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GENERAL GEOLOGY AND MINERAL DEPOSIT OF CHIBOUGAMAU DISTRICT

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OF THE
CHIBOUGAMAU DISTRICT OF QUEBEC

By

Gary Mervyn Archibald

Submitted in partial fulfillment of the
requirements for the degree of Master of
Science in Geology at the University of
Michigan

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ABSTRACT

The Chibougamau mining district, includes parts of McKenzie, Obalski, Roy, Lemoine, and McCorkell townships and is located in the eastern part of Abitibi territory of Quebec.

Basic Keewatin volcanics and minor acidic flows are dominant in the northern part of the district. Tuffaceous sediments overlie the volcanics in a belt 3500 feet wide in the northern part. Intruded into this Keewatin sequence are three types of intrusive rocks. A gabbro-anorthosite basic complex, with associated granitic and dioritic phases has been intruded along the crest of a north-northeast striking anticline in the southern part of the district. The second type of intrusion is represented by sills and irregular masses of basic and ultrabasic rocks which have intruded the volcanics and tuffaceous sediments in the northern part of the district. Later dikes of diorite, gabbro and diabase occupy northeast and northwest striking fractures. Remnants of the Chibougamau sedimentary series outcrop in a few areas in the northern part of the district.

The rocks of the region have been compressed into easterly trending anticlines and synclines. Cutting across the folds are three major sets of faults. The major faults which strike northeast consists of the McKenzie Narrows, Tache Lake and Gwillim-Campbell Lakes faults. Minor faults with a northeast strike are numerous in the district. Smaller shears which strike northwest are very abundant and in many cases are the important sulphide structures. A set parallel to the trend of the formations - the north-northeast set - is exemplified by the Lac Sauvage Fault.

ABSTRACT - continued

The most important types of mineral deposits are magnetite - ilmenite and sulphide replacement deposits and gold-quartz veins.

The titaniferous magnetite deposits are either alteration products located in serpentinite bodies or are products of magmatic differentiation in gabbro intrusives. The tonnage of these deposits is large.

The replacement sulphide deposits have been subdivided into pyrite-pyrrhotite-chalcopyrite, arsenopyrite-pyrrhotite-sphalerite, pyrite-magnetite-chalcopyrite, and pyrrhotite-chalopyrite deposits. The pyrite-pyrrhotite-chalcopyrite deposits - the major economic deposits in the district - are locallized by northwest to east-west striking shear zones in anorthosite or less commonly in the gabbro-anorthosite transitional zone. The deposits are controlled by pitches and rolls in the shear zone, the nature of country rocks, intrusion of dikes and post-mineral faulting. The pyrite-magnetite-chalcopyrite deposit is confined to a brecciated zone in the Grandine granite plug, whereas the arsenopyrite-pyrrhotite-sphalerite deposits occupy highly fractured zones in ultrabasics. The pyrrhotite-chalcopyrite mineralization is seen in slightly sheared tuffs, near gabbro sill contacts or in shear zones in ultrabasics or basic intrusives.

The gold-quartz veins which occupy minor shear zones in diorite or gabbro bodies are not of economic significance. These gold-quartz veins are thought to be lower intensity types.

The paragenetic sequence of mineralization in all of the deposits, excluding the pyrite-magnetite-chalcopyrite deposits, follows a normal paragenetic sequence. Quartz, siderite, magnetite, arsenopyrite, pyrite, quartz, pyrrhotite, sphalerite, chalcopyrite, galena,

ABSTRACT - continued

late gangue and low temperature minerals crystallized in approximately that order. The paragenetic sequence of mineralization in the pyrite-magnetite-chalcopyrite deposit is very unusual. Here the sequence of crystallization is pyrite, quartz, magnetite, hematite, chalcopyrite, calcite, and molybdenite.

Two or three periods of fracturing in all of the deposits has subdivided the mineralization into stages.

The late age of gold mineralization in the gold quartz veins and the periods and origins of mineralization are discussed.

INTRODUCTION

Location and Location

The Chibougamau district lies in the eastern part of Abitibi Territory of Quebec, about 320 miles north of Montreal and 224 miles east of the west boundary of the Province. The district includes the greater part of McKenzie, Roy, and Obalski townships, the north-west corner of Lemoine township and the extreme western portion of McCorkill township.

The Chibougamau district can be reached by a gravel road from St. Felicien. Before the completion of the railroad and highway, the only means of access was by two canoe routes, one from Askelaneo River Station and the other from St. Felicien at the west end of Lake St. John.

Topography and Drainage

The Chibougamau district lies north of the high land between the St. Lawrence River and James Bay. The topography in the northern and in the southern parts of the district is in marked contract. In the northern part, the predominant topographic features are parallel belts of ridges and hills which follow the conspicuous east-west strike of the rocks. Between the ridges are narrow valleys and lowlands, with small lakes. The relief in this area ranges from 300 to 600 feet. The topographic relief is small in the area South of Chibougamau Lake, David Lake and Dore Lake; this area is hilly and largely drift-covered with a few prominent ridges. About half of the surface of the southern part consists of lake-filled depressions.

The area is drained principally by the Chibougamau river, which flows northwestward into the Nottaway River and ultimately to James Bay.

The tributaries of the Chibougamau River drain the major lakes in the Chibougamau district. Lake Chibougamau is rectangular in the shape and covers an area of 90 square miles. David Lake, Gwillin and Bourbeau Lakes are other large bodies of water in the district. Numerous smaller lakes with a pronounced east-west trend parallel to structure occur in the northern part of the district. However, in the southern part of the area, ice movement was an important factor in the formation of north north-easterly trending lakes.

History and Present Status of Copper Mining

The recorded history of the Chibougamau area goes back to the seventeenth century when it was discovered by early explorers travelling on the direct route between Lake St. John and James Bay. The visits made in the seventeenth and the eighteenth centuries by missionaries and French fur traders made available a certain amount of geographic information, but it was not until 1870 that the first geological reconnaissance was attempted.

Chibougamau, like other copper mining districts, has witnessed periods of prosperity as well as years of dormancy. The years 1903-1911, 1929-1937, and 1948 to the present represent the three major periods of mining activity in the Chibougamau district. The first period was initiated in 1903 by P. McKenzie who discovered gold, copper, and asbestos in the Lake Chibougamau area. For eight years, extensive surface exploration work, mainly for gold, was undertaken. In 1910-11 the Chibougamau Mining Commission, headed by Dr. A.E. Barlow of McGill, reported on the economic possibilities of the area. The investigators concluded that the known copper and gold occurrences were not of sufficient importance to justify mining development. Consequently, interest waned, and it was not until 1929 that extensive prospecting was conducted in the Chibougamau district for the second time. However, final results were disappointing and exploration work ceased in 1937. The third and major period of prosperity was initiated with the completion of the 152 mile gravel road from St. Felicien to Chibougamau in 1948. Since then many companies have carried out extensive exploration work, and numerous ore bodies have been proven. The Canadian National Railway completed a service line between Beattyville and Chibougamau, a distance of 155 miles, in 1957. This railroad will allow concentrates to be shipped directly to the smelters at Noranda.

Following extensive diamond drilling on the Campbell Chibougamau property, a three compartment shaft was collared in 1953 and underground development has been carried out on 11 levels from the 150 foot level to the 2150 foot level. The Campbell Chibougamau mine is one of the three producers in the Chibougamau district. A second copper producer, owned by Campbell Chibougamau Mines is located on the Cedar Bay Ore Zone.

The shaft on Merrill Island property was collared in 1952 and bottomed at 1000 feet. Six levels have been developed and stoping sections have been laid out. A 500-ton mill was completed in the Spring of 1958.

Shafts and underground development work have been completed at the Quebec Chibougamau Goldfields, the Chibougamau Jaculet, Copper Rand and Obalski properties. These mines are inactive at the present time.

Two major producers which are not in the Chibougamau district should be noted. The Opemiska mines, 20 miles west of Chibougamau is located on a large high grade sulphide ore deposit. A 840 ton/mill is treating the ore. The second producer: Chibougamau Explorers is located approximately 50 miles south of the Chibougamau townsite. There are seven levels which are in various stages of development, the lowest at a depth of 1050 feet. The mill capacity is 550 tons per day.

Previous Geological Work

Geological work was initiated in 1870 by J. Richardson, who made a reconnaissance survey of the area and discovered sulphide mineralization on the east side of Portage Island. Obalski and Duieux made an extensive study of the mineral occurrences from 1903-1908. In 1910, the Chibougamau Mining Commission, consisting of Dr. Barlow of McGill University, E.R. Faribault of the Geological Survey of Canada, and Professor J.C. Gwillin from Queen's University, completed its investigation of the mineral occurrence in the district; the report was published in 1911. Geological mapping was started in 1929 by Retty who mapped McKenzie Township. In 1934, Norman mapped the Chibougamau and Dore Lake areas, completing the work started by Mawdsley in 1930. With increased interest in the Chibougamau district, the Quebec Department of Mines undertook detailed mapping in the Dore and Chibougamau Lakes area. Dr. R. Smith mapped the south-west quarter of McKenzie township in 1951. The detailed mapping was extended to the east by Dr. G. Allard. He completed mapping of the southeast quarter of McKenzie township in 1952. The north half of Obalski township was surveyed in 1951-1952 by Dr. R.B. Graham. Dr. Horsecroft (1956) and Mr. E. Gauche (1957) mapped in detail the southwest and southeast quarters of Roy township respectively. The latter two geological reports have not been published.

Scope and Purpose of Present Study

The writer, through a study of 93 polished sections from 25 different localities, has attempted to correlate and categorize the paragenesis of the ore deposits and mineral occurrences in the Chibougamau district. The structure of the district and its role in the control of the ore deposits is considered.

A geological map of the district was compiled from detailed maps (some of which have not been published), regional maps, and information obtained by the writer while working in the Chibougamau district. The writer visited all of the major mineral occurrences in the district for the Quebec Department of Mines. These examinations or visits will be published as a preliminary report. The location of the major ore deposits and minor mineral occurrences of the district are indicated on the map.

Acknowledgments

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GENERAL GEOLOGY

General Statement

The predominant geological features of the Chibougamau region are two volcanic Keewatin greenstone belts which extend westward from the Grenville Province. The Chibougamau basic complex, the Opemiska Lake granite, and the Simon-Scott Lakes acidic intrusives separate the two Keewatin greenstone belts.

Description of Rock Types

Volcanic Rocks

The oldest rocks, the volcanic flows and minor interbedded pyroclastics and sediments, form an altered assemblage that is similar to the Keewatin greenstones occurring in other parts of Quebec and Ontario. The volcanic assemblage is divided by the Chibougamau complex into two east-west striking bands; the northern and southern belts. Only the northern belt occurs in the Chibougamau district. The northern volcanic belt has been intruded by a series of ultrabasic and basic sills, and stocks.

Mawdsley and Norman (1935) believe that the extrusives were once continuous over most of the district, but that they now occur as belts and remnants, invaded by different intrusives. The volcanics are exposed over approximately 25 per cent of the total area.

The characteristic rock type of the volcanic assemblage is metabasalt with minor andesitic, rhyolitic, and trachytic flows. Coarse volcanic clastics, which are interbedded with the volcanics, outcrop in comparatively narrow bands at Portage Bay, Bear Bay and Tache Lake. The meta-volcanics are usually very massive, but in places show various structures, including flow bands, scoreaceous and ropy structures, fragmental tops, pillows and amygdules. Locally the volcanics are schistose, especially near intrusive bodies and shear zones. Dr. R. Smith (1952) reported that volcanic sequence is 12,000 feet thick just southeast of Antoinette Lake.

Feldspathic sediments overlie the volcanics north of Lake Chibougamau in the trough of an east-west trending syncline. The belt is approximately 3500 feet wide and extends eastward from Blondeau Lake to the McKenzie Narrows fault, a distance of 15 miles. Remnants of narrow belts of feldspathic sediments outcrop east of the McKenzie Narrows fault. The feldspathic group consists of water-lain tuffs and pyroclastic with interbedded acid volcanics.

Igneous Intrusive Rocks

The igneous intrusive rocks are divided into three distinct classes. The three divisions are the basic sills and irregular masses, the Chibougamau basic complex, and later dikes.

The basic sills and irregular masses occur north of the Chibougamau basic complex in the northern volcanic belt. Most sills and irregular intrusives show gradational contacts between two or more rock types. Following Smith (1953), the writer firmly believes that all of the sills and irregular bodies were differentiated while in a horizontal position. Later regional folding has changed the attitude, so that now the bodies have a vertical dip. The intrusives consist of meta-diorite and meta-gabbro, pyroxenite, peridotite-serpentinite and gabbro-pyroxenite bodies.

Smith (1953) described a typical meta-gabbro and meta-diorite sill in the southwest quarter of McKenzie township as follows:

> "The meta-diorite sill 1000 to 2000 feet north of Antoinette Lake grades into meta-gabbro and then into vertically layered untrabasic rock near its south contact. From this it is inferred that the sill was intruded in a horizontal position and that a layer of the mafic constituents accumulated near the bottom during crystallization. The conclusion is supported by similar evidence from several other sills, so that it is tentatively concluded that the sills were intruded before the lavas and pyroclastics were folded into their present vertical position."

Mawdsley and Norman (1935) stated that gabbro intrusives with highly altered dioritic and gabbroic facies are relatively common on the northern part of the district.

Three well-defined intrusions of serpentine and pyroxenite, described by Mawdsley and Norman (1935), the Rapid River, the Gunn Bay, and the McKenzie Narrows bodies outcrop east of the McKenzie Narrows Fault; other small intrusives occur west of the fault. Serpentinite and pyroxenite are usually closely related in these bodies, and the pyroxenite characteristically forms along the outer borders. The gradation from pyroxenite into peridotite in some of these intrusives suggests that differentiation has taken place. Smith (1953) suggests that the pyroxenite-serpentinite bodies are younger than the diorite-gabbro sills on the basis of fresh pyroxene in the ultrabasics, and that the ultrabasic sills may be pre-folding in age.

A few of the gabbro sills, and bodies which do not contain diorite phases may have pyroxenite at the borders. Smith (1953) has reported that the transition from pyroxenite to gabbro is seen in a few pyroxenite intrusives.

The Chibougamau basic complex was emplaced along the crest of a north-northeast striking anticline. The complex is horseshoe shaped and each limb is 1 to 3 miles wide. The total area of the basic complex is approximately 120 square miles and its outcrop occupies approximately one-third of the Chibougamau region. The rock types represented includes granite, diorite, anorthosite, and gabbro.

Associated with the transitional-anorthosite-gabbro sequence are porphyritic gabbro, diorite, and fine grained gabbro. All the above rock types have been grouped into an older intrusive series called the Dore Lake group (Graham 1956). The porphyritic gabbro, diorite and fine grained gabbro occur as irregular bodies of relatively small size in the Cache Lake and Cache bay areas. Graham (1956) believes that all these quartz free, basic rock types are genetically related.

The sequence of anorthosite to transition zone to gabbro is not encountered everywhere along the northwest limb of the complex. The transition zone and even the gabbro may be completely lacking. A belt of serpentinite north of Magnetite Bay is in contact with the anorthosite and appears to be genetically related. The contact between these two rock types is masked by extensive alteration and some shearing (E. Gauthier †). In some places along the northwest limb of the Chibougamau basic complex, the anorthosite-transition zone-gabbro sequence has been repeated and these associated rocks may or may not be separated by basic volcanics.

G. Allard (1953) stated that the anorthosite is the oldest rock type in the area, whereas the gabbro which occurs at the margins of the complex is the youngest.

R.B. Graham (1956) gives a description of the altered anorthosite. This rock is composed of secondary minerals, including sericite, andesine, chlorite, clinozoisite, epidote, carbonate, and minor quartz. The mineralogical changes from anorthosite to gabbro has occurred through a progressive decrease of epidote-zoisite group, and by an increase in the amounts of chlorite, hornblende, and magnetite. The alteration has masked any primary structures in the anorthosite.

The younger intrusive series, called the David Lake group (Graham 1956), includes quartz-rich granites, granodiorite, younger diorite, quartz gabbro, and quartz diorites.

Granite is the predominant rock type of this group, and comprises the Chibougamau batholith, a small stock near Moon Lake, probably the Grandine plug in Roy township and other smaller bodies. The Chibougamau

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† E. Gaucher, Personal Communication 1957.

Table 1.

Summary Tabulation of Rock Units in the
Chibougamau District

(from Mawdsley and Norman 1935)

Cenozoic	Recent & Pleistocene	Sand, gravel, morainic material.
Proterozoic	Chibougamau Series (Huronian?)	Oliv. diab. & gabbro
		Congl. (Rapid River)
		Conformity
		Congl., ark., greywacke, quartzite, sericite & qtzose schist (south of Rapid Bay).
Archean Early Precambrian		Greenstone dikes, olig-alb. granite, & gneiss, syenite, diorite, felds. porphyry qtz-feld porphyry & rhyolite dikes.
		Intrusive volcanic breccia.
		Diorite & related qtz. bearing highly altered dioritic rocks anorth. & assoc. gabbro & serp. serp., pyroxenite, gabbro & altered gabbroic rocks.
	Keewatin?	Feldspathic sediments, breccia, & acid volcanics, black slate.
		Volcanic flows, mostly of intermediate composition, some basic, some pyro & sediments.

granite batholith, which has intruded the anorthosite along the axes of the alticline, occupies the south central part of the district. (Graham 1956). Only a small portion of the batholith outcrops in the district. The granites are characterized by high quartz content, low percentage of ferro-magnesium minerals and sodic plagioclase. Potash feldspar is rare.

Pegmatitic phases and quartz porphyry are closely associated with the granite.

Quartz gabbro, granodiorite, and quartz diorite outcrop in small masses in the Cache Lake and Moon Lake areas. The younger diorite forms a border phase between the anorthosite and granite.

Intrusive volcanic breccia crops out in the small area northwest of Dore Lake. Mawdsley and Norman (1935) believe that the intrusive volcanic breccia is older than the granite. Small outcrop areas of syenite occur in the northern part of the district in the Bourbrau Lake area. The syenite probably belongs to the younger intrusive series (David Lake group).

Gray feldspar porphyry and gray fine-grained quartz diorite dikes are very widespread especially in the anorthosite. These dikes are genetically related to the Chibougamau granite batholith and represent a differentiate of the granite. They lie in northwest and northeast trending fractures, and have highly variable dimensions. The porphyry types usually grade into aphanitic acidic dike rocks (Graham 1956).

Dikes of diorite and gabbro cut gray feldspar porphyry and gray fine-grained diorite dikes and hence are younger (Graham 1956). One large dioritic dike in the southeast quarter of Roy township is approximately 600 feet wide and has been traced along its northeast strike for 15 miles. The gabbro and diorite dikes are relatively unaltered and show definite chilled borders (E. Gaucher - Personal Communication, 1957).

Olivine diabase and diabase dikes are believed to be the youngest rocks in the region. Mawdsley and Norman (1935) stated that the dikes are younger than the Chibougamau sedimentary series.

Sedimentary Rocks

Remnants of the Chibougamau series, consisting of conglomerates and arkose which show little metamorphism, occur in the northern part of the district. The Chibougamau sedimentary series is separated from the volcanics by a great angular unconformity. The sedimentary rocks cap higher hills in the Bourbeau Lake belt. They also occur in a down faulted block that lies between McKenzie and Gunn Bays in the northeast corner of Lake Chibougamau. The wedge-shaped block of sediments southeast of McKenzie Bay is believed to be thicker than 3400 feet and to consist, in ascending order, of a basal conglomerate member, a thick group of massive arkoses, and a thin upper conglomerate (Mawdsley and Norman 1935). In other outcrops, the conglomerate may overlie the arkose.

Retty (1929) and Mawdsley and Norman (1935) believe the sediments to be Cobalt or Upper Huronian in age.

Regional Alteration

Hydrothermal alteration is developed on an extensive regional scale in the rocks.

The volcanic rocks, although highly altered, maintain their primary structures according to Mawdsley and Norman (1955). The basic volcanics consist of varying proportions of secondary amphibole, chlorite, minerals of the epidote-zoisite group, sodic plagioclase, and minor amounts of quartz, titanite, lexcoxene and carbonate. The acidic rocks are altered to albite, white mica and lesser amounts of carbonate and epidote-zoisite minerals. Schistosity has been developed in the volcanics near intrusive rocks, but is better exhibited near or within shear and fault zones.

In the basic to ultrabasic intrusive rocks, saussuritization of the basic plagioclase to more sodic types and to epidote-zoisite and sericite is well exhibited. The primary pyroxene has been completely altered to hornblende and to chlorite. Carbonate is also important in the anorthosite. Sericitization and chloritization are confined to shear and fault zones (Mawdsley and Norman 1935).

The acidic intrusive rock types have not been altered to such a high degree as the more basic rock types. Biotite and hornblende are altered to chlorite. The sodic feldspar has been partly or extensively altered to sericite and minerals of the epidote-zoisite group. Quartz in some cases has been converted to interlocking granules (Mawdsley and Norman 1935).

The dike rocks are very fresh and the minerals have not been altered on a regional scale. The gray dioritic dikes, however, have been extensively modified by hydrothermal solutions along mineralized shear zones.

Glacial Geology

Low ridges of sand and gravel are characteristic of the topography in the southwestern part of the district. Many reefs and islands in Dore and Chibougamau lakes are drumlin-shaped in outline and consist of sand, gravel, and boulders. Morainic deposits have their long axis parallel to the glacial striae, which in Obalski township, trend S.50°W. to S.60°W., over most of the area, and S.35°W. to S.40°W., in the extreme southern part. (Graham 1956). Glacial debris is fairly common in the northern part of the district and occurs in the valleys.

STRUCTURE

Regional Structure

Folding

The rocks of the region have been compressed into large eastwest striking folds. Minor folds associated with the larger folds have not been identified in the region.

The axis of the synclinal fold north of Lake Chibougamau extends from Lake Antoinette to McKenzie Bay and appears to be offset by the north-easterly-trending McKenzie Narrows fault. The feldspathic sediments east of Bourbeau Lake form the central part of a synclinal structure. Ultrabasic to basic sills were intruded along the trough of this syncline. The adjacent southeast anticline is occupied by the Chibougamau basic complex (Mawdsley and Norman 1935). To the west, the Simon-Scott Lake granodiorite and the Opemiska granite batholiths also appear to have been intruded along the same anticlinal axis. A corresponding northern anticline and syncline have been postulated by Norman (1940).

Faulting

The faults in the region may be grouped into three sets according to the general strike.

The east-northeast set of faults dip steeply and parallel the strike of the formations. These faults are associated with wide zones of schistosity and carbonatization. Topographic lineation, schistosity, and carbonate zones are in general the only indication of the faults. Relative displacements on the faults are difficult to prove. The Lac Sauvage fault zone, which contains a very wide zone of carbonate and minor sulphide mineralization, has been traced by Smith (1953) and others for a distance of 12 miles.

The north-northeast set includes the McKenzie Narrows, Tache Lake, Gwillim Lake-Campbell-Bachelor Lakes, and Mistassini-Huronian faults. These are relatively parallel regional faults with a large displacement, and all appear to dip steeply to the southeast. The displacement on the faults is measured in thousands of feet. For example, the McKenzie Narrows fault has a horizontal displacement of 5000 feet. The boundary of the anorthosite has been offset 6000 to 7000 feet by the Tache Lake fault (Mawdsley and Norman 1935). Displacements on the Gwillim Lake-Campbell Lake-Bachelor Lake fault and the Mistassini-Huronian fault are still unknown. These fault zones are of economic significance since they have acted as channelways for hydrothermal mineralization, but they are not considered the dominant control of the ore deposits. Norman (1940) believes that these northeasterly faults were formed by a strong thrusting from the southeast.

The detailed description of the McKenzie Narrows and Tache Lake faults will be considered under local structure.

The Gwillim Lake-Campbell-Bachelor Lake fault is believed to extend for a distance of 145 miles. This fault has been described by Gilbert (1953), Mawdsley and Norman (1935), Shaw (1938) and others in different localities. Whether this assumed fault is continuous is a matter of conjecture.

The Mistassini-Huronian Fault zone is believed by Gill and Wilson (1943), Mawdsley and Norman (1935) and others to represent an extensive fault zone parallel to the Grenville-Huronian contact. Evidence supporting this fault is described by numerous authors. In 1938, Norman described disrupted strata in the Mistassini area in a zone 1 to 4 miles wide. Near the fault, the Mistassini gneisses and schists have foliation which dips southeast. G. Sater (Personal Communication 1957), who mapped southeast of the Mistassini Lake, stated that the dolomites near the contact were highly sheared and in part recrystallized. The writer found that the sedimentary rocks of Mistassini age in the Temiskami River area were highly folded and faulted near the contact, whereas further from the contact, the sedimentary beds were relatively flat-lying. Neale (1952) bas given evidence for major faulting along the contact south of the Mistassini Area. Norman (1940) believes that the numerous northeast faults and diabase dikes that occur in the Chibougamau district are good evidence for the existence of the Grenville-Huronian fault zone.

The shear zones with northwesterly strike are usually associated with intense vertical schistosity and in many places with zones of carbonates. Associated with the shear zones are the main copper deposits of the region. Smith (1953) has stated that right hand horizontal separations of about 1000 feet are indicated in some of these faults in southeastern quarter of McKenzie township.

Local Structure

Folding

As indicated in Plate 1, a large synclinal fold strikes east-west in the northern part of the district. The axis of the southern anticline lies south of the district. The major ore deposits occur along the northwest flank of this major anticline.

Faulting

The Lac Sauvage Fault zone, which has been traced for over 12 miles, trends east-northeast in a direction parallel to the strike of the volcanics. It has been traced from the west side of McKenzie Township to Dore Lake. The zone of schistosity and carbonate is approximately 300 feet wide and appears to branch in several places. The characteristic minerals are calcite, siderite, sericite, chlorite and chloritoid with minor sulphides. Several notable sulphide mineral deposits, Baker Talc and No. 3 zone at Chibougamau Jaculet, are located in branching parts of the major zone. Displacement is difficult to determine. Small faults parallel to the trend of the volcanics are very common in the district.

The north northeast set is represented by the McKenzie Narrows fault which follows the McKenzie Narrows in the northeastern part of the map area. Northeast of Portage Bay the approximate position of the fault is more closely defined by McKenzie Narrows and a chain of lakes northeast of Rapid Bay. The assumed fault line on Portage Island follows a depression 600 feet wide that in places is very distinct (Mawdsley and Norman 1935). Drilling in the lake on the Chibougamau Jaculet and Bateman Bay properties failed to discover the fault zone. However, on the Bateman Bay peninsula a strong shear zone between anorthosite and volcanics was delineated by diamond drilling (Archibald 1958). They may represent the southern extension of the McKenzie Narrows fault. Drilling on the Copper Rand property traced the fault southward. The rock within the fault zone is a chlorite-sericite-carbonate schist with a strike of N.60°E. and a 49°SE. dip (Archibald 1958). Farther west of Merrill Island, diamond drilling on the Campbell Chibougamau Mines property indicates that the fault zone swings from N.45°E. to N.60°E. Here the zone is 50 feet wide and the dip is vertical. To the south a talc-sericite schist zone 55 feet wide with a dip of 40°NW. is probably the southwestern extension of the zone. On the Obalski property, a talc-sericite-chlorite zone 100 feet wide and dipping 70-80°SE was encountered in diamond drilling (Archibald 1958). Graham (1956) states that the shear zone is exposed in the bed of a creek which flows from Cache Lake to Dore Lake. The rock in the creek bed is brecciated over width of 20 feet, and for 50 feet to the northwest the rock formations are fractured, schistose, and carbonatized. The most marked effect produced by the fault on the Chibougamau strata southeast of Rapid Bay is the development of a deformed sericitic zone about 1200 feet wide in the quartzose and arkosic sediments. The sericitic zone strikes N.50-60°east and dips either vertically or steeply southeast (Mawdsley and Norman 1935). From the evidence cited, it can be shown that the fault is probably continuous throughout its length, but the fault plane is irregular with local changes in strike and dip. The segment of the McKenzie Narrows fault, south of Portage Island, has been renamed the Dore Lake fault. The opinion presently hald by local geologists is that the McKenzie Narrows fault and the Dore Lake fault are two separate faults. The McKenzie Narrows fault, as described by Mawdsley and Norman (1935) would include the fault segment north of Portage Island. The writer has retained the name McKenzie Narrows fault for the entire length of the fault.

Along the McKenzie Narrows fault east of Rapid Bay a thin conglomerate was thought by Norman (1936) to be lying unconformably above the lower member of the Chibougamau series. The underlying quartzite of the lower member is strongly schistose, whereas the conglomerate of the upper member shows little indication of shearing. It is believed that some movement took place between the deposition of the lower member of the Chibougamau series and the upper member. Late movements brought the earliest Pre-cambrian rocks against the Chibougamau series. There is, however, even later, possibly post mineralization, movement on the fault. Mawdsley and Norman (1935) have postulated a horizontal displacement of 5000 feet, as evidenced by offsetting of an ultrabasic sill in the northeastern part of the district. The southeastern side of the fault has been displaced southwest. The Tache Lake fault which strikes north-northeast is a well defined structural feature between Tache Lake and Bag Bay on Lake

Chibougamau. The southeast dip of the fault place is suggested by the 45° to 65° SE dip of the shear planes in the anorthosite and gabbro along the east side of the trench (Mawdsley and Norman 1935). The north boundary of the anorthosite is offset 6000 to 7000 feet north on the east side of the fault. Other horizons are offset with a similar relative movement and magnitude. The Tache Lake fault has been traced from Lake Chibougamau northward to Tache Lake and it is possible that it may extend farther northeast.

Numerous small northeasterly striking faults, which vary from small joint-like fractures to strongly brecciated and sheared zones, randomly occur throughout the district.

Faults of the northwest set are widespread and are usually the sulphide-bearing structures of the Dore Lake area. The northwesterly striking shear zones associated with the northwest striking faults are usually 100-200 feet wide and are carbonatized and strongly schistose. Final movement on the northeast set of faults was later than the major movements of east to southeast faults (Graham 1956). Dikes of gray fine-grained quartz diorite, gray feldspar porphyry, diorite, and gabbro in many places lie along these northwest shears. Since some of the dikes are sheared, it is possible that they were affected by subsequent local movement. Minor northwest faults have been mapped in the northern part of the district.

MINERAL DEPOSITS

Introduction

The mineral deposits of the Chibougamau district may be divided into three major categories - magnetite-ilmenite deposits, sulphides deposits, and gold quartz veins.

The magnetite-ilmenite deposits occur in gabbro as a product of magmatic differentiation, and in serpentinite, where they have formed as alteration products of ferro-magnesium minerals. The titanium concentration is highly variable, but Graham (1956) states that the titanium-rich magnetite formation invariably occurs in fresh gabbro, whereas titanium-low magnetite formations are localized in altered serpentinite.

The sulphide deposits can be subdivided on the basis of the predominant sulphide minerals present.

Pyrite-pyrrhotite-chalcopyrite deposits which are of the greatest economic significance occur near Chibougamau and Dore Lakes. Many of the sulphide deposits are concentrated along the northwest and southeast sides of Dore Lake, and near the McKenzie Narrows fault. Several others - Portage Island, Yorcan and New York Honduras Rosario mineralized zones - are near or under Lake Chibougamau. "The major pyrite-pyrrhotite-chalcopyrite deposits and mineralized zones are usually associated with the altered anorthosite mass or phases of it, with concentration of ore along northwest or east-west shear zones. The hydrothermal alteration is in places intense.

Arsenopyrite-pyrrhotite-sphalerite deposits occur in a peridotite-serpentinite sill near Berrigan Lake. This deposit is unique, since arsenopyrite, sphalerite, and galena are relatively abundant.

The pyrrhotite-chalcopyrite mineralization is concentrated in the northern part of the Chibougamau district, but it is not of economic significance. The writer believes this mineralization is related to the gabbro-pyroxenite sills.

The gold quartz veins are not restricted to any one geological rock type, but are distributed randomly throughout the district. These veins are of no economic significance.

Minor occurrences of asbestos have been reported in the Chibougamau district. The main showing is located on Asbestos Island in McKenzie Bay.

Magnetite-Ilmenite Deposits

The magnetite-ilmenite deposits can be classified into two groups, the serpentinite occurrences and gabbro occurrences.

Serpentine Occurrences

The Magnetite Bay iron formation occurs on the Roycam Copper property between the anorthosite mass to the south and altered volcanics to the north. The formation extends west and east of the Roycam property. The iron formation is composed of fine-grained black serpentinite containing abundant magnetite as disseminations, stringers, and larger masses (Mawdsley and Norman 1935).

North of Portage Lake, on Portage Island, the east-northeast trending contact between the gabbro-anorthosite mass and the volcanics is marked by a band of iron formation some 200-250 feet wide and of undetermined length. This formation consists of a fine-grained serpentinized rock which contains magnetite as stringers and as disseminations (Archibald 1958).

Other iron-bearing serpentinite bodies have been reported by government geologists in the southeast quarter of Roy Township. Size and tonnages of these serpentinite masses are unknown.

Gabbro Occurrences

A zone of magnetite-bearing gabbro, which lies between Cachee Lake and Dore Lake, has been mapped for a length of 2 miles in a north-south direction (Graham 1956). The magnetite formation lies along the gabbro-transition zone contact in a zone 100 to 500 feet wide. The zone dips 20° to 50°W. and is parallel to the contact. The alternating sheets of magnetite and magnetite-bearing gabbro range in width up to 1 foot. Graham (1956) states that ilmenite occurs as grains and as lamellar intergrowths along octahedral planes in the magnetite. Magnetite was observed as scattered anhedral grains in the gabbro; Graham (1956) suggests that the iron formation is a product of differentiation.

A similar magnetite formation which lies between gabbro and a anorthosite-gabbro transition contact has been traced for 1200 feet on Portage Island. The formation varies in width from 400-500 feet.

Two main titaniferous magnetite horizons have been outlined in the gabbro-anorthosite complex southeast of Lake Chibougamau (Assad 1957). The major zone is 180 feet wide in outcrop, and is separated from the other zone by an average of 125 feet of host rock. The second zone is 60 feet wide. Both have been followed along the north-east strike for a distance of 7200 feet. The magnetite is coarse, and occurs both as a somewhat massive oxide and as disseminations in gabbro and anorthosite. In the massive variety, the magnetite occurs as one-half inch to two foot bands of pure oxide which are not continuous over any great distance (Assad 1957).

Pyrite-Pyrrhotite-Chalcopyrite Deposits

Distribution and General Character

The major sulphide deposits of the district are replacements, located in the horseshoe-shaped anorthosite basic complex and near the McKenzie Narrows fault. However, minor mineralized zones are found in the basic lavas and ultra-basic intrusives which lie north of Chibougamau and Dore Lakes. All the ore zones are confined to schistose and brecciated anorthosite or transition zones in the Dore Lake area. These deposits are irregular in plan and in cross section, and represent sulphide replacement in shear zones. The main mineralized zones have a strike of N.45°W. to

N.60°W., usually with a steep dip either to the north or south. A few of the mineralized zones have an east-west strike; these include the A-zone of Quebec Chibougamau Goldfields and the mineralized shear zone on the Atlas property. The Yorcan ore deposit, which has the largest tonnage in the Chibougamau district, has a N.75°E. strike with a variable dip. In the upper horizons the deposit has a steep southerly dip, but in the lower horizons, the ore body is horizontal. The two mineralized zones on Portage Island, Hematite Point, and Copper Point zones are mainly brecciated and fractured zones with a reported northeast strike.

Plunge of the deposits varies from east to west. The No. 1 and West No. 2 zone of the Chibougamau Jaculet properties plunge steeply west, whereas the east No. 2 plunges steeply to the east. The Quebec Chibougamau A-zone and the Yorcan deposit plunge 45°E. and 30 E. respectively. Plunges of the other deposits are still unknown.

Control of Deposits

The ore zones are controlled mainly by (1) shearing, (2) dikes, and (3) composition of country rock.

The mineralization is confined to shear zones which usually have a variable dip. The shears pitch and roll, and ore has been concentrated in the rolls along the fault plane. With a change of dip, the ore zone may increases in size and possibly in grade. The Henderson zone on the Yorcan property illustrates such a concentration of mineralization. The ore zone dips steeply to the south in the upper horizons. At the 250 foot horizon, at the west end, and the 750 horizon at the east end of the ore zone, the dip abruptly changes to a very low angle. Massive ore has been concentrated along this change of dip. The flat portion of the mineralized shear does not make ore whereas the main Henderson zone has a considerably higher grade (Archibald 1958). With more underground development, it is possible that the change of dip will be found to be a deciding factor in the localization of larger and higher grade ore zones.

Introduction of dikes followed the intrusion of the granite batholith and probably took place after the major shearing. The gray fine-grained diorite and gray feldspar porphyry dikes, possibly along with green or more basic dikes, have been intruded along northeast and northwest tension or shear zones. In most of the ore zones which occur in the anorthosite, numerous dikes and dike swarms have been mapped both underground and on the surface. The dikes have been hydrothermally altered especially in the ore zones and consequently they are easily mistaken for the highly altered anorthosite (Graham 1956). The dikes themselves vary in width from a few inches to 50 feet. In the ore zone the smaller ones are elongate in shape but are not presistent. However, larger dikes may persist in the ore zone or outside of the mineralized deposit. A large gray feldspar porphyry dike has been mapped for a vertical distance of 1000 feet in the Merrill Island deposit. A predominant feldspar porphyry dike, 20-40 feet wide, separate two ore zones on the Campbell Chibougamau Kokko Creek property (Archibald 1958).

Renewed movement along the northeast striking shear zones created dilatant zones near the dikes (Graham 1956 - G. Allard 1953). These low pressure zones have acted as channelways and ore controls. The highly sheared character of some of the dikes in the ore zones, especially the feldspar porphyry and gray dioritic dikes, suggest later movement.

It is thought by some geologists that the basic or green dikes were intruded after renewed movement along the northwest shear zones, and are possibly contemporaneous with the mineralization †(D. Asbury P.C.). The dikes may have acted as barriers to the penetrating ore solutions

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† (D. Asbury, Personal Communication, 1957)

(Graham 1956). At Copper Rand, there is an increased in grade of ore near the dikes suggesting that damming of the ore solutions has taken place (D. Asbury P.C.). At the Kokko Creek deposit, a peristent dike separates two ore bodies, and it is thought that this dike may represent a definite ore control.

All the major deposits found to date in the Chibougamau district occur in altered anorthosite or the transitional zone. Minor mineralized zones do occur in the volcanics and basic intrusives in the district, but they are of little economic significance. The brittle anorthosite would fracture very easily. On the other hand, basic rocks are less brittle and possibly a resealing of shear zones has taken place. A second feature that should not be overlooked is the possible chemical favorability or selectivity of the anorthosite by the ore solutions. The Opemiska and Chibougamau Explorer mines, outside the Chibougamau district, occur in shear zones in basic to ultrabasic rock types, and differ from the typical Dore and Chibougamau Lakes host rock association.

Post-mineral faults, which have a northeast and northwest strike, appear to have restricted some of the mineralized zones, but displacements are usually small.

Graham (1956) stated that the copper-bearing shear zone on the Chibougamau Kayrand property has been cut into two nearly equal segments by a fault striking N.70°E. The apparent horizontal displacement along the fault place is 150 to 200 feet to the left. In the Merrill Island property Graham (1956) says:

> "Several other northeast faults displace the sulphide-bearing structure. Apparently horizontal displacements are, for the most part, less than 100 feet."

Assad (1957) stated that about 200 to 300 feet south of the Eaton Bay zone is a fault that strikes N.70°W. and dips 48 to the south, and which appears to bound the shear zone at the south end. A northeast striking cross-fault dipping 60-70° west has been located at the east end of the ore deposit on the Campbell Chibougamau Kokko Creek deposit. The major mineralized A-zone on the Bateman Bay property changes in strike from N.80°W at the west boundary of the property to N.45°W in the east part. A crosscutting northeasterly striking fault could explain this difference in strike. Another hypothesis is that the strike of the shear zone is irregular. The No. 1 Chibougamau Jaculet zone appears to have been offset a horizontal distance of 100-300 feet. Whether this separation represents faulting or an echelon mineralized shear zone is, in the writer's mind, controversial.

Wall Rock Alterations

The altered anorthosite illustrates changes in mineralogy and resultant colors from the borders of the shear zones to the core of the deposit.

Three stages of hydrothermal activity have been recorded (Graham 1956).

First: The least altered varieties of anorthosite contain oligoclase, white mica, and chlorite in varying amounts and minor amounts of clinozoisite, zoisite, and epidote. The normal anorthosite is dark green in color and is slightly schistose.

Second: Within the shear zones the matrix has been altered by dynamic metamorphism to an aggregate of chlorite and white mica or talc. In several localities, chloritoid is associated with the white mica. The color of the highly schcistose anorthosite is yellow to greenish-yellow due to abundance of sericite.(Graham believes that chlorite and sericite are in part stress minerals).

Third: Hydrothermal minerals are associated with the sulphides in varying amounts. These include quartz, albite, oligoclase, carbonate chlorite, sericite zoisite, talc, muscovite, clinozoisite and minor amounts of apatite, rutile, leucoxene, and epidote. These minerals occur in a variety of forms, including aggregates, lenses, veinlets, and complete replacements. The hydrothermal minerals give the highly altered anorthosite a bluish-gray hue which is diagnostic in prospecting for other deposits (Graham 1956).

Some of the gray and green dikes have been similarly altered in the sulphide zones. The hydrothermal alteration zone varies in width in the different deposits and extends from a few feet up to 300 feet into the country rock.

Pyrite-Magnetite-Chalcopyrite Deposit

The pyrite-magnetite-chalcopyrite deposit occurs in a brecciated zone in granite on the Grandine property.

The deposit differs from the other sulphide zones in having a pronounced high intensity mineral assemblage.

A chloritic granite known as the Grandine granite plug underlies the property in the area of the main sulphide zone. Immediately north of the Grandine granite is a narrow belt of rhyolite, 80 to 100 feet wide. Farther north a series of basaltic and andesitic lava flows have been intruded by basic to ultrabasic sills.

The Grandine fault, which is highly mineralized with pyrite and shows strong development of graphite appears to truncate the mineralized zone on the east. Another strong shear zone, which strikes N.80°E. and dips vertically, occurs along the contact between the rhyolite and andesite. The most intensely sheared part of the zone is 10 feet wide, but shearing extends over a width of 125 feet into both the rhyolite and the andesite.

The mineralized zone appears to strike N.20°E. and dips 60° east, but the limits are not well-defined (Graham 1953). The most pronounced fracturing trends northeasterly.

The mineralization consists of pyrite and chalcopyrite in massive form, in stringers along shatter planes, and as disseminated grains between the fractures. Specular hematite and magnetite occur as selvages along some of the fractures and in veinlets up to 3 inches wide. Later fractures, which cut the mineralized zone, contain molybdenite (Graham 1953). The sulphide mineralization does not occur in the rhyolite lying across the northern extension of the zone.

Wall rock alteration is almost lacking in the mineralized zone. Possibly minor amounts of chlorite were introduced with the hydrothermal sulphide-bearing solutions (Graham 1953).

Pyrrhotite-Chalcopyrite Deposits

The pyrrhotite-chalcopyrite deposits in the volcanic belt are of no economic interest but are very numerous in the northern part of the district. Many of the mineralized showings occur in siliceous tuff near gabbro-pyroxenite sills. Other prospects occur in minor shear zones which traverse the sills or in minor shear zones parallel to the bedding in the tuff formations. The mineralization consists of fine-grained pyrrhotite, minor chalcopyrite, and sphalerite with or without minor pyrite. Trace amounts of gold and silver have been reported from assays.

On the Bell Chibougamau property (Graham 1953) four sulphide lenses occur in fractured and slickensided serpentinite and pyroxenite. The lenses all strike north-south and are nearly vertical. They are 15 to 20 feet long and from 3 to 7 feet wide. The mineralization consists of fine-grained massive pyrrhotite cut by stringers of chalcopyrite with minor pyrite and sphalerite.

Two sulphide zones in schistose tuff have been explored on the O'Leary Malartic property in Roy Township (Graham 1953). The West zone, which has been traced for 400 feet varies from 2½ to 3 feet in width, strikes east-west and dips 65°S. The mineralization consists of fine-grained massive pyrrhotite; contains minor pyrite and a little chalcopyrite.

The East zone about 1000 feet east of the West Zone is about 2½ feet wide. The mineralization is not massive like that to the west, but the chalcopyrite is more abundant and occurs in lenses with pyrrhotite and minor pyrite. At the east end of this zone, sphalerite is present, forming an important part of the mineralization (Graham 1953).

Additional showings of massive or disseminated pyrrhotite occur in the tuffs on the Bouzan - New Jason property and at the Flicka Red Lake Mines. Chalcopyrite accompanies the pyrrhotite at both prospects. Pyrite is quite abundant at the Flicka Red Lake Mines.

Products of wall rock alteration are sparse. Sericite has formed in the tuffs, whereas serpentine and chlorite occur in the shear zones in the ultrabasics. Silicification associated with the tuff is probably diagenetic in origin.

Arsenopyrite-Pyrrhotite-Sphalerite Deposits

Distribution and General Character

The arsenopyrite-pyrrhotite-sphalerite deposits are illustrated by the Tache Lake Mines property near Berrigan Lake. The Berrigen Lake area is underlain by easterly striking peridotite-pyroxenite sills with remnants of basic volcanics. Two sulphide zones have been explored by trenching and diamond drilling just north of Berrigan Lake. The North zone is located 400 to 650 feet north of the center of the north shore of Berrigan Lake (Smith 1953). The other is on the north shore near the east end of the lake and is called the "Berrigan zone".

The North zone is a zone of shattering and brecciation in the otherwise massive serpentinized pyroxenite (Smith 1953). The deposit includes two branches, one striking north, and the other northeast. The northeast branch is 260 feet long at surface with a width of 10 feet at the northeast end. This zone dips 35° to 80°W. The north branch, which has been explored for 230 feet at surface, is for the most part 4 to 6 feet wide. Several other high grade zones of smaller size have been explored in this area.

The brecciated and shattered zone has been mineralized first by fine-grained quartz and some rusty carbonate (Smith 1953). The sulphide minerals consisting in the order of decreasing abundance, pyrrhotite, sphalerite, galena, chalcopyrite, pyrite and arsenopyrite, are concentrated in veins and masses in the vein quartz and silicified wall rock. Galena is rare in other exposures, and the relative abundance of the other minerals varies (Smith 1953).

The Berrigan zone, which is about 1300 feet long and of variable width, outcrops along the north shore of the Berrigan Lake (Smith 1953). The sulphide-bearing carbonatized and brecciated zone is about 40-100 feet wide with a strike of east-northeast. Two parallel zones, one north and the other south of the main zone, and the east extension of the main zone contain appreciably less sulphides (Smith 1953).

The immediate wall rocks of the Berrigan zones are mostly serpentinized dunite and sheared serpentinite with some altered pyroxenite.

Pyrrhotite and sphalerite are by far the most abundant sulphides in surface exposures of the zone. There is some chalcopyrite, but galena is absent or rare. Relatively high nickel values have been reported by company officials.

Control of Deposits

The two zones are confined to brecciated and sheared zones in ultrabasic intrusives. The general trend of the shearing and brecciation is either north-easterly or easterly parallel to the trend of the rock formation; a few zones have a northerly strike (Smith 1953). These mineralized zones are very irregular in shape and sulphide tenor may in part depend on the tendency of the sulphides to replace chert or quartz Smith (1953) says:

> "Within the Berrigan zone, irregular thin layers of dark grey, very fine-grained to cherty quartz are veined and partly replaced by sulphides. In some places layers of massive sulphides occur in carbonated rock perhaps having completely replaced a layer of siliceous host rock. Sulphides are commonly scarce, in the carbonatized rock between the siliceous layers."

The north zone also illustrates this selective replacement of the hydrothermal chert or quartz. Dialatant zones may also have been important in localizing the ore solutions.

Wall Rock Alteration

The brecciation and fracturing was followed by the introduction of fine-grained quartz and some rusty-weathering carbonate in the fractures and in the wall rock. The country rock in the ore zones is black and aphanitic, apparently consisting of chlorite and carbonate. The immediate wall rocks consists of the dunites, peridotites, and pyroxenites which have been highly serpentinized by regional metamorphism (Smith 1953).

Gold Quartz Veins

Distribution and General Character

The gold-quartz veins are all concentrated in minor shear or brecciated zones in dioritic or gabbroic sills or stocks. Graham (1956) suggests that the gold tenor is considerably lower in those parts of the veins which lie in a quartz diorite or quartz gabbro country rock. He believes that higher values are associated with the fine-grained gabbro intrusion. All the veins appear to represent fillings of quartz, gold and minor sulphides along minor shear zones. Arsenopyrite is relatively abundant in the Noranda gold-quartz veins, but in other veins in the district it is completely lacking.

The well-known McKenzie gold vein on Portage Island, which has an explored length of 700 feet and a width up to 30 feet, occupies an east-west shear zone within transition gabbro-anorthosite (Assad 1956). Quartz, pyrite, and chalcopyrite with minor gold are the main minerals in the vein. The gold values are very erratic and the average tenor appears to decrease below 400 feet (Assad 1956). The gold occurs in the native state (Mawdsley and Norman 1935).

Three gold-quartz veins have been explored on the Obalski property (Graham 1956). These veins vary in strike from east to southeast and occupy narrow shear zones in fine-grained gabbro and quartz diorite. The quartz veins are lense-like and appear to pinch out at each end. The veins vary in length from 800 feet to 2400 feet and in width from ½ to 3 feet. The vein minerals are milky quartz, pyrite, chalcopyrite, and very minor gold. Vugs are common in the quartz veins and in places are lined with quartz crystals which are cut by fractures filled with massive chalcopyrite (Graham 1956). Stringers of pyrite and chalcopyrite up to 3 inches in width are found in these veins (Graham 1956).

Three quartz veins are well developed in shear zones in quartz diorite on Norbeau Mines property.

The No. 1 vein is a brecciated zone that shows rude banding parallel to the contact between the quartz vein and wall rock. Fragments of wall rock have been enclosed in vein quartz. Pyrite and arsenopyrite are the most abundant sulphides with minor amounts of chalcopyrite, sphalerite, and gold. The wall rock, particularly in the foot wall of the vein, is well mineralized for a distance up to 3 feet. The No. 2 zone which has a similar northeast strike closely resembles the No. 1 quartz vein (Carmichael 1940).

The No. 3 quartz vein, which strikes east-west with a steep dip to the south, has been traced for a distance of 1 mile. The vein lies in schistose zone some 10 feet wide, whereas the quartz vein itself is two feet wide. Norman and Mawdsley (1935) have reported pyrite, arsenopyrite and minor native gold from the west end of the No. 3 quartz vein.

The Lac Fleury deposit occurs in an easterly striking rusty carbonated shear zone at a metagabbro-metadiorite sill contact outcropping near Fleury Lake (Graham 1953). Two veins, one to three feet wide, are exposed in an exploration shaft. Both dip 55° to 70° to the south, and cut the dip of the shear zone. The veins, including white milky quartz contain smaller amounts of coarsely crystalline ankeritic carbonate, abundant pyrite and irregular blebs and masses of chalcopyrite in small amounts.

Wall Rock Alteration

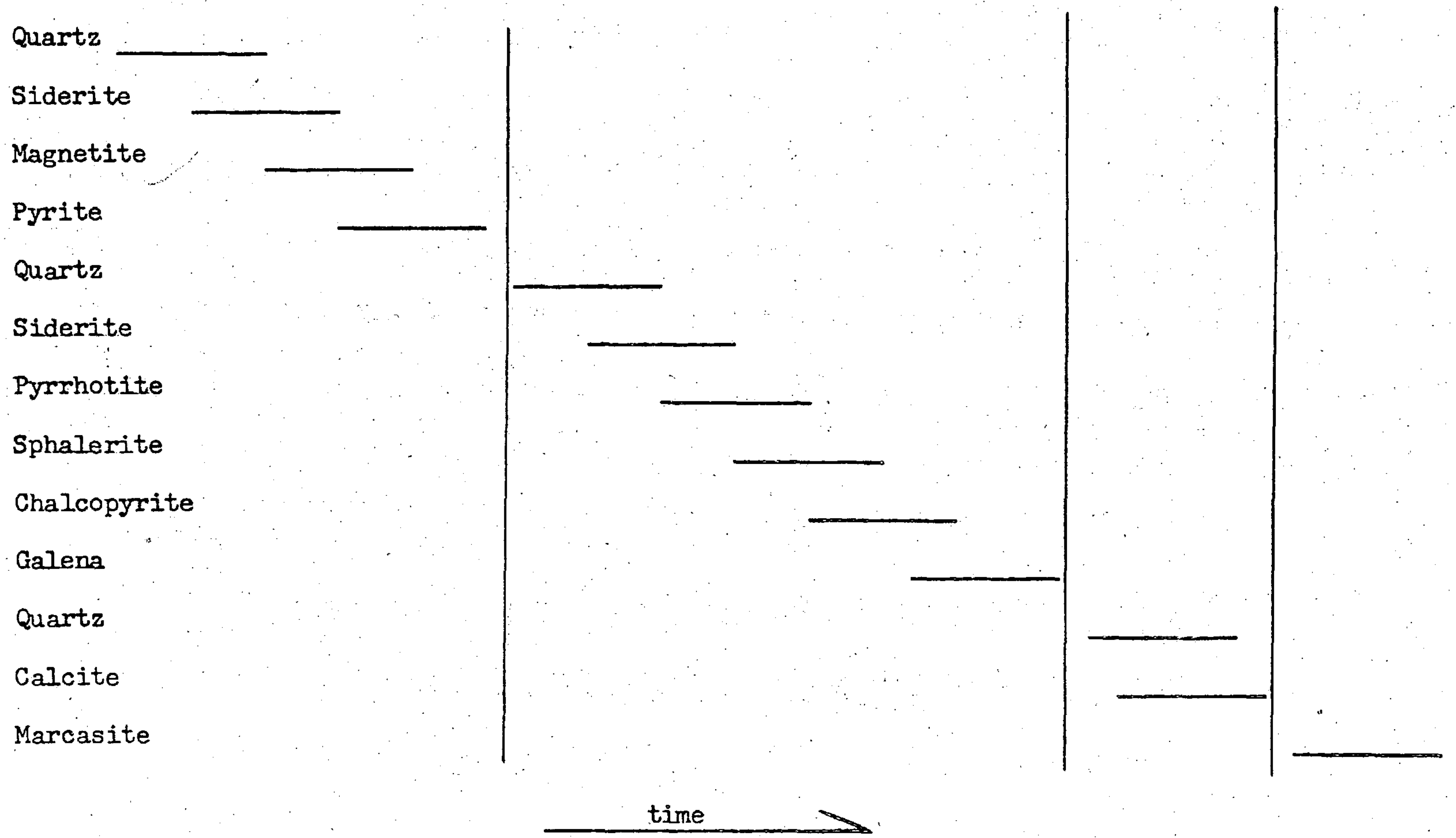
The wall rock alteration can be classified as early and late.

Chlorite and actinolite are thought to be directly associated with the shearing (Carmichael 1940). Carbonization is associated with most of the wall rocks of the gold-quartz types and is believed to have formed early. Carmichael (1940) described the presence of leucoxene in the wall rocks. The leucoxene is associated with chlorite, serpentine, actinolite, and carbonate. Later carbonate introduction has occurred in the wall rocks of the No. 1, No. 2, and No. 3 zones in the Norbeau Mines.

MINERALOGY AND PARAGENESIS

General Statement

All the mineral deposits, excluding the pyrrhotite-chalcopyrite mineralized zones, are thought to be genetically related to the Chibougamau granite batholith. The pyrite-magnetite-chalcopyrite assemblage, which occurs as a mineralized zone in the Grandine property, is associated with a small granitic plug. This plug, known as the Grandine granite, resembles the Chibougamau granite, mineralogically and represents an outlier. The above association of pyrite-magnetite-chalcopyrite is a high temperature assemblage. Hematite and molybdenite also occur in the deposit. This mineral deposit crystallized earlier than the main sulphide zones. The principal economic deposits of pyrrhotite-pyrite-chalcopyrite were the next to be deposited. Following a period of deformation, offsetting of the sulphide mineral zones, and opening of shears and fractures, a third period of mineral deposition took place. The arsenopyrite-pyrrhotite-sphalerite deposits are definitely later than the pyrrhotite-pyrite-chalcopyrite mineralization as observed in the Opemiska Mines workings. The gold-quartz deposition is believed to have occurred later than the deposition involving arsenopyrite, but evidence for the age of this mineralization is not complete.



Vertical lines indicate movement.

Diagram 1 - Paragenetic sequence of mineralization of the pyrite-pyrrhotite-chalcopyrite deposits.

Pyrite-Pyrrhotite-Chalcopyrite Deposits

These deposits are characterized by abundant pyrite-pyrrhotite, and chalcopyrite, with very minor amounts of sphalerite, galena and magnetite.

Magnetite, which is rarely noted in hand specimens, occurs as euhedral grains in the wall rock, and less commonly in the ore zone.

Pyrite is very abundant both in the wall rock and ore zones and usually is observed as euhedral-subhefral grains. Minor cobalt substitution for iron in pyrite is very diagnostic in these deposits.

Pyrrhotite has been reported in nearly all deposits, except for the mineralized shear zones of siderite and calcite. The Baker Talc, Copper Rand-Copper Cliff zones, and the slightly mineralized portions of the Lac Sauvage Fault zone appear to be totally lacking in pyrrhotite. However, in the other deposits, pyrrhotite is very abundant. Gold substitution in pyrite and pyrrhotite has been reported by mine officials.

Sphalerite is very rare, but is concentrated as small irregular masses in the pyrrhotite-pyrite-chalcopyrite deposits. Elsewhere it is observed as small blebs, usually associated with chalcopyrite. The sphalerite is usually dark brown in color and probably represents a higher temperature variety (Allard 1953).

Chalcopyrite, which is the only copper mineral, appears in nearly all of the mineral occurrences. Chalcopyrite contains submicroscopic inclusions of gold in the crystal lattice (Allard 1953). Galena occurs only in minute blebs in some of the deposits. It can only be seen under the microscope.

Quartz, calcite, and siderite are the abundant gangue minerals.

Quartz is the most abundant of the gangue minerals in the polished sections and is usually replaced by the later sulphides. Massive quartz is veined and replaced by a mixture of chalcopyrite and pyrrhotite (Figure 2) from Merrill Island. In most cases, quartz appears to have followed a period of fracturing. Quartz also surrounds and fills small fractures in pyrite. However, in one specimen from the Cedar Bay zone, pyrite crystals are aligned along quartz boundaries (Figure 3). In several other sections quartz inclusions in pyrite suggest an early age of quartz. Deposition of quartz continued intermittently throughout most of the period of mineralization. Most of the sulphide minerals including pyrrhotite were observed to be cut by late quartz veinlets (Figure 15 Lake Chibougamau Mines).

Magnetite was observed in three specimens. The magnetite is usually subhedral to anhedral and is thought to be the first metallic mineral to crystallize. From the textural evidence, it would seem that the sulphides are later and have to some extent replaced magnetite. Minute blebs of chalcopyrite are common in anhedral magnetite; chalcopyrite has corroded magnetite along grain boundaries in a specimen from Quebec Chibougamau Goldfields (Figure 4). Relationships between pyrite and magnetite were observed in two specimens. Subhedral to anhedral magnetite grains are in contact with anhedral pyrite in these sections. Textural evidence between pyrite and magnetite is not clear but it is thought that magnetite preceded pyrite in the paragenetic sequence - see Figure 4. Similar magnetite has been reported by Graham (1956) and Allard(1953) from the Merrill Island deposit.

Pyrite commonly occurs as fractured subhedral to anhedral grains in the polished sections. This early sulphide has been selectively replaced by chalcopyrite, and degrees of this replacement were observed from the different localities. Slight chalcopyrite replacement has been guided by fractures as seen in Figure 5 (Baker Talc property). Pyrite has been deeply emabyed and corroded by chalcopyrite in numerous specimens. A higher intensity of replacement is well exemplified by the island and see texture in a few sections. Pyrrhotite less commonly replaces pyrite along grain boundaries in a specimen (Figure 9) from the Yorcan deposit and other polished sections. Sphalerite which replaces pyrite to a minor extent was observed as replacement veinlets in fractured pyrite (Figure 6 - Bateman Bay Mines). Pyrite makes up approximately 50 per cent of the total sulphides in the specimens studied.

Siderite is abundant in polished sections from the Baker Talc, Bateman Bay and Copper Rand properties, and is later than early quartz, see Figure 7 (Baker Talc property). Chalcopyrite and sphalerite less commonly replace siderite along cleavage planes or along grain boundaries (Figure 8 - Bateman Bay property). Textural evidence suggests that most of the pyrite is older than siderite. However, in a specimen from Copper Rand, pyrite is noted as small crystals lying along the siderite-wall rock mineral boundaries. Deposition of siderite is believed to have begun before and overlaps the pyrite mineralization.

The three sulphides, pyrrhotite, sphalerite, and chalcopyrite followed the early gangue of pyrite and magnetite in approximately that order.

Pyrrhotite is one of the most frequent observed minerals in the polished sections. Pyrrhotite has preceded sphalerite in the paragenetic sequence, but extensive overlapping has occurred. Pyrrhotite corrodes quartz and only relaces pyrite - see Figure 4 (Yorcan deposit). Pyrrhotite commonly replaces the country rock and inclusions and relict textures in pyrrhotite are not uncommon. Chalcopyrite, which is usually associated with pyrrhotite, embays that earlier sulphide in many polished section (Figure 10 -

Quebec Chibougamau Goldfields).

Sphalerite closely followed pyrrhotite in the paragenetic sequence. Generally its replacement of pyrrhotite has been controlled by the pyrrhotite grain boundaries. This texture resembles the so-called "mutual" textures of simultaneous deposition, but remnants of pyrrhotite frequently occur in sphalerite (Figure 11 - Lake Chibougamau Mines). However, an earlier age of sphalerite is postulated in a specimen from Campbell Chibougamau Mines (Figure12). A branching veinlet of pyrrhotite which showed random extinctions under crossed nicole appears to traverse massive sphalerite. The textural relationships between sphalerite and chalcopyrite are well shown in the deposits. Generally chalcopyrite deeply emabys massive sphalerite as exemplified in Figure 13 (Campbell Chibougamau Mines). Sphalerite is usually well-twinned, and oriented chalcopyrite blebs vary in size, shape and number, and are thought to represent replacement of sphalerite by chalcopyrite. Figure 14 (Merrill Island Corp.) illustrates irregular blebs of chalcopyrite along the 110 twin lamellae in sphalerite. Oriented inclusions of pyrrhotite were noted in massive sphalerite in one speciment from Chibougamau Kayrand. This textural relationship was also interpreted as a replacement texture. Allard (1953) explains the presence of oriented chalcopyrite blebs in sphalerite by unmixing. Sphalerite is quite uncommon in the polished section from the pyrite-pyrrhotite-chalcopyrite deposits.

Chalcopyrite makes up approximately 25 per cent of the total sulphides in the polished sections. Chalcopyrite selectively replaces pyrite, either by veining or along the borders, and it embays and replaces all earlier minerals.

Galena is very rare in the specimens studied, and only minor amounts of this mineral were noted in a few sections from the Quebec Chibougamau Goldfields in the Merrill Island zone. Galena usually occurs as replacement blebs in pyrite, chalcopyrite, and less commonly in sphalerite.

Marcasite, which was seen only in one specimen from the Chibougamau Kayrand mineralized zone appears to selectively replace pyrite and veins sphalerite. In Figure 15, a portion of the marcasite veinlet in the upper part of the microphotograph appears to occur along the late calcite-sphalerite contact. This evidence proves that marcasite followed calcite in the paragenetic sequence.

Late quartz and calcite veinlets cut the sulphides in some of the polished sections studied. Textural evidence of the paragenetic relationship between late quartz and calcite could not be determined (Figure 16).

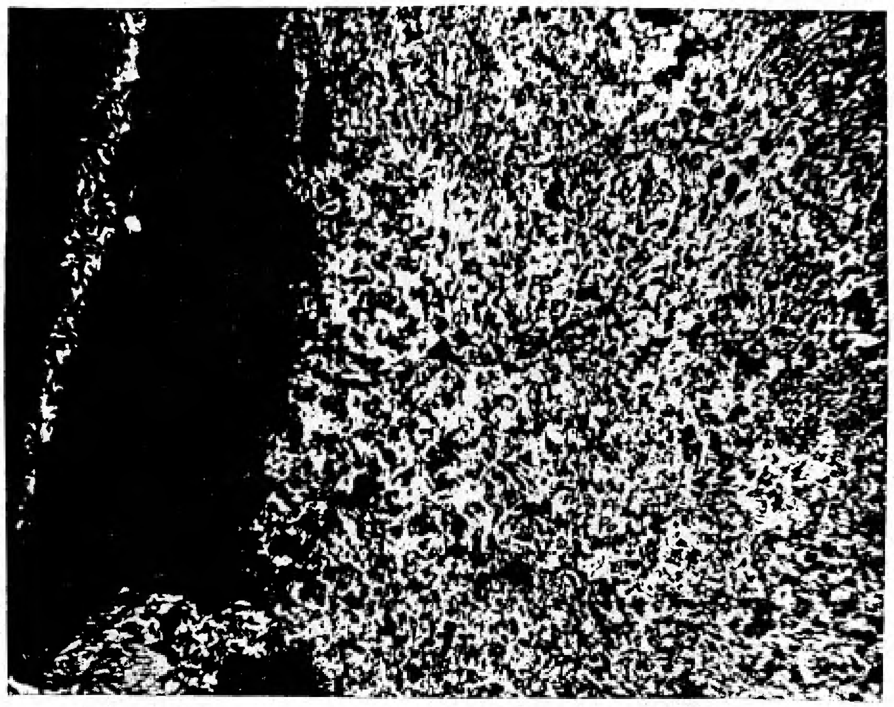


Fig. 2. Mixture of Chalcopyrite (cp) and pyrrhotite (po) veining early quartz (qu). Campbell Chibougamau Mines. (M.C. 53 473). Approx. x55.

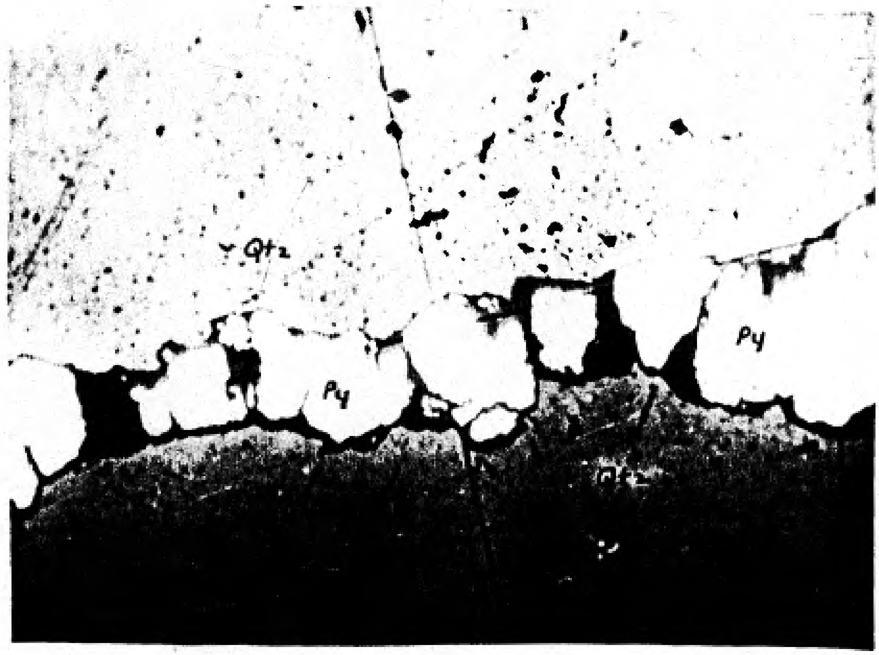


Fig. 3. Pyrite (py) anhedral lying along the grain boundaries in quartz (qu). Campbell Chibougamau Mines (Cedar Bay Zone). Approx. x130.

Fig. 4. Magnetite (mg) replacing early gangue (G). Chalcopyrite (cp) blebs in magnetite (mg). Slight replacement of fibrous gangue and magnetite by chalcopyrite. Mutual textures exists between magnetite (mg) and pyrite (py) at top of the photograph. Quebec Chibougamau Goldfields. A-zone. (CH-28). Approx. x55.

Fig. 5. Subhedral pyrite (py) showing shattering and subsequent filling of fractures by chalcopyrite (cp). Small chalcopyrite (cp) blebs, in pyrite (py) probably represent diffusion texture. Note only slight replacement of pyrite (py) by chalcopyrite (cp) along fractures. Baker Talc (CH-26). Approx. x55.

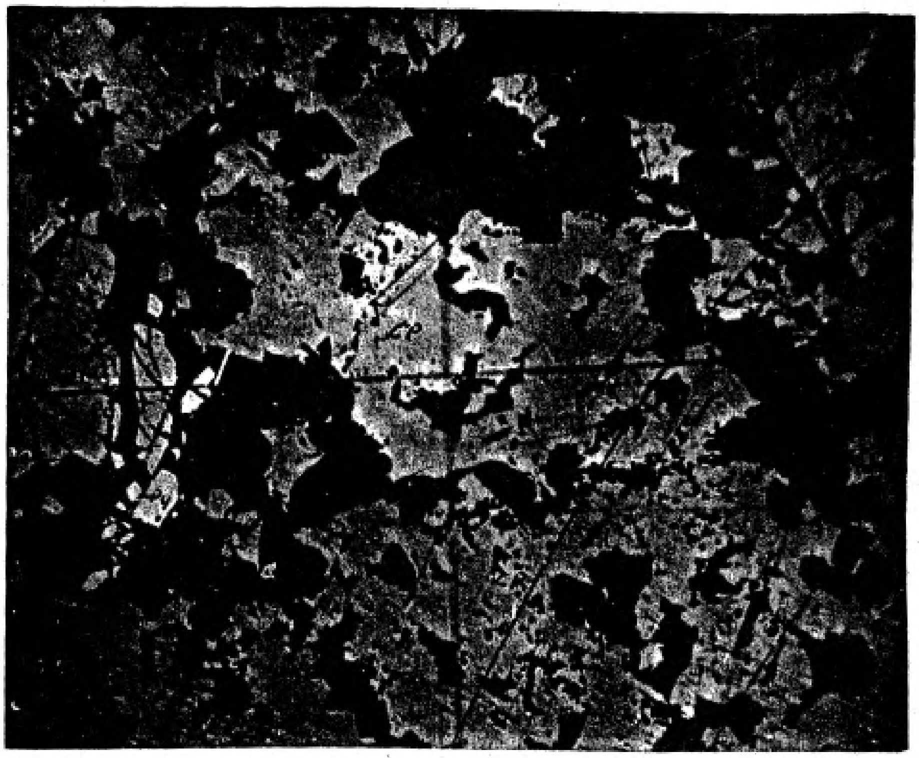


Fig. 6. Pyrite (py) showing fracturing and subsequent replacement by sphalerite (sl) along fractures. Note sphalerite (sl) and chalcopyrite (cp) in typical association. In many places chalcopyrite (cp) deeply embays sphalerite (sl). Bateman Bay Mines C- zone. (CH-33). Approx. x55.

Fig. 7. Siderite (8) is shown, embaying quartz (qu). Remnants of quartz (qu) appear in anhedral pyrite (py). Siderite (sid) probably later than pyrite (py). Baker Talc (CH-26). Approx. x55.

Fig. 8. Sphalerite (sl) replacing siderite (sid) along cleavages. Note blebs of chalcopyrite (cp) in sphalerite (sl). Bateman Bay C— zone. (CH-33). Approx. x130.

Fig. 9. Pyrrhotite (po) and chalcopyrite (cp) veining and replacing pyrite (py) along grain boundaries. Note "atoll" texture in the lower central part of photograph. Embayments of chalcopyrite (cp) in massive pyrrhotite are typical.
Yorcan Exploration-Henderson zone. (CH-54). Approx. x55.

Fig. 10. Pyrrhotite (po) and chalcopyrite (cp) in typical relations. The chalcopyrite (cp) embayments, are numerous, and very deep. Quebec Chibougamau Goldfields. A-zone (CH-13). Approx. x55.

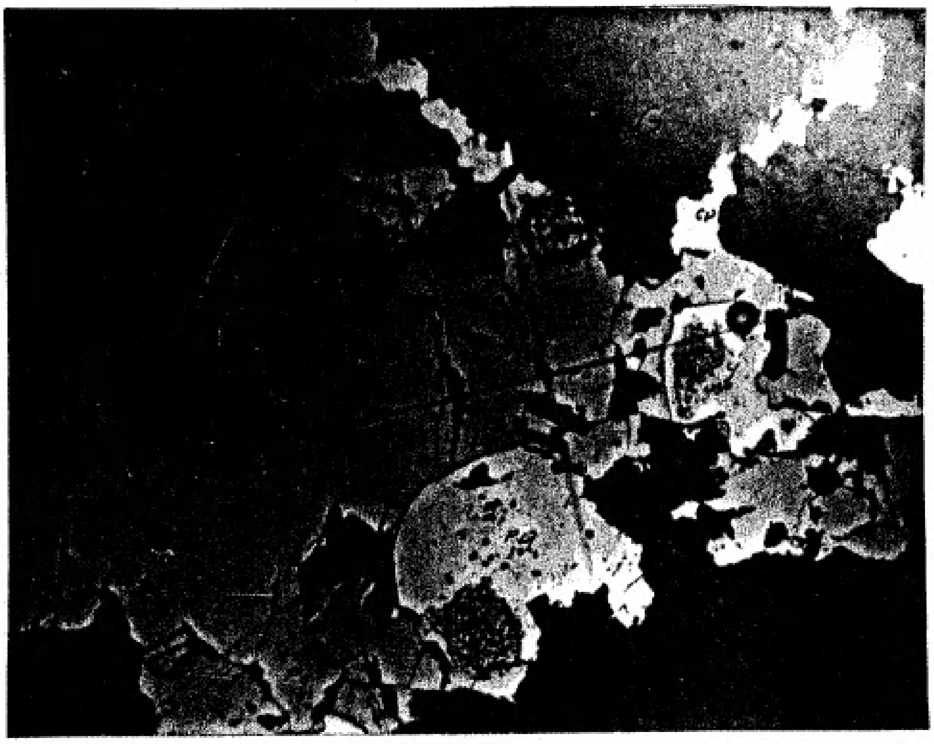


Fig. 11. Subhedral pyrite (py) showing slight replacement of pyrrhotite (po) along grain boundaries. Sphalerite (sl) replacement of pyrrhotite (po) has occurred along train borders. Note remnant of pyrrhotite (po) bleb in sphalerite (sl). Lake Chibougamau Mines - (CH-50) Approx. x130.

Fig. 12. Branching veinlet of pyrrhotite (po) traversing sphalerite (sl). Veinlet of pyrrhotite (po) showed extinctions. Pyrrhotite (po) replaces early fibrous gangue (G). Campbell Chibougamau Mines. (M-9-353-7). Approx. x55.

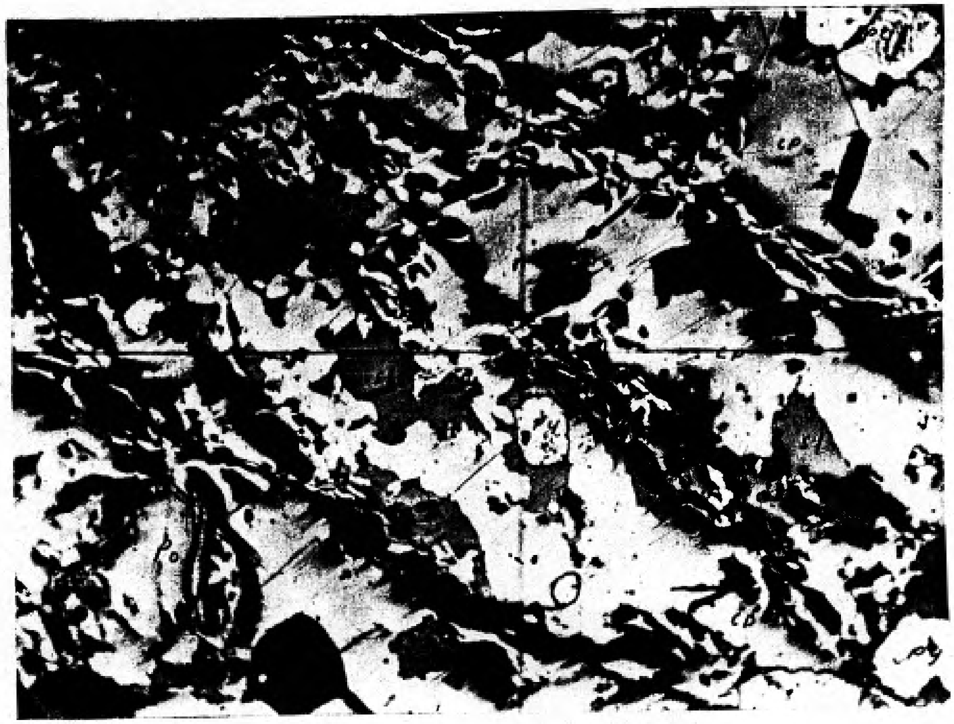


Fig. 13. Chalcopyrite (cp) deeply embaying sphalerite (sl). Campbell Chibougamau Mines. (CCM-10). Approx. x55.

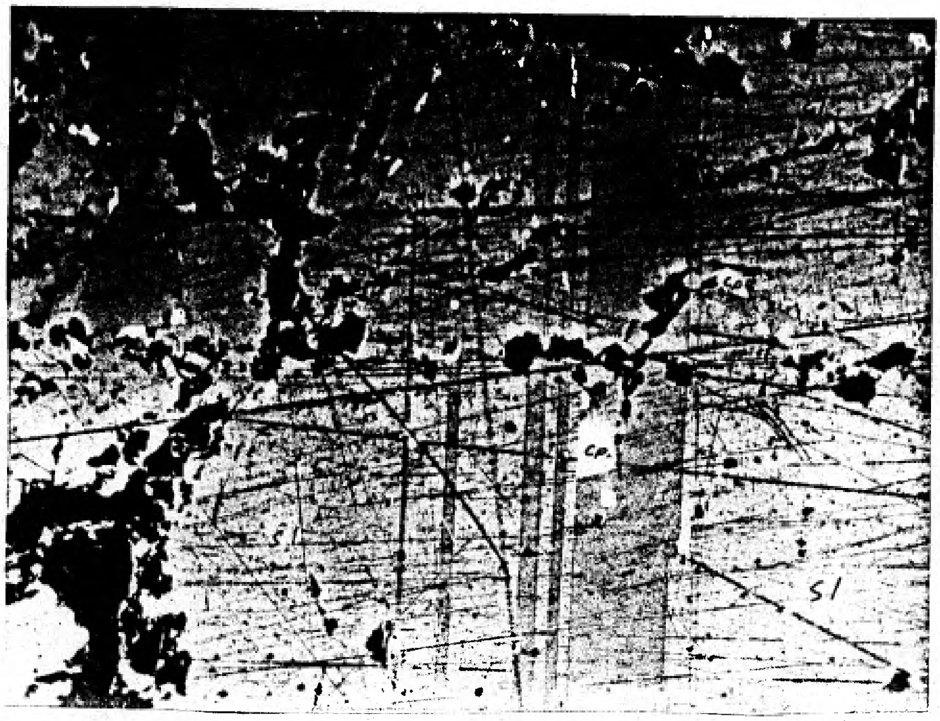


Fig. 14. Oriented blebs of chalcopyrite (cp) along twin lamellae in sphalerite (sl). Merrill Island Corp. (M-30). Approx. x130.

Fig. 15. Incipient veinlets of marcasite (mc) replacing sphalerite (sl) and gangue (G). Marcasite (mc) younger than calcite (cal). Chibougamau Kayrand (CH-10). Approx. x130.

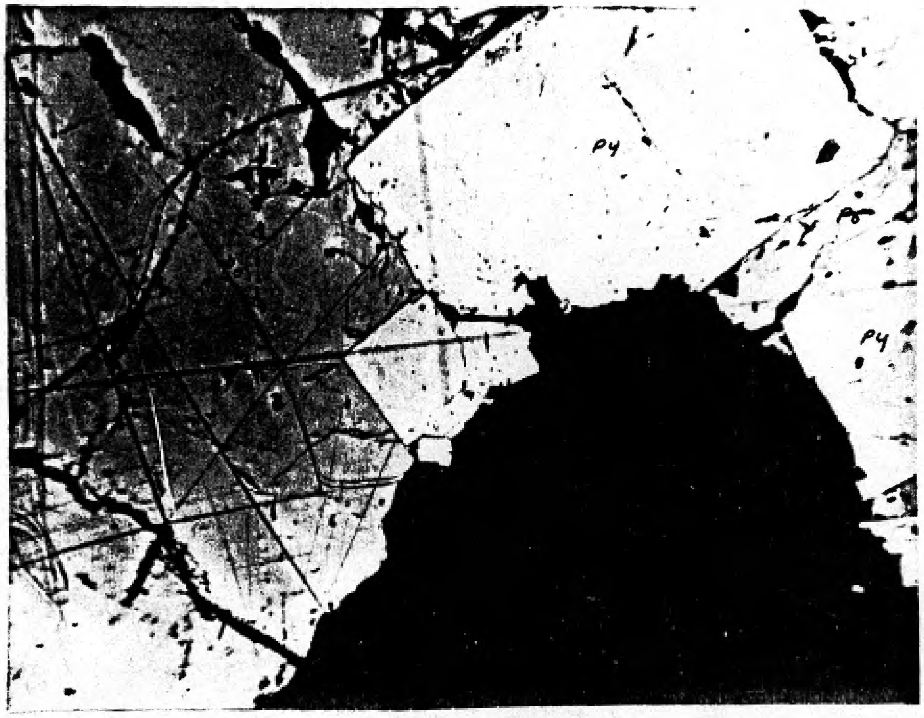
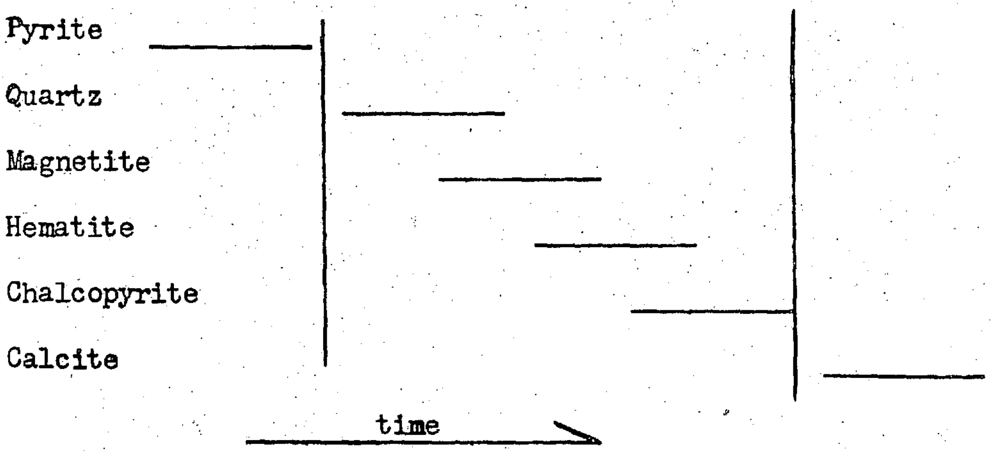


Fig. 16. Euhedral pyrite (py) showing replacement of chalcopyrite (cp) and pyrrhotite (po) along grain boundaries. Late quartz (qu) veins pyrrhotite (po). Lake Chibougamau Mines (CH-48). Approx. x130.

Pyrite-Magnetite-Chalcopyrite Deposit

Diagram 3 - Paragenetic sequence of mineralization of the pyrite-magnetite-chalcopyrite deposit.



Vertical line indicates movement.

Pyrite and chalcopyrite are the most widespread minerals present in the Grandine deposit. Pyrite commonly occurs as subhedral to euhedral grains with chalcopyrite in the brecciated granite. Frequently these minerals are concentrated as stringer ore along fracture planes or occur as disseminations in the wall rock (Graham 1953).

Magnetite and hematite occur as selvages along some of the fracture planes, and as veinlets up to three inches wide in the brecciated zone.

In hand specimens, molybdenite is commonly observed as small flakes lining fracture planes, which traverse the earlier formed minerals.

Pyrite, which appears as subhedral to anhedral grains, is the most abundant mineral in the polished sections. Grains of pyrite are normally fractured and these fractures have guided chalcopyrite, quartz, and hematite replacement and vein filling. The intensity of chalcopyrite replacement of pyrite is low as compared with replacement in the main sulphide deposits (Figure 17). Hematite either embays pyrite or occurs as subhedral grains along fractures in pyrite (Figure 18). Good textural relationships between pyrite and magnetite were lacking. The close association of magnetite to later hematite, and the fact that magnetite has not been fractured suggest that pyrite preceded magnetite in the paragenetic sequence.

Quartz deposition probably followed the fracturing in the pyrite (Figure 17). Evidence for early quartz was not observed in the specimens studied but the possibility of its occurrence is not precluded. Figure 19 clearly shows the textural relationship between quartz and the later iron oxides. This figure shows hematite replacing quartz along grain boundaries, and projection of magnetite needles into the quartz grain. Chalcopyrite either has embayed quartz or occurs as replacement blebs in this early gangue mineral (Figure 17).

Magnetite makes up approximately 15 per cent of the total metallic minerals present, and is noted as pseudomorphic blades or needles after hornblende or actinolite. Chalcopyrite replacement has been guided to a certain extent by needle borders. Remnants of magnetite blades in hematite are relatively common (Figures 20 and 21).

Hematite is observed as well-formed grains in pyrite, but more frequently is seen as irregular masses in the polished sections. Replacement along pyrite boundaries and in fractures in pyrite by hematite is of high intensity in the specimens. Frequently hematite replaces magnetite (Figure 20) and quartz (Figure 19), and is in turn replaced by chalcopyrite (Figures 20 and 21). Hematite is very widespread in the specimens from this pyrite-magnetite-chalcopyrite deposit.

Chalcopyrite is one of the abundant minerals in this suite, and follows hematite in the paragenetic sequence. Chalcopyrite veins and embays pyrite and replaces magnetite, hematite, and quartz quite extensively (Figure 20). Figure 21 illustrates chalcopyrite replacing magnetite needles, pyrite along fractures and hematite along grain boundaries.

Calcite, although not abundant, veins some of the minerals, especially chalcopyrite (Figure 22).

In hand specimens, fractures filled with flakes of molybdenite traverse all the metallic minerals (Graham 1953).

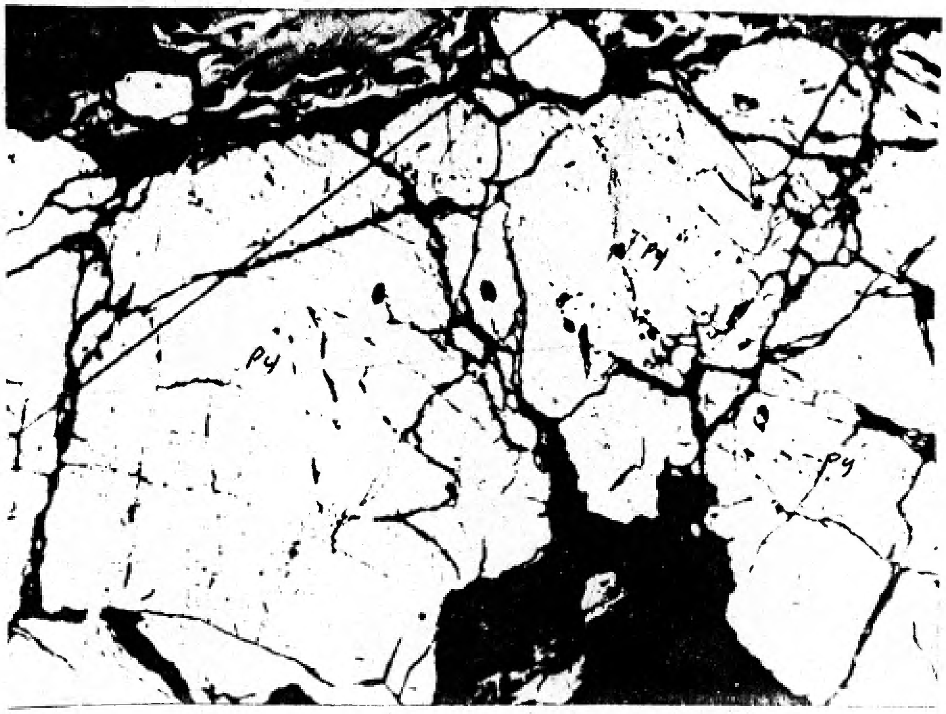


Fig. 17. Massive pyrite (py) showing, fracturing and subsequent filling by quartz (qu) and chalcopyrite (cp). Chalcopyrite (cp) also replacing pyrite (py) along grain boundaries. Note replacement blebs of chalcopyrite (cp) in quartz(qu). Grandine Chibougamau Mines (GM-3). Approx. x130.

Fig. 18. Hematite (hm) replacing anhedral pyrite (py) along grain borders. Note anhedral hematite (hm) along fractures in pyrite (py). Felted magnetite (mg) at top of photograph. Grandine Chibougamau Mines (GM-20). Approx. x130.

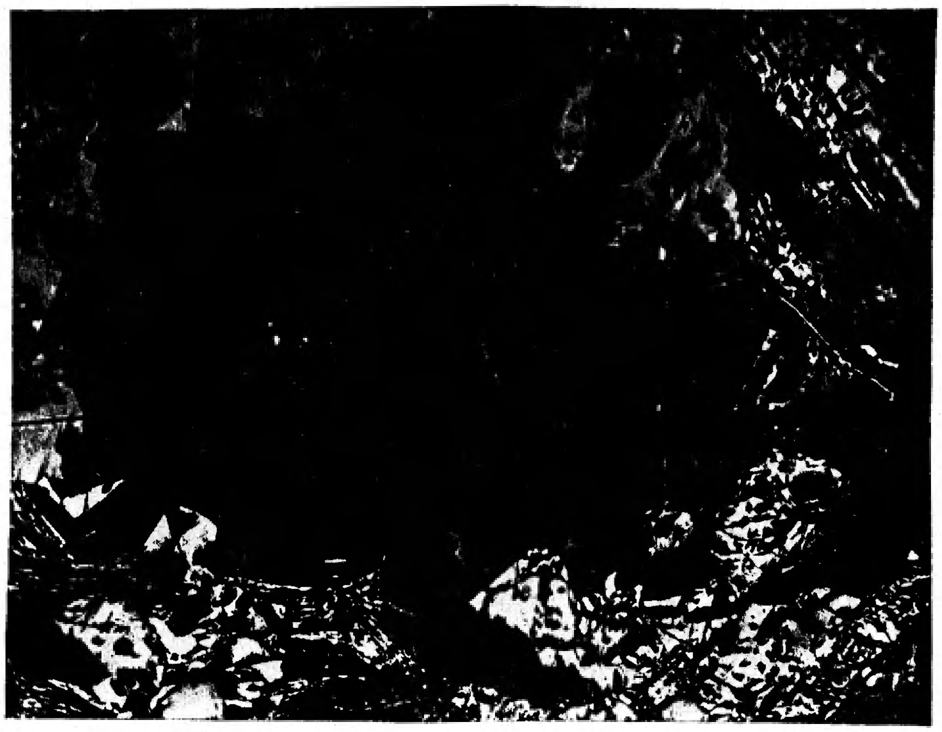


Fig. 19. Blades or needles of magnetite (mg) projects into a quartz (qu) grain. Hematite (hm) replacing quartz (qu) along grain boundaries. Grandine Chibougamau Mines (GM-20). Approx. x130.

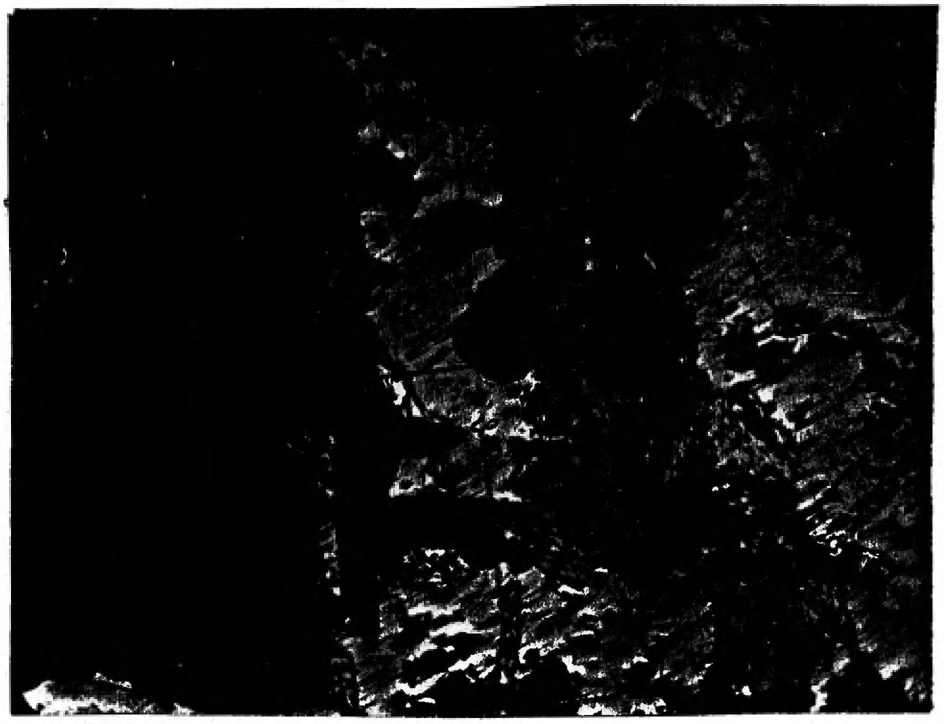


Fig. 20. Chalcopyrite (cp) replacing hematite (hm) along grain boundaries and needles of magnetite (mg). Remnants of magnetite (mg) needles in hematite (hm). Grandine Chibougamau Mines (GM-26). Approx. x130.

Fig. 21. Chalcopyrite (cp) replacing anhedral pyrite (py), hematite (hm) and magnetite (mg). Note remnants of magnetite (mg) needles in hematite (hm). Grandine Chibougamau Mines (GM-7). Approx. x55.

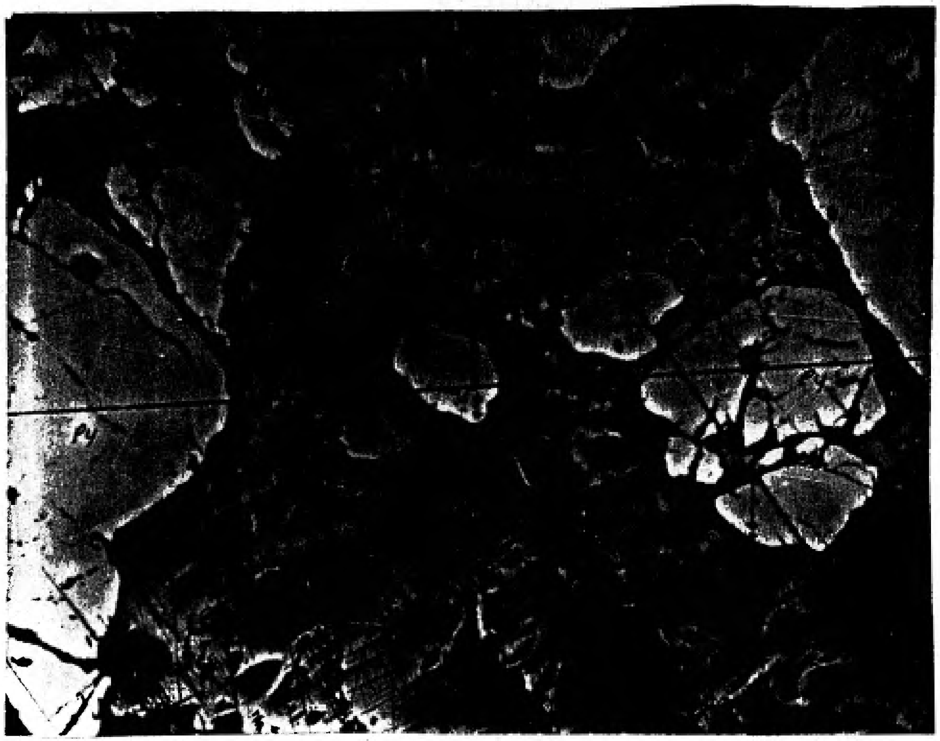
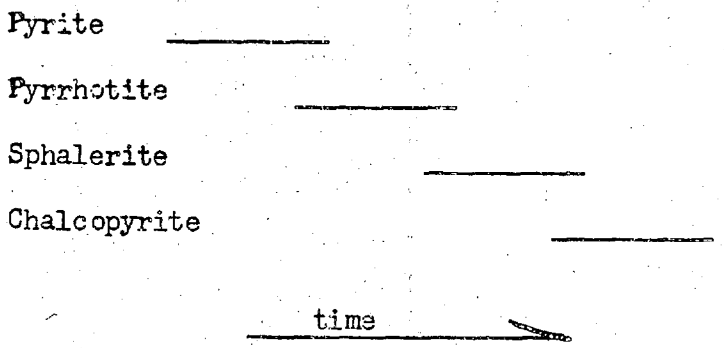


Fig. 22. Calcite (cal) veins chalcopyrite (cp). Light mineral pyrite (py). Grandine Chibougamau Mines (GM-3). Approx. x130.

Pyrrhotite-Chalcopyrite Deposits

Diagram 4 - Paragenetic sequence of mineralization of the pyrrhotite-chalcopyrite deposits.



The mineralized zones at Belle Chibougamau consist of fine-grained massive pyrrhotite, which has been cut by chalcopyrite veinlets (Graham 1953). Pyrite is only locally present, occurring as euhedral to subhedral crystals. In the main showing, sphalerite was usually noted as fine grains in pyrrhotite.

Pyrite was observed as a few slightly corroded euhedral grains in pyrrhotite in one specimen from Belle Chibougamau mines.

Pyrrhotite which followed the minor pyrite deposition is the most abundant mineral present in the polished sections. Pyrrhotite in general preserves the original wall rock texture and corrodes euhedral pyrite grains. Sphalerite replacement of pyrrhotite has been controlled by grain boundaries. Frequently, pyrrhotite remnants showing relict texture are enclosed in massive sphalerite. This textural feature indicates the age relationship between these two minerals. Chalcopyrite has selectively replaced pyrrhotite by embayment in the two polished sections studied - see Figures 23 and 24.

Sphalerite deposition closely overlaps the pyrrhotite phases in the specimens. Sphalerite has replaced pyrrhotite along grain boundaries, and has been replaced in turn by chalcopyrite. Deep embayments by chalcopyrite are characteristic of the preceding replacement (Figure 24). Zinc sulphide makes up approximately 20 per cent of the total sulphides present.

Chalcopyrite is fairly abundant in the specimens and has replaced both pyrrhotite and sphalerite.

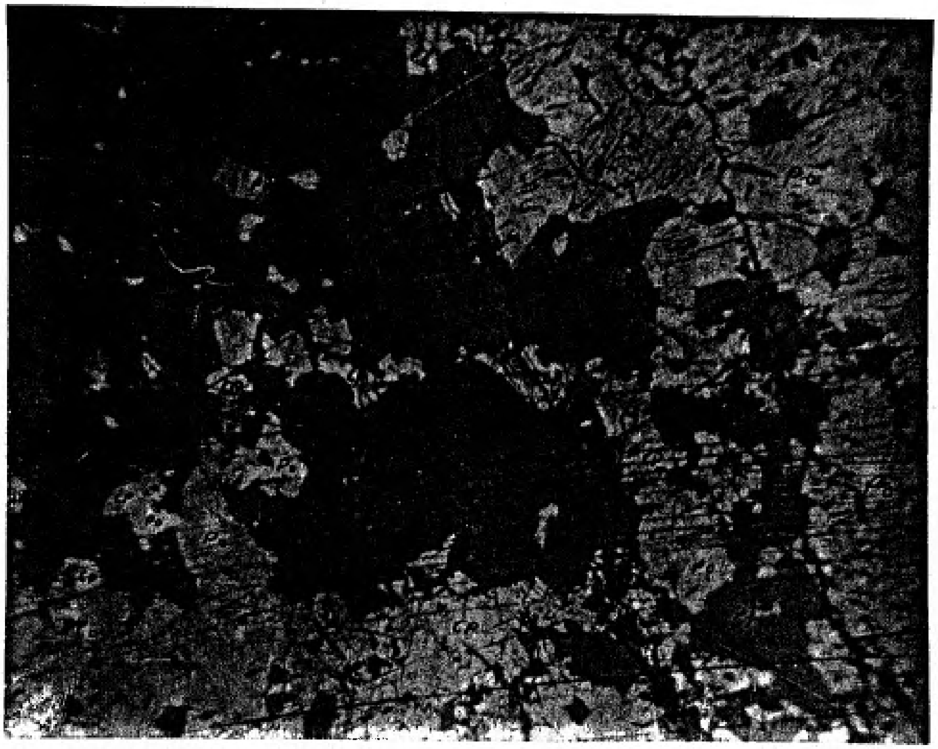


Fig. 23. Pyrrhotite (po) and sphalerite (sl) in typical relations. Remnants of pyrrhotite (po) with well preserved original rock texture occurring in massive sphalerite (sl). Chalcopyrite (cp) replacing both the above minerals. Limonite (li) veinlets traversing all the sulphides. Bell Chibougamau Mines (CH-32). Approx. x130.

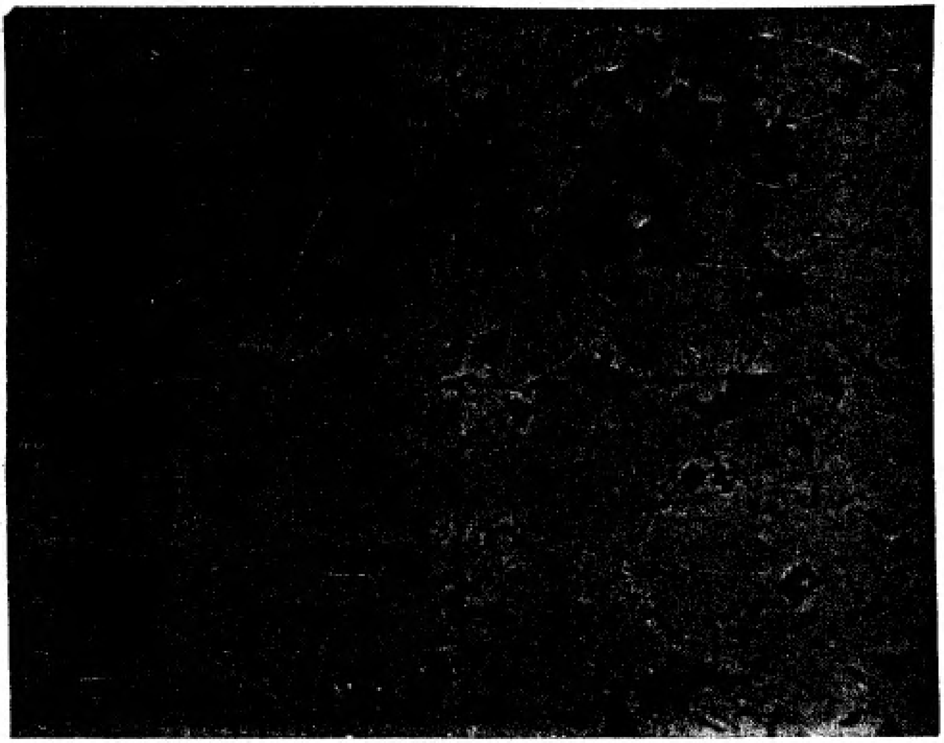
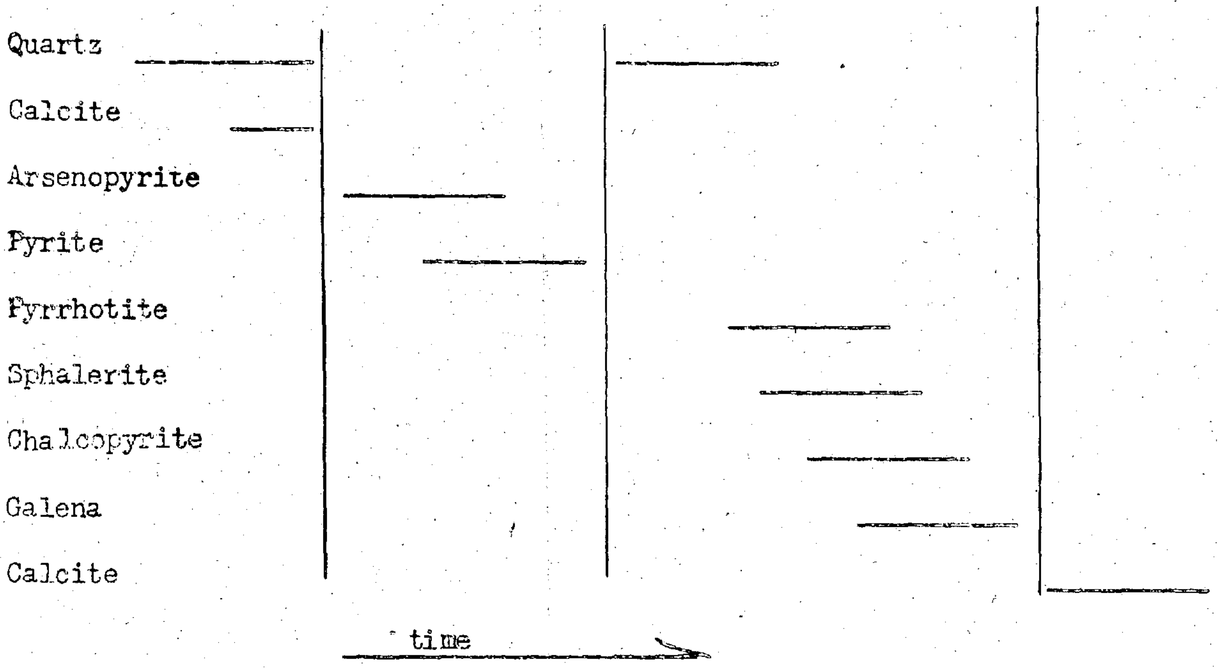


Fig. 24. Chalcopyrite (cp) replacing sphalerite (sl). Bell Chibougamau Mines (CH-32). Approx. x130.

Arsenopyrite-Pyrrhotite-Sphalerite Deposits

Diagram 5 - Paragenetic sequence of mineralization of the arsenopyrite-pyrrhotite-sphalerite deposits.



Vertical lines indicate movement.

The important mineral assemblage is pyrrhotite and sphalerite which makes up approximately 60 per cent of the total sulphides in the Tache Lake deposits. Arsenopyrite is very widespread but has only been reported from the north zone of mineralization. Pyrite is not abundant, and galena occurs only in minor amounts in the mineralized zones. Chalcopyrite is not uncommon and appears to contain gold in the crystal structure (Smith 1953). All the sulphides have selectively replaced cherty quartz, which is thought by Smith (1953) to be the first mineral to crystallize. Early "rusty calcite" has been described from the mineralized zones, and a later period of calcite crystallisation followed the deposition of the sulphides (Smith 1953). Marcasite and a possible second generation of sphalerite were noted in polished sections.

Quartz is the earliest phase of mineral deposition. Quartz crystallization probably extended over the pyrite and arsenopyrite phase. Small embayments of arsenopyrite, in quartz, indicate the age relationship of these two minerals (Figure 25). However, in Figure 29, quartz appears to vein arsenopyrite, and matching of opposite walls of the quartz veinlets in arsenopyrite suggests vein filling. It is possible that these "veinlets" represent remnants in the metallic mineral. The later sulphides, sphalerite (Figure 29) and pyrrhotite, have embayed quartz quite extensively in the specimens.

Calcite followed early quartz as evidence by field relationships and hand specimens (Smith 1953).

The first metallic mineral to crystallize is arsenopyrite, which is quite abundant in the polished sections. Arsenopyrite is in general observed as subhedral to anhedral grains in the sulphides. Quartz inclusions in arsenopyrite indicate that arsenopyrite follows quartz, and other gangue minerals in the paragenetic sequence. All the sulphides (pyrrhotite, galena, sphalerite and less frequently chalcopyrite) have extensively replaced arsenopyrite either along fractures or along grain boundaries. Pyrite-arsenopyrite relationships were observed in several polished sections. A pyrite replacement vein (Figure 27), and grains of pyrite at the junction of several arsenopyrite crystals (Figure 28) show that arsenopyrite preceded pyrite in the paragenetic sequence.

Pyrite makes up approximately 5-10 per cent of the total metallic minerals present, and is commonly observed as fractured subhedral to anhedral grains. Pyrite is clearly embayed and veined by sphalerite (Figure 27), galena, and to a minor degree, by chalcopyrite and pyrrhotite.

Pyrrhotite deposition took place after a period of fracturing in arsenopyrite and pyrite. Pyrrhotite, which is usually massive, is one of the most abundant minerals present in the suite of sections. The three sulphides, pyrrhotite, sphalerite and chalcopyrite are closely associated in the specimens, and extensive overlapping of these crystallization phases is postulated. Mutual textures between sphalerite and pyrrhotite are not uncommon, as evidenced by straight contacts between these minerals (Figure 30). However, slightly embayed remnants of pyrrhotite, which were observed in sphalerite (Figure 32) indicate the position of these two minerals in the paragenetic sequence. Chalcopyrite replacement is decidedly later and has occurred along pyrrhotite grain borders (Figure 33 and Figure 31). Remnants of pyrrhotite in chalcopyrite are not frequent (Figure 32).

Sphalerite closely followed the pyrrhotite deposition, and is the second most abundant mineral in the specimens. It is commonly twinned, and oriented chalcopyrite inclusions are located along twin lamellae. Figure 34 shows blebs of chalcopyrite along twin lamellae and along grain boundaries in randomly oriented sphalerite grains. Less frequently, chalcopyrite embays sphalerite along grain borders.

Chalcopyrite is usually closely associated with pyrrhotite and sphalerite. Textural relations indicate a minor overlapping of chalcopyrite with the other sulphides. Chalcopyrite makes up a small percentage of the total sulphides.

Galena is very widespread and is frequently observed as irregular masses which commonly show convex borders towards the sulphides. Galena replaces all earlier minerals by veining and embayment. Rarely, irregular masses of galena occur in chalcopyrite replacing that earlier copper sulphide. Blebs of sphalerite, which are relatively abundant in massive galena have been interpreted as remnants (Figure 30). Cubic cleavage is developed in a few specimens. The triangular pits did not show evidence of being deformed by external forces.

Calcite, which follows a period of fracturing, veins most of the sulphides (Figure 35).

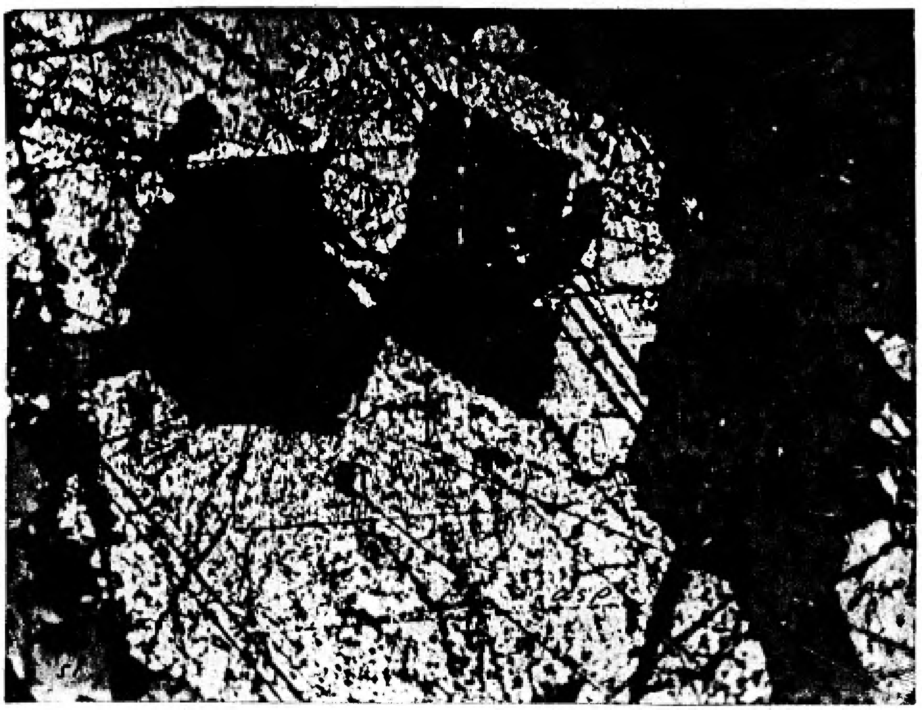


Fig. 25. Arsenopyrite (asp) with numerous inclusions replacing early quartz (qu). Sphalerite (sl) veining arsenopyrite (asp). Tache Lake Mines (T.L.M.-22). Approx. x130.

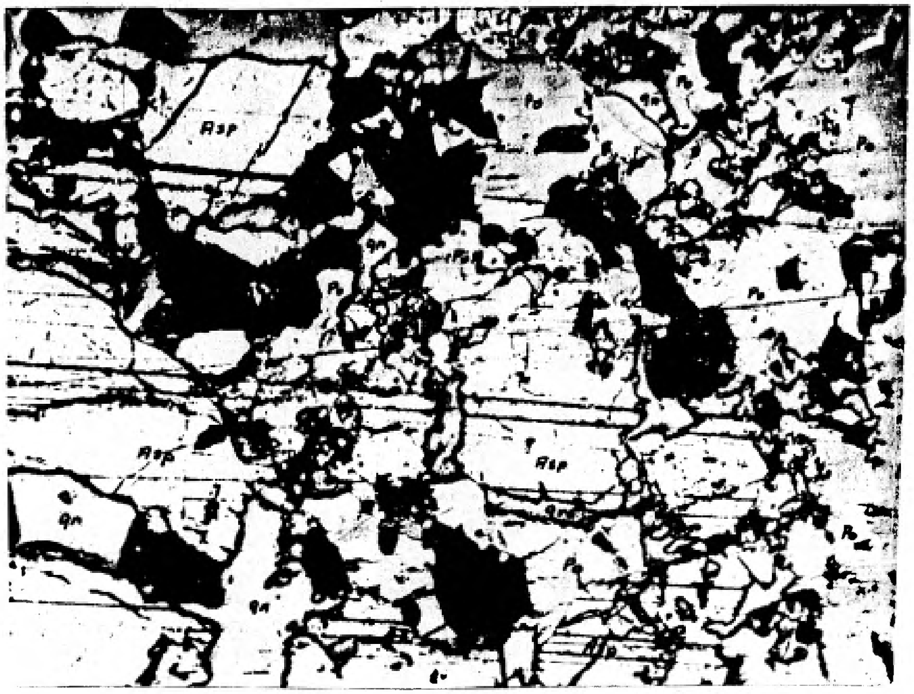


Fig. 26. Replacement veins of galena (gn) and pyrrhotite (po) guided by fractures in arsenopyrite (asp). Tache Lake Mines (T.L.M. 16). Approx. x55.

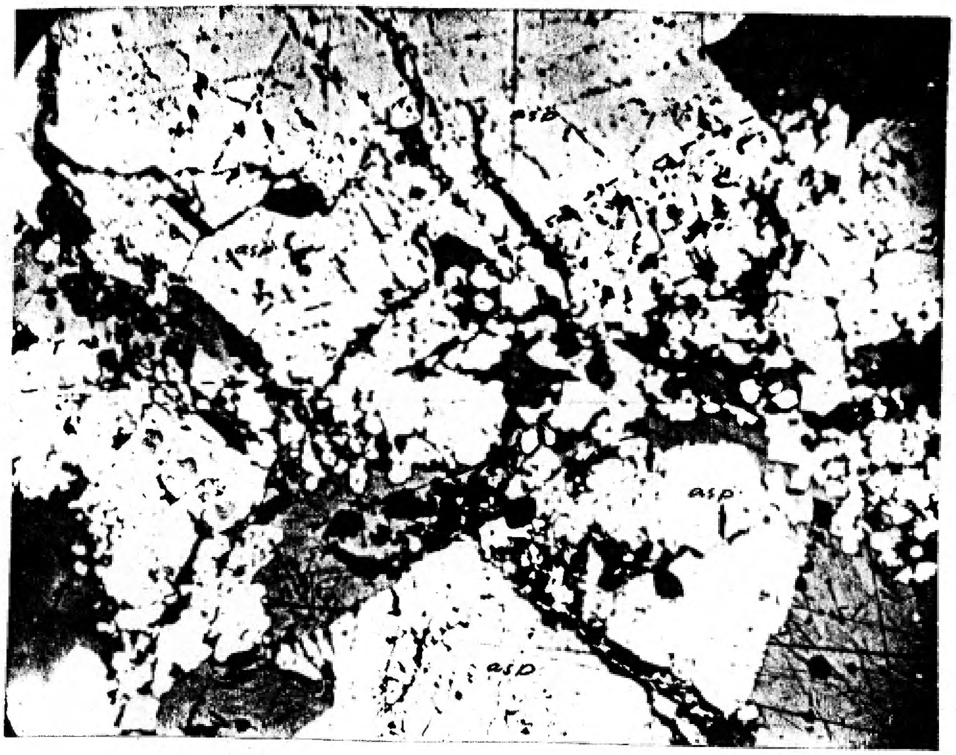


Fig. 27. Vein of pyrite (py) traversing arsenopyrite (asp) grains. Sphalerite (sl) veining and replacing both minerals. Tache Lake Mines (T.L.M. -2). Approx. x55.

Fig. 28. Grains of pyrite (py) at the junctions of several arsenopyrite (asp) crystals. Tache Lake Mines (T.L.M. -2). Approx. x130.

Fig. 29. Quartz (qu) filling fractures in arsenopyrite (asp). The matching of apposite walls of the veinlets indicate fracturing filling. Sphalerite (sl) embaying quartz (qu) and replacing arsenopyrite (asp). Tache Lake Mines. (T.L.M.-S.27). Approx. x130.

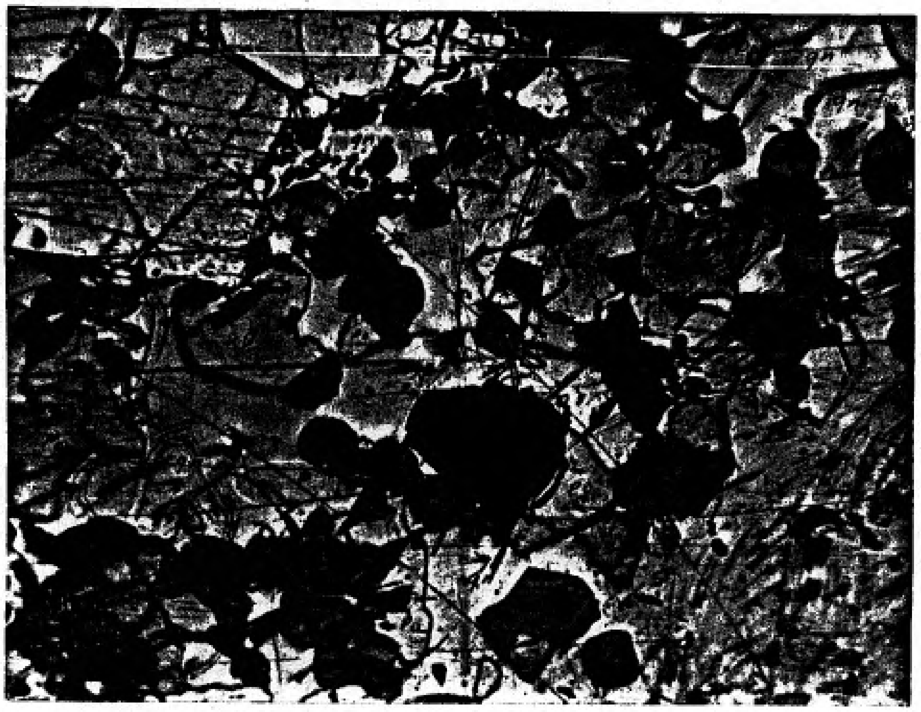


Fig. 30. Irregular shaped blebs of sphalerite (sl) and pyrrhotite (po) in galena (gn). Sphalerite (sl) and pyrrhotite (po) showing mutual textures. Galena (gn) replacing the two above minerals and veining arsenopyrite (asp). Tache Lake Mines (T.L.M. -16). Approx. x55.

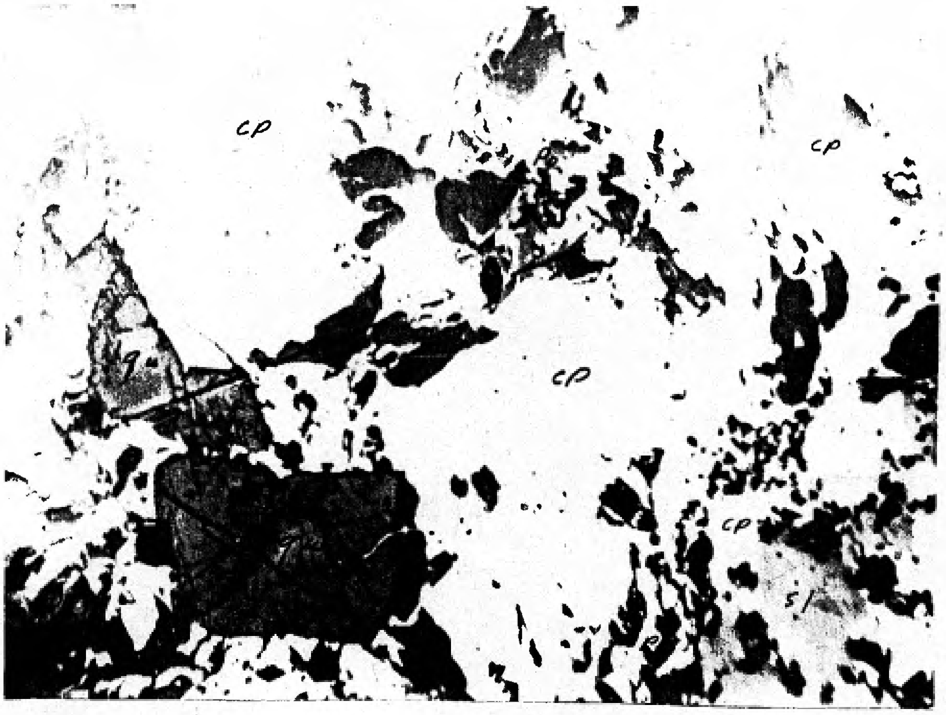


Fig. 31. Sphalerite (sl) and pyrrhotite (po) replaced by chalcopyrite (sp) by embayment. Early quartz (qu) showing corrosion by chalcopyrite (cp). Tache Lake Mines (T.L.M. A-37). Approx. x130.

Fig. 32. Remnants of pyrrhotite (po) in sphalerite (sl). Tache Lake Mines (T.L.M. 16). Approx. x55.

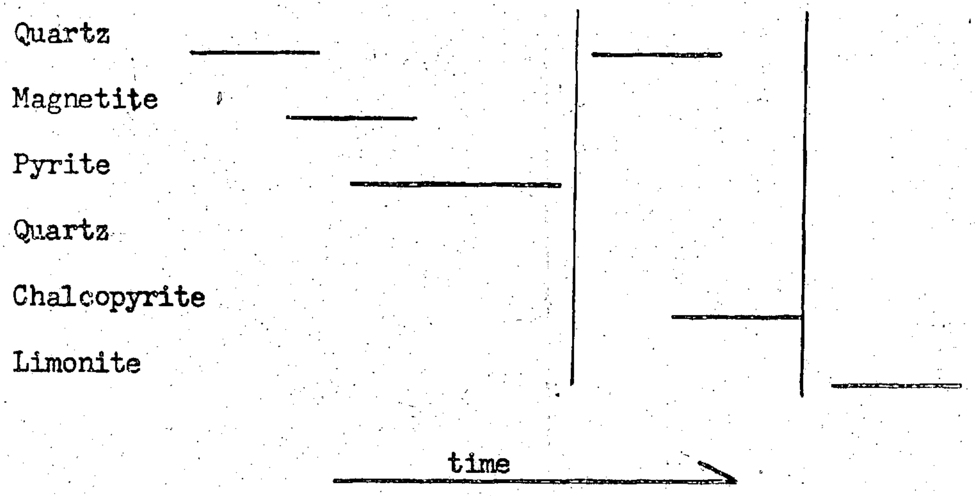
Fig. 33. Chalcopyrite (cp) and pyrrhotite (po) in typical relations. Sphalerite (sl) replaced by chalcopyrite (cp). Tache Lake Mines (T.L.M. -A37). Approx. x130.

Fig. 34. Twinned sphalerite (sl) illustrating blebs of later chalcopyrite (cp) along twin lamellae. Arsenopyrite (asp) and pyrrhotite (po) replaced by sphalerite (sl). Note blebs of galena (gn) in sphalerite (sl). Tache Lake Mines (T.L.M. -16). Approx. x130.

Fig. 35. Calcite (cal) veining galena (gn) and pyrite (py). Tache Lake Mines (T.L.M. -2). Approx. x130.

Gold-Quartz Veins

Diagram 6 - Paragenetic sequence of mineralization of the Obalski gold-quartz vein.



Vertical lines indicate movement.

Mineralogy and Textural Relationships

The quartz in the Obalski Gold-quartz veins is usually milky in appearance and commonly contains numerous vugs (Graham 1956). Pyrite commonly occurs along fractures in quartz, and in lenses and stringers associated with chalcopyrite. Sphalerite, magnetite, pyrrhotite, and gold have been reported from this deposit.

Quartz, which is the most abundant mineral, began crystallizing before pyrite, and probably the period of its deposition overlaps the pyrite phase. Small pyrite grains are aligned along quartz boundaries indicating the usual age relationship between these two minerals. Probably a small percentage of quartz was deposited after pyrite as evidenced by veinlets of quartz in pyrite (Figure 36). Chalcopyrite replaces quartz to a slight degree (Figure 38).

Magnetite was frequently observed as irregular masses, or more rarely as large subhedral grains. Anhedral pyrite grains against subhedral magnetite suggest that magnetite is older. Chalcopyrite replacement of magnetite is slight. See Figure 37.

Pyrite is the most abundant metallic mineral present, usually occurring as subhedral to anhedral grains. Pyrite is fractured in some cases, and contains inclusions of quartz. This is especially so of pyrite found in the wall rock. Pyrite has followed part of the quartz deposition of magnetite. It has in turn been slightly replaced by chalcopyrite along grain boundaries - see Figure 38.

Sphalerite was observed as a few small blebs, but textural relationships between sphalerite and the other minerals were lacking.

The chalcopyrite replacement of quartz, magnetite and pyrite is not extensive. Chalcopyrite replaces pyrite and corrodes quartz (Figure 38). Chalcopyrite makes up approximately 5 per cent of the total minerals.

The writer did not observe gold, but it has been reported along fractures in pyrite and quartz by Allard (1953).

Fig. 36. Quartz (qu) veins and surrounds subhedral pyrite (py). Obalski gold quartz vein (1280 B). Approx. x130.

Fig. 37. Magnetite (mg) subhedral and pyrite (py) anhedral showing mutual texture. Probably better crystallized (magnetite) is older. Note chalcopyrite (cp), replacing gangue (G) Quartz (qu) dark grey mineral. Obalski gold quartz vein (1283 B). Approx. x130.

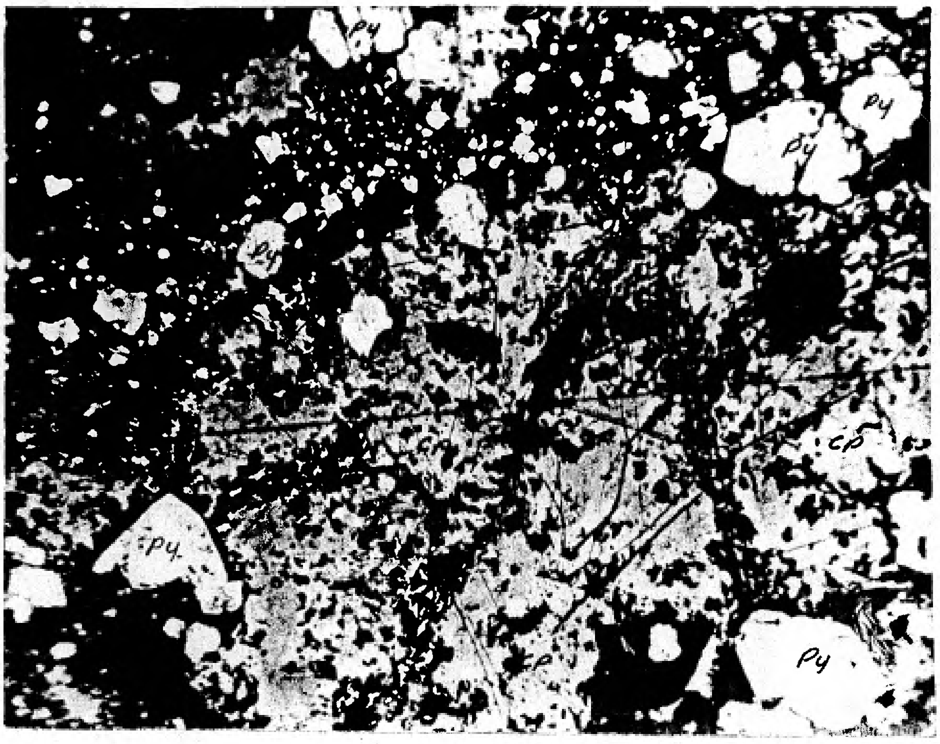


Fig. 38. Quartz (qu) and pyrite (py) slightly replaced by chalcopyrite (cp). Obalski Gold quartz vein (1280 B). Approx. x55.

ORIGIN OF THE DEPOSITS

The pyrite-pyrrhotite-chalcopyrite deposits have been formed at moderate temperatures and pressures and are classified by the writer as high intensity mesothermal or low intensity hypothermal deposits. The deposits are believed to be genetically related to the Chibougamau granite batholith which lies south of Dore Lake. Graham (1956) states:

> "The assemblage of albite, oligoclase, quartz, and chlorite that is so closely associated with the sulphide mineralization is basically the same as that which comprises the granite, gray fine-grained quartz diorite dikes, and grey feldspar porphyry dikes. This strongly suggests that they all have a common origin which can most conveniently be referred to the granite underlying the southern part of Dore Lake and most of Chibougamau Lake".

Whether or not this is a plausible suggestion as to the origin of the deposits is somewhat debatable. The writer postulates that the pyrite-pyrrhotite-chalcopyrite deposits are the oldest deposits associated with the Chibougamau granite batholith. The other two types, the arsenopyrite-pyrrhotite-sphalerite deposits, and the gold-quartz veins are believed to be younger.

The pyrite-magnetite-chalcopyrite deposit is unique in that the minerals are believed to represent the highest intensity phase of deposition in this district. Magnetite, hematite, and chalcopyrite are the abundant high temperature minerals. Minor amounts of molybdenite crystallized at a later stage (Graham 1956). A small showing with similar high temperature minerals has been described by Mawdsley and Norman (1935) in sheared Grandine granite along the northwest side of Portage Island. It is here concluded that these high intensity mineral deposits are genetically related to the Grandine granite plug.

The pyrrhotite-chalcopyrite deposits which occur either in slightly sheared siliceous tuffs or transverse faulted basic to ultrabasic intrusives differ in many respects from the pyrite-pyrrhotite-chalcopyrite group. Pyrite is either lacking or minor in amount, whereas calcite, siderite, and quartz are completely absent in these deposits. The field relations suggest that the pyrrhotite-chalcopyrite mineralized zones are genetically related to the gabbro-pyroxenite sills. The basic to ultrabasic sills are exposed near the mineralized showings, and the mineralization appears to decrease away from the immediate gabbro-tuff contact. The origin of the mineralized shear zones in ultrabasic intrusive rocks is not evident. The shearing is of small magnitude, and the mineralization closely corresponds to the mineral assemblage in the siliceous tuffs.

The arsenopyrite-pyrrhotite-sphalerite deposits are somewhat unusual in that considerable amounts of arsenopyrite are present. Only two other mineralized zones in the Chibougamau region, the northwest-striking arsenopyrite shear zone in the Opemiska mines and the Norbeau gold-quartz vein on the Noranda property, contain considerable amounts of arsenopyrite. These three mineral occurrences are located near the assumed Gwillim-Campbell Lake fault, and it is possible that the sulphide solutions from the Chibougamau granite batholith permeated along the fault zone (Allard 1953). The arsenopyrite shear zone which strikes north-west has offset the No. 1 and No. 2 sulphide zones in the Opemiska Copper Mine workings. The mineralized shear zone has been traced for 500 feet on surface with a left hand displacement of 50 to 100 feet (Archibald unpublished). This strongly suggests that the arsenopyrite mineralization has followed the main sulphide deposition.

Since the arsenopyrite mineralization is definitely later than the main sulphide stage in the Opemiska mine workings, the arsenopyrite and associated deposition in the Norbeau gold-quartz vein is also believed to be later. Allard (1953) carried out spectrographic studies on pyrite samples from the Obalski gold-quartz showings, and concluded that the pyrite contained very minor amounts of cobalt. Since the main sulphide zones in the Dore and Chibougamau Lakes areas contain cobaltiferous pyrite, it would appear that the Obalski gold-quartz veins and the massive sulphide zones were not deposited in the same period of seposition. Secondly, native gold has only been reported from the gold-quartz veins and the Opemiska arsenopyrite shear zone, but gold is believed to occur as submicroscopic masses in chalcopyrite and less commonly so in pyrite and pyrrhotite in the main sulphide deposits (Allard 1953). Native gold which occurs late in the paragenetic sequence has been reported by Allard (1953) from the Obalski gold-quartz veins, by Carmichael (1940) and Norman and Mawdsley (1953) from the Norbeau gold-quartz veins. Very little is known of the McKenzie quartz vein and the Lac Fleury vein, but it is thought that these two also represent a late period of gold deposition. The source of the hydrothermal solution was probably the granite batholith in the Dore Lake area.

CONCLUSIONS

It is probable that the deposits were formed under uniform high temperatures and pressures and as with most other Pre-cambrian deposits, hypogene zoning is not evident. Norman and Mawdsley (1935) and calculated the thickness of the remnants of the Chibougamau sedimentary series, which are believed to be upper Huronian in age, to be in excess of 3400 feet. These probably represent the lower members of the Huronian series, whereas the upper dolomites which outcrop around Mistassini Lake have probably been eroded. The sedimentary cover at the time of mineral deposition would greatly exceed 3400 feet, and would conceivably range up to tens of thousands of feet. With such a great depth of burial, the deposits should be classified as high mesothermal or hypothermal. From the mineralogical evidence, most of the deposits would be classified as high intensity deposits, with the probably exception of the gold-quartz veins.

The gold-quartz veins, as based on Lindgren's classification would be lower intensity type. The reasons suggesting that the deposits are lower intensity are as follows:

1. Decrease of gold tenors at depth.
2. The quartz is milky, a low temperature variety, containing numerous vugs. This is commonly observed in the Obalski gold-quartz veins, where large vugs up to three feet in diameter have been reported by Graham (1956). These cavities are commonly lined with milky quartz crystals. Carmichael (1940) described the quartz veins at Norbeau Mines as showing banding or crustification. The edges of the quartz veins contain numerous fragments of wall rock.

3. Gold appears to have crystallized last and consequently would be of the lowest intensity. Carmichael (1940) and Norman and Mawdsley (1935) clearly stated that gold is the latest mineral to crystallize in the Norbeau mines. Gold commonly lies along fractures in the arsenopyrite, but less commonly it occurs in quartz.

J.B. Mawdsley (1938) stated that gold was the last mineral to be introduced in the arsenopyrite shear zone at the Opemiska Mines. Noble (1951) at the Homestake Mines stated that the gold was the youngest mineral there, but he suggested that gold might have remained in solution and did not crystallize until conditions were favorable. Mawdsley (1938) described examples of gold deposits in Canada where the gold was one of the last minerals to be deposited. He says:

> "Distinctly late gold raises the question of the soundness of classifying many gold deposits on the basis of their associated vein minerals."

The writer postulates three major surges of hydrothermal solutions from the Chibougamau batholith at different times. The first two are of high intensity, whereas the third represents lower intensity. The pyrite-pyrrhotite-chalcopyrite type which is commonly associated with the anorthosite and near the McKenzie Narrows fault is believed to be the oldest. The pyrite of this assemblage contains cobalt and this is diagnostic of the deposits. The arsenopyrite deposits in the western part of the district lie near the assumed Gwillim-Bachelor Lakes fault. ~~The hydrothermal~~ solutions probably moved along the fault crystallizing in dilation zones (Allard 1953). The evidence at the Opemiska Mine, which is 20 miles west of Chibougamau townsite is clear. A shear zone which is mineralized with quartz, arsenopyrite, pyrite, sphalerite, galena, specularite, and gold (Allard 1953) offsets the main sulphide zones. It is assumed that the other arsenopyrite mineralization in the area is also younger than the pyrite-pyrrhotite-chalcopyrite deposition. At the Tache Lake Mines deposits, the later sulphides have selectively replaced early quartz, and this replacement appears to be the controlling factor in the deposition.

The relation of the gold-quartz veins is in doubt, but they are thought to be younger than the other deposits. Allard (1953) decided that the pyrite in the Obalski gold-quartz veins contained very minor amounts of cobalt and consequently differ from the pyrite in the main sulphide deposits. Spectrographic studies of pyrite from the other gold-quartz veins have not been attempted, but it is concluded that the two different types of deposits originated from different hydrothermal solutions. From the evidence cited previously, it appears that the gold-quartz veins are of lower intensity, and sould crystallize after the pyrite-pyrrhotite-chalcopyrite and possibly after the arsenopyrite-pyrrhotite-sphalerite mineralizations.

The paragenetic sequence of the different types of deposits can be correlated and all illustrate the so-called normal sequence with the possible exception of the pyrite-magnetite-chalcopyrite deposit. This sequence will be discussed later. Bandy (1940), Newhouse (1928), Butler and Burbank (1929), and Gilbert (1924) have concluded the normal sequence to be as follows:

1. Iron oxides.
2. Arsenic, iron, cobalt, nickel, sulphides.
3. Sulphides of zinc, copper, and lead.
4. Sulfo-salts of copper.

5. Sulfo-salts of silver.
6. Native elements.

In the Chibougamau district, magnetite, arsenopyrite, and quartz (early or later than pyrite) are the minerals which have crystallized first.

Following a period of fracturing which is represented in most polished sections, pyrrhotite, sphalerite, and chalcopyrite were deposited. Chalcopyrite is definitely later than sphalerite and pyrrhotite in the three types of deposits containing these minerals. The age relationships between pyrrhotite and sphalerite indicate extensive overlapping. Sphalerite is definitely later than pyrrhotite in the pyrrhotite-chalcopyrite deposits. Figure 24 shows blebs of pyrrhotite containing relict texture in massive sphalerite. Pyrrhotite is usually replaced by sphalerite in the Tache Lake deposits. Evidence in the other polished sections from the pyrite-pyrrhotite-chalcopyrite deposits point to an earlier age of pyrrhotite. However, in Figure 12, veinlets of pyrrhotite cut sphalerite. The pyrrhotite in the veins shows random extinctions, and the writer believes this suggests an early age of sphalerite in this section. Allard (1953) and Graham (1956) have given the paragenetic sequence as being pyrite, pyrrhotite, chalcopyrite, and sphalerite, but the writer concludes that the pyrrhotite and sphalerite are nearly contemporaneous, and chalcopyrite is later.

Galena is undoubtedly later in both the Tache Lake Mines deposits and in the Quebec Chibougamau gold field (Merrill Island deposit).

Gold was probably the latest metallic mineral to crystallize (Allard 1953) and (Mawdsley and Norman 1935).

Late quartz and calcite were the latest gangue minerals to form.

Marcasite only occurs locally and represent low temperature of formation. Marcasite was observed in two polished sections where it veins sphalerite and appears to be younger than calcite (Figure 15).

The paragenetic sequence of the pyrite-magnetite-chalcopyrite mineralized zone does not follow the normal sequence. Pyrite which is fractured has preceded the magnetite-quartz-hematite-chalcopyrite assemblage. Hematite is commonly observed along fractures in pyrite and chalcopyrite appears to be guided in some cases by fractures in that early sulphide. From this evidence, it appears that there is a major break after the pyrite crystallization. Following this break, quartz, magnetite, hematite, and chalcopyrite were deposited in approximately that order. In hand specimens, fractures lined with molybdenite flakes cut the earlier minerals (Graham 1956). The Grandine deposit has crystallized under unusually high temperature and pressure conditions.

The relationship of pyrite and pyrrhotite is of interest in the Chibougamau mineral deposits. Pyrrhotite which is very abundant in the main sulphide deposits is completely lacking in the gold-quartz veins, the pyrite-magnetite-chalcopyrite deposit, and in calcite-siderite shear zones. Pyrite, on the other hand, is absent or occurs only in very minor amounts in pyrrhotite-chalcopyrite zones that are genetically related to gabbro sills. However, in the other deposits, pyrite is a dominant mineral.

In conclusion, the writer suggests that the hydrothermal solutions originated from three sources: the Chibougamau granite batholith, the basic sills, and the Gradine granite plug.

The deposits genetically related to the Chibougamau granite appear to have formed from three waves of hydrothermal solutions: the first, the main sulphide deposits, secondly the arsenopyrite-pyrrhotite-sphalerite deposits, and thirdly the lower intensity gold-quartz veins.

A major break in mineralization has taken place between quartz-arsenopyrite-pyrite or quartz-pyrite deposition and the later sulphides in the first two deposits. This break in the pyrite-pyrrhotite-chalcopyrite deposition may have resulted from the intrusion of the dioritic dikes, but evidence supporting this idea is lacking. Dike intrusion followed the pyrite or the pyrite and pyrrhotite minerallization and remaining sulphides in the Noranda district (Price 1934, Cooke H.C., James W.F., and Mawdsley J.B. 1934). This would compare in certain respects to the break in mineralization in the Chibougamau mining district. Locally, a second break between sulphides and later calcite and quartz vein filling is evident in the mineral deposits.

A slight period of fracturing between the deposition of pyrite and late quartz is recorded in the Obalski gold-quartz veins, probably dividing the sequence into two stages. Carmichael (1940) states that there are three stages of mineralization in the Norbeau gold-quartz vein.

Three major stages of mineralization were observed in the pyrite-magnetite-chalcopyrite deposit which is genetically related to the Grandine granite. The first consists of pyrite, the second, quartz, magnetite, hematite, and chalcopyrite, and the third, the molybdenite mineralization.

The breaks in mineralization can be explained by the formation of dilatant zones due to renewed movement along the fault plane. These zones of dilation or low pressure areas would be favorable environments for mineral deposition.

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	-	900	20	"	Py.,Cp.,Carb.,minor Po., minor Sl.	"	"
	-	800	10-40 ft.	"	Py.,Cp.,Sid.,minor Sl.	Chl.,Talc,Chloritoid, Carb.	"
	-	500 level-240	500 level-10	"	"	"	"
	-	300	22	"	"	"	Surface D.Drilling
	-	150 level-750	Variable	Dissemations & Massive	Py.,Po.,Cp.,Cal.,Qtz., minor Sl.	Qtz., Ser.,Chl.,Carb., Talc	Surface D.Drilling,Shaft Sinking Underground Development
	-	150 level-750	"	Disseminated	"	"	"
	-	-	"	Marginal	"	"	"
	-	1000	"	Marginal	"	"	"
	-	-	"	Disseminations	Po.,Cp.,minor Py., Carb.	"	Surface D.Drilling Trenching
	-	-	"	"	Po.,Py.,Cp.,minor Sl., Carb.,Qtz.	"	"
	45E	350+	50	Pods and Stringers	"	Qtz.,Chl.,Ser.,Carb.	Surface D.Drilling Shaft Sinking Underground development
	-	280	15	"	"	"	Surface D.Drilling
	-	300	Variable	"	"	"	"
el- . el-	30E	2600+	"	Stringers and Disseminations	Py.,Qtz.,Cp.,Sid.	Qtz.,Ser.,Chl.,etc.	"
	"	"	"	Massive	Cp.,Py.,Po.,Sid.,	"	"

	Eaton Bay	Altered Anorthosite and dikes	N60W	70SW	-	900	20	"	Py.,Cp.,Carb.,minor Po., minor Sl.
	Machin Point	Sheared Gabbro	N60W	-	-	800	10-40 ft.	"	Py.,Cp.,Sid.,minor Sl.
	Hanging Wall	Altered Anorthosite and dikes	N60W	-	-	500 level-240	500 level-10	"	"
	South Eaton Bay	"	N60W	-	-	300	22	"	"
Merrill Island Corp.	A	"	N45W	Vertical	-	150 level-750	Variable	Dissemations & Massive	Py.,Po.,Cp.,Cal.,Qtz., minor Sl.
	B	"	"	65S	-	150 level-750	"	Disseminated	"
	C	"	"	Vertical	-	-	"	Marginal	"
	D	"	"	70NE	-	1000	"	Marginal	"
Portage Island Mines	Copper Point	"	Possibly NE	-	-	-	"	Disseminations	Po.,Cp.,minor Py., Carb.
	Hematite Point	Altered Anorthosite	"	-	-	-	"	"	Po.,Py.,Cp.,minor Sl., Carb.,Qtz.
Quebec Chibougamau Goldfields	A	Altered Anorthosite and dikes	On surface-N60W Underground-E.-W.	45-70S	45E	350+	50	Pods and Stringers	"
	B	"	N65W	-	-	280	15	"	"
	H	"	"	-	-	300	Variable	"	"
Yorcan Exploration Ltd.	Hanging Wall	"	N75E	Upper Level-Steeply S. Lower Level-Flat	30E	2600+	"	Stringers and Disseminations	Py.,Qtz.,Cp.,Sid.
	Henderson	"	"	"	"	"	"	Massive	Cp.,Py.,Po.,Sid.,

Diagram 2.

Paragenetic sequence of mineralization of the individual Pyrrhotite-Pyrite-Chalcopyrite Deposits.

Location	Numbers of Sections	Paragenesis
Atlas Chibougamau	CH-19 CH-21	Quartz Pyrite Pyