deposit.

The Radiore "A" deposit probably lies near the contact zone of the groups but east of the Bell river the lithologic sequence and structure is complicated. However three deposits here (Bell Channel, Bell Channel No. 4 zone, Garon Lake) are near the north (top?) limit of the rhyolitic rocks of the Lac Watson Group type.

It is notable that the host rocks of the Garon Lake deposit are similar to a band of layered tuffs that outcrop near the northwest corner of the property and that neither of these tuff units appears to be contiguous to the host rocks of the other deposits in the vicinity. The sulfide masses here would not be confined to a single stratigraphic unit as are the south band deposits.

The general propensity of the sulfides for volcanic rocks is demonstrated by the Radiore "E" deposit which is engulfed in the Bell River complex.

Host rocks

The rocks included within or impregnated with sulfides are moderately or extremely altered rocks: combinations of bedded pyroclastic rocks, tuffite, fractured and altered rhyolite, and diverse breccias and chloritic schists. The host rocks of the Garon Lake deposit are contact metamorphic rocks that are believed to be derived from volcanic tuffs, breccias and chert.

The north band deposits (New Hosco, Radiore "A", Bell Channel, Garon Lake, Radiore "E") are grossly conformable lenticular masses whose main host rocks are stratified pyroclastic material. Tuffite beds occur above and below the sulfide masses and in part are the host or occur mixed with the sulfides. The northern boundaries of the sulfide masses tend to be clear-cut conformable contacts that lie near, but not necessarily against, massive lavas. The southern or basal parts of the deposits usually do not have distinct boundaries.

The south band deposits (Mattagami Lake, Orchan, Bell Allard, Consolidated Mining and Smelting) are remarkably similar and lack the association with coarse pyroclastic units of the north band deposits. The main deposits are overlain by lavas of the Wabassee Group and the upper ore-contacts are conformable and delimited by the "key" tuffite except locally where tongues of ore have breached the tuffite. The undersides of the sulfide masses are irregular and extend downward into altered rhyolitic rocks. The lateral extremities of the sulfide masses narrow gradually and merge with the tuffite.

Thus the tops and lateral extremities of the south band sulfide masses are related to lithologic contacts (or depositional interfaces), whereas their lower extremities are related mainly to discordant structural elements. The small Consolidated Mining and Smelting Company deposit is unusual in that the sulfide mass lies some distance below the tuffite contact, within rhyolitic rocks of the Lac Watson Group. The Bell Allard Mines deposit is intercalated with the tuffite rather than bounded by a tuffite layer.

The rocks stratigraphically below the sulfide masses are well metallized whereas the lavas above contain usually only limited fracture fillings or disseminated pyrite.

The spaces occupied by the larger sulfide masses of the south volcanic band, if "filled" with rhyolite would provide a harmonious lithologic sequence. Thus the sulfide masses have probably replaced sectors of the rhyolitic rocks.

The relations between the distribution of sulfides and primary lithologic features in both volcanic bands can be summarized as follows: 1) The host rocks are mainly interlava pyroclastic units, tuffite and fractured rhyolite. 2) The upper sulfide contacts are usually conformable to bedding, while the lower contacts are indistinct and commonly not related to lithologic discontinuities. 3) The upper stratigraphic limit of metallization, or the upper contacts of sulfide masses, are usually marked by the base of a relatively massive lava flow or delimited by layers of cherty tuffite, or, where these are absent, by autoclastic breccias with chert fragments.

Although the general distribution of sulfides is clearly related to the stratigraphic and lithologic circumstances, the specific sites of the ore masses are not lithologically unique. Presumably other factors have influenced the metallization.

Relations to Intrusive Rocks

All the deposits lie within two miles of the main part of the complex* and usually close to large subsidiary intrusions. Despite considerable geophysical and drilling work, no sulfide masses have been found within the plutonic rocks of this sector of the complex.

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* A small metallized zone at Daniel Mines (near Gouault river) is an exception in that it is more than 2 miles away, and masses of barren sulfides occur north and south of the area.

A variety of dikes, of several ages, occur near and within the sulfide masses. The following discussion mainly concerns the two major types of dikes: gabbros related to the Bell River complex and post-ore lamprophyres, siliceous and feldspathic dikes. Some small pre-ore dikes have been recognized at New Hosco Mine and Mattagami Lake Mine. These are minor intrusions and generally more altered than the Bell River complex dikes.

The gabbroic intrusive rocks around the periphery of the Bell River complex have been discussed (p. 32) and, because of their spatial and petrographic relations, they are considered to be subsidiary intrusions of the Bell River complex that have been folded with the volcanic rocks. Dikes and sills of these rocks occur within or adjacent to all the sulfide deposits and in part may intrude the sulfide masses. Specific relations are illustrated in Figure 5.

At the Mattagami Lake Mines deposit several narrow porphyritic gabbro dikes traverse the ore. The contact relations, though not definitive, indicate that the dikes intrude the ore. A similar sill, segmented by transverse faults, occurs west of the Orchan orebodies. Near surface the sill extends over the sulfide body. There is no close physical relation between this dike and the ore zones. The gabbro intrusion which is adjacent to the south flank of the New Hosco deposit has an irregular though distinct contact that protrudes into the ore zone. The gabbro is unmetallized except for the normal disseminated sulfides. The ore-host at Radiore "A" deposit is cut at a low angle by the eastern extremity of a large gabbro sill, and sulfide zones occur on both sides of the gabbro. The Bell Channel deposit is adjacent to the south contact of a large sill of gabbro and the upper, western extremity of the sulfide mass abuts against an irregularity in the gabbro contact. Only a part of the sulfide mass is in direct contact with the gabbro, and there is no consistent relation between the gabbro contact and the amount of sulfides. The gabbro contains no significant amounts of sulfides, though minor amounts of pyrite and chalcopyrite were seen in a narrow schist zone within the gabbro. The Radiore "E" deposit is confined to volcanic rocks virtually enclosed by the Bell River complex. The small porphyritic gabbro dikes in the sulfide masses generally do not contain significant amounts of sulfides, even within intensely metallized volcanic rocks.

In general, despite the commonness of gabbro intrusions, near and in the metallized zones, they do not appear to have influenced the degree or location of metallization. A possible exception to this has been noted at New Hosco mine.

Several types of small dikes have definite intrusive relations to the sulfide masses. The most common are relatively unaltered dark lamprophyres and feldspathic and siliceous dikes.

These dikes transect the gabbro intrusions and commonly occupy post-ore faults such as those at Mattagami Lake and Orchan Mines. Both varieties can have sharp "chilled" contacts against the metallized rocks or ore and contain no sulfides except for disseminated pyrite. Even very thin dikes are persistent. To summarize, a definitive comprehensive analysis of the chronological relations between the several suites of intrusions and the ores must await extensive underground observations and the correlation of the terminology used at the different mines. However, the available evidence indicates that a granitoid suite of dikes, related to the post-orogenic or late orogenic plutons, are clearly post-ore in age and at least some of the gabbros related to the Bell River complex are post-ore.

As the complex was intruded before the volcanic rocks were extensively folded, it follows that the sulfide masses themselves were emplaced before orogeny and long before the granites. Nevertheless this conclusion need not imply that there was any long interval of time between the emplacements of the sulfides and the gabbro complex.

Structural Environments of Deposits

Three general structures, singly or in combination, are present near the metallized zones. These are: a) schist zones and fractured zones b) small folds c) transverse faults.

Schist zones and fractured zones

Extremely schistose rocks, such as chlorite schist, sericite-chlorite schist and, less commonly, talc (serpentine)-chlorite schist occupy crude planar zones near or within the metallized zones. Those at Orchan and New Hosco deposits (Figure 5) are fault zones marked by dislocations of strata. Elsewhere, the schist zones trend parallel to the strata and dislocations are not usually discernible. Some of these no doubt mark longitudinal fault zones; others are confined to incompetent units, such as chloritized pyroclastic rocks, and developed without marked faulting.

The main shear zones at Mattagami Lake Mines occupy the axial zone of the anticline and extend downwards into the fractured, chloritized and silicified rhyolites but are not found in the lavas overlying the orebody. The discontinuity may be due to the abrupt change from incompetent chloritized rocks to competent lavas.

Irregular lenses, stringers and disseminated forms of sulfides occur within schist zones but the metallization is generally lean. The coincidence of the schist zones with the walls of more or less massive sulfide bodies, at some deposits, might suggest that the sulfides have replaced part of the zones of schists, but the presence of non-schistose inclusions within the ores and the sparse amounts of metals in the schists tend to disprove this. A complicating factor to consider in relating the ore to the schist zones is the fact that the sulfides are notably fractured and foliated near the schist. This post-ore deformation blurs the structural relations.

The fault-schists at Orchan mine adjoin parts of the orebodies and in part extend above the metallized zones into the Wabassee lavas. The mine geologists (Nels Vollo, personal communication) consider that these are important ore controls as rich shoots extend downwards along the schist zones.

No adjacent schist zone was found beneath the Bell Allard deposit where it was studied. The pod of massive sulfides at the Consolidated Mining and Smelting property appears to be isolated from the main zone of schistose rocks.

Narrow bands of schists occur within the host rocks of the New Hosco deposit and a particularly intense zone of shearing and contortion occurs 200 feet north of the metallized zone. Virtually no sulfides are present in the drill cores that were examined from this structure.

The pyroclastic deposits at the Radiore "A", Bell Channel, and Bell Channel No. 4 deposits are moderately to extremely schistose. At the Radiore "E" deposit the host rocks are fractured rather than schistose although there are a few bands of biotitic schist that may be analogous to the chlorite schists elsewhere.

In general, the deposits are not distinctly related to, or emplaced within fault-schists. Some of the host rocks are markedly schistose, but, with some exceptions, the schistosity appears to be a local consequence of incompetency. The important exception is Orchan Mines where the deposits are disposed along schistose fault zones.

The other main type of structure, common to most deposits, is the "brecciated (or fractured) and silicified" facies of the rhyolite. This type of deformation and alteration, accompanied by veinlet-type sulfides, occurs beneath all the ore masses in the south band deposits and is analogous to some of the silicified breccias adjacent to the north band deposits. The proximity of epigenetic zones of cherty silica to layers of chert suggests that both modes of occurrences of silica are related to volcanic hydrothermal processes (p. 27) and that the fracturing occurred during volcanism.

Compared to the orogenic structures these fracture zones are rather innocuous features but nevertheless may have been important channel-ways during metallization as they are pre-ore structures.

Folds and warps

Five sulfide masses, the Mattagami Lake main orebody, the No. 2 orebody, and orebodies at Orchan Mines are enclosed within fold structures; anticlines envelop parts of the Mattagami deposits,whereas the Orchan structures are irregular flexures or warps. The New Hosco deposit lies within the north limb of a large anticlinal structure and some of the sulfide lenses are warped in accord with small flexures.

The fact that fold structures encompass the largest deposits is, at first sight, evidence that anticlinal folds, in combination with other structures and lithologic features, have controlled the emplacement of the sulfide masses. This leads to the assumption that the folds formed before the ores were emplaced.

In view of other evidence that post-ore deformation has occurred, the possibility that the folds are post-ore must also be considered.

The following relations are pertinent: some sulfides are folded on a small scale or exhibit deformation textures; the most persistent delimiters of the sulfide zones, even within folds, are essentially lithologic features and structures that are probably not related to folding deformation; some of the deposits appear to be intruded by pre-folding gabbro, related to the Bell River complex. Thus, several independent relations indicate that the sulfides have been folded or subjected to folding stresses.

If the metallization preceded the folding, the apparent structural entrapment of the sulfide masses acquires a different aspect as it could be argued that the presence of a large mass of plastic sulfides might instigate a local fold during the regional deformation.*
Alternatively, the sulfides could have been emplaced, or locally mobilized, during the folding and still bear the imprints of deformation. Either hypothesis has some merit as it is consistent with the broader geologic relations.

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* The abrupt closure of the fold around the Mattagami Lake No. 2 orebody (1,200 feet southeast of the main deposit) might be interpreted in this fashion.

Transverse faults

The detailed geology of the deposits is complicated by numerous small transverse faults. Their presence, but usually not their orientations, can be readily discerned in drill core; a few were seen in underground workings.

The transverse faults at the Orchan deposits have displaced the orebodies and small faults offset the ore boundaries at Mattagami Lake Mines orebody. The northwest fault across the medial part of the Radiore "A" deposit appears to offset the otherwise continuous sulfide lens.

In general the transverse faults offset the sulfides and the schist zones and the apparent movements are mainly post-ore.

The structural relations of the deposits can be summarized as follows: the most common structural environments are zones of fractured, brecciated and erratically schistose rocks; the sulfide masses tend to lie near the top limit of these structures and above more dispersed sulfides; the upper limit, where determined, of the metallized structures is also upward in the stratigraphic sense and bounded by certain lithologic units.

Parts of Orchan Mines deposits lie within fault-schists. Elsewhere, most schist zones and transverse faults do not appear to have significant spatial relations to sulfide masses and usually are not metallized.

Fold structures occur only at the larger sulfide masses and are not a prerequisite for the concentration of the smaller sulfide lenses.

The main structures (except the brecciated zones and perhaps the earliest faults) appear to be imposed on the sulfide masses. The writer favors the hypothesis that many of the fold and schist structures developed locally because of the presence of incompetent materials, namely the altered host rocks and sulfides.

SUMMARY AND CONCLUSIONS

General field relations

Most of the deposits are distributed along an extensive stratigraphic zone. The zone is the contact between the Wabassee Group and the Lac Watson Group and is marked by concomitant accumulations of pyroclastic deposits, siliceous chemical sediments and probably iron sulfides. The host rocks of the deposits, and their stratigraphic circumstance, are related to a broad-scale change in volcanic events.

A large differentiated mafic intrusion, the Bell River complex, intrudes the volcanic pile and has been folded with the volcanic rocks, probably into an anticline. The stratigraphic zone of sulfide deposits is now rudely parallel to the periphery of the complex and would have overlain the top of the complex before it was folded.

Characteristics of the deposits

1) The host rocks are altered tuff, agglomerate, "tuffite" and fractured rhyolitic rocks. The lava units contain only sparse amounts of metallic minerals, usually along small fractures and around pillow margins.

2) The spatial distributions of sulfides are asymmetrical. Zones of dispersed sulfides tend to culminate stratigraphically upwards as discrete masses of sulfides.

The upper contacts of the large sulfide masses in the south volcanic band are concordant to stratification and are delimited by some lithologic features such as a layer of tuffite or the base of a lava. The lower sectors of the same deposits have irregular contacts, and apophyses of sulfides extend downward along transverse structures and merge with the zones of dispersed sulfides.

Thus the south band deposits, if viewed from above (in the literal sense) have a "strata-bound" aspect suggesting that the sulfides might be syngenetic. However when viewed from below, the sulfide masses appear to have epigenetic "roots".

The sulfide masses of the north volcanic band are also associated with asymmetric zones of dispersed sulfides. However, the sulfide masses tend to have more regular lensoid forms and the asymmetry of the zones of dispersed sulfides is not so marked as that of the other deposits.

The spatial patterns of metallization demonstrate that lithologic or stratigraphic discontinuities were prime determinants of the degree and place of metallization.

3) The sulfides crystallized at high temperatures. Kullerud's sphalerite geothermometer and Arnold's pyrrhotite geothermometer give a range of apparent temperatures from 425°C. to 615°C.

4) The sulfide masses are heterogeneous mixtures of sulfides with non-homogeneous fabrics. Large sectors of the deposits contain relatively barren iron sulfides and magnetite. The main ore materials are mixtures of sphalerite and pyrite with small amounts of chalcopyrite.

Chalcopyrite also forms separate ore zones.

There is a tendency for stratiform masses of sphalerite to overlie zones of copper ore and both to overlie more or less barren zones of magnetite, pyrite and pyrrhotite.

The general aspect of the ores of the sulfide masses as seen under the microscope are similar to those of replacement-type deposits. Paragenetic relationships at most deposits indicate that the earliest sulfide is a dense variety of pyrite that has been fractured and impregnated with sphalerite, pyrite and chalcopyrite. However, copper was intimately associated with the deposition of zinc as small exsolution blebs of chalcopyrite in the sphalerite crystals. Some chalcopyrite, accompanied by pyrrhotite, was emplaced subsequent to the pyrite-sphalerite ore as stringers. The magnetite component of the deposits has several relations. Some (e.g. at Radiore Mines) is a layered variety of iron formation. More commonly, magnetite has a veining relation in the masses of barren pyrite or forms clots or disseminations in chloritized host rocks and appears to have been introduced epigenetically.

A particularly regular bedding of pyrite, sphalerite, chert and phyllosilicates can be recognized in some specimens of the tuffite ore-type. Because of its perfection the bedding is distinguished from banding and is considered to be a depositional fabric for the tuffite ore-type. The bedded sulfides are disorganized by microstructures, recrystallization, the development of automorphic crystals and splotches and the introduction of veinlets of coarse sulfides.

5) The wall rocks and host rocks of the deposits are variably silicified, chloritized and at some deposits intensely carbonatized. The extensiveness and intensiveness of the alteration effects are related to the structural and textural condition of the host and country rocks. The fractured rhyolites and pyroclastic deposits have been particularly susceptible to metasomatic alteration.

Whether the predominant alterations were synchronous with the metallization is not known as the general types of alteration can be attributed to several causes. These include volcanic thermal waters or gases, contact metasomation during the intrusion of the gabbros and low-grade dynamo and thermal metamorphism of regional extent.

One deposit (Garon Lake Mines) lies within the metamorphic aureole of a granitic intrusion. Here cordierite-anthophyllite rocks may have developed from deformed and chloritized rocks.

6) Subsidiary gabbro intrusions of the Bell River complex transect the host rocks of the deposits. Some dikes appear to intrude the sulfide masses. The Radiore Mines "E" deposit is engulfed in the north margin of the complex.

The field relations indicate that some of the gabbro intrusions are post-metallization in age. Numerous other small dikes, post-gabbro in age, intrude the sulfides.

The Bell River complex is folded and presumably was intruded before or during the regional deformation. Thus the apparent intrusive relations between the gabbro and ores are in accord with the deformed aspect of the sulfides.

Environment of metallization

The circumstantial evidence suggests that the deposits are analogous to those that form under volcanic-plutonic conditions, which is comparable, for example, to those of the Japanese island arcs. The synthesis of the local and general field relations, the microscopic and geothermometrical data are consistent with the following hypothesis.

A) In space: The deposits formed in physical and chemical "traps" at or near the extant top of a volcanic pile. The "traps" were pervious pyroclastic deposits and fractured, altered rhyolite that were sealed from above by lavas and chert layers. The physical "traps" were also chemical "traps" in that they contained syngenetic iron and sulfur such as that in the tuffite sulfides.

The existence of these "traps" is not difficult to recognize. The conjecture as to their effectiveness requires that they existed before the country rocks became extensively deformed and rendered pervious. Most of the deformation structures such as small folds and transverse faults do appear to be superimposed on the metallized zones and thus post-ore in age.

B) In time: The sulfides exhibit the textures and structures of deformed rocks and are folded and faulted. These features can be interpreted as the imprint of the regional deformation. This is consistent with the apparent intrusive relation between some of the Bell River Complex gabbros and the sulfide deposits. The most likely time of the main sulfide emplacements corresponds to a short interval, during Wabassee volcanism, perhaps coincident with the intrusion of the Bell River complex.

C) Mode of emplacement: Many of the sulfide masses in the south volcanic band occupy the apices of metallized fractured zones. The asymmetry in the intensity of metallization and alteration culminating upwards in concentrations of sulfides, suggest that copper and zinc were transported upwards, across the volcanic units.

The high apparent temperature of crystallization indicated by the geothermometers may be an approximation of the temperatures of deposition of the sulfide masses. Such high temperatures may indicate local, pronounced thermal gradients. Such thermal conditions are common in sub-volcanic environments.

The variations in the type and amounts of sulfides within individual deposits appear to be due to compound modes of deposition.

It is speculated that the zones of dispersed sulfides that extend down from the undersides of sulfide masses are epigenetic mineralization in conduits which reached the extant topographic surface. The lamellae of sulfides in tuffite were sedimented as thermal spring deposits.

The bulk of the ore sulfides and magnetite have an epigenetic mode of occurrence, that is, they appear to have impregnated and replaced sectors of rock which in most instances lay a few feet to several tens of feet below either the tuffite layers or basal parts of Wabassee lavas.

APPENDICES

Appendix A

Prospecting

The following remarks concern prospecting for the various types of metals that have been found in the area. For this purpose it is convenient to classify the types of metallized zones on the basis of the metal and what appears to be the prime feature of their geological setting as follows: 1) Strata-bound deposits of base metals; 2) Structure-bound deposits of base metals; 3) Nickel associated with ultrabasic rocks; 4) Gold, bismuth and molybdenite in fractures, veins and schist zones.

1) The strata-bound masses of zinc and copper minerals include the orebodies found to date. Their pronounced disposition to lie at the upper contact of the Lac Watson Group indicates that the extrapolated segments of this contact are possible general environments of new deposits. Specific sites might be indicated by magnetic anomalies (as all deposits in the region contain magnetic minerals) and particular

attention should be given to sectors where the rhyolitic rocks are intensively fractured, chloritized and silicified. If dispersed sulfides are found in the circumstances which are noted above, then the conjunction of zones of dispersed sulfides with lavas or cherty units of the Wabassee Group (stratigraphically upwards) should be sought. Indications of local warps and flexures may also be significant.

A few small strata-bound concentrations of copper and zinc occur in the upper parts of the Wabassee Group, particularly in local environments similar to those of the main deposits.

The zonation of sulfide minerals in many of the deposits should be noted as it would be possible to intersect a barren part of a metallized zone. Similarly the empirical relations indicate that discrete concentrations of zinc ore or of copper ore might be found in the same vicinity.

2) The "strata-bound" deposits, discussed above, are also associated with various types of deformation structures. But because imilar structures are common throughout the area, they seldom provide specific features to prospect. However, minor amounts of chalcopyrite are essentially structure bound and disseminated or are in veinlets in the longitudinal schist zones around Matagami lake and within both volcanic rocks and the Bell River complex. Thus settings similar to the Chibougamau-type deposits (schistose fault zones in large mafic and anorthositic plutons) could be found in the Bell River complex.

3) Concentrations of nickeliferous pyrrhotite occur in the peridotite intrusion at Mattagami Lake Mines. Other intrusions of this type appear to be rare in the map-area.

4) Only a few quartz vein-type gold occurrences have been found. It is notable that, during the "rush", exploration diamond drilling was focused on base metals. A comprehensive review of old drill core and assaying of pyritic quartz veins, metallized dikes, etc. are merited.

The most significant concentrations of gold yet discovered have been described (Northern Quebec Explorers). The extensiveness of this metallization and its well-defined limitation by fractures are encouraging features. It is possibly significant that this gold occurs near the outer limit of the aureole of amphibolite-stage contact metamorphism of the Dunlop Bay intrusion.

Small amounts of molybdenite and bismuth also are spatially related to the Dunlop intrusion. Geochemical techniques might be applied advantageously in prospecting for these minerals under the heavy vegetation in this sector.

Appendix B

Analyses of rocks*

1) Porphyritic rhyolite	(From drill-hole No. 23, Bell Allard Mines, range VIII, Galinée township)
2) Spherulitic rhyodacite	(From drill-hole No. 21, Bosada Syndicate, Daniel township, northwest of Watson lake)
3) Andesite-basalt	(From large island 10,000 feet east of mouth of Allard river, Isle-Dieu township)
4) "Tuffite"	(Key tuffite" on 150 level, Mattagami Lake Mines, range X, Galinée township)
5) Gabbro	(From drill-hole No. 10, Norvalie Mines, range III, Isle-Dieu township)
6) Anorthosite	(From anorthosite layer, 30 ft. wide at Chenal rapids, range II, Isle-Dieu township)
7,8) Magnetite	(From layer at Chenal rapids, range II, Isle-Dieu township) (Partial analysis)

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* All analyses by the Laboratories of the Quebec Department of Natural Resources. Analyst: Zoltan Katzendorf.

Table 4 - Chemical Analyses of Rocks

	1	2	3	4*b	5	6	7
SiO_2	67.84	66.99	52.64	72.16	49.77	49.81	Fe 30.25
TiO_2	0.32	0.86	1.34	0.40	1.70	0.15	TiO 8.70
Al_2O_3	14.64	12.95	14.16	15.07	14.73	27.71	Cr 0.05
Fe_2O_3	6.21	0.60	3.23	Fe total 1.53	5.49	0.62	
FeO	4.09*a	5.23	8.74		9.58	1.31	
MnO	0.04	0.12	0.18	0.04	0.13	0.05	
MgO	1.06	2.03	5.15	1.18	5.18	0.70	
CaO	0.70	2.46	7.74	0.55	4.97	11.12	8
Na_2O	5.21	4.39	2.56	1.02	3.36	4.35	
K_2O	1.52	0.94	0.13	4.52	0.75	1.02	Fe 31.03
Li_2O		0.00	0.00		0.00		TiO 9.18
P_2O_5	0.02	0.18	0.15	0.08	0.14	0.02	Cr 0.00
H_2O+	1.73	1.96	3.53	2.27	3.14	2.26	
H_2O-	0.03	0.11	0.07	0.04	0.10	0.03	
CO_2	0.32	1.03	0.32	0.10	0.57	0.85	
S (total)	0.75	0.02	0.05	0.30	0.17	0.02	
BaO	0.12	0.02	0.00	0.05	0.01	0.11	
Cr_2O_3		0.00	0.01	*c	0.01		
V_2O_3	0.002	0.02	0.06		0.09	0.002	
ZrO_2		0.07	0.01		0.01		
F	0.09						
SrO	0.04	0.01	0.02	0.004	0.02	0.04	

*a includes Fe from pyrite
*b most of sulfides removed before analysis
*c semi-quant. spec. analysis; 0.05%-0.5% (Cu, Pb, Yt, Zr) 0.001%-0.01% (Cr, Ca, Li, Mo)

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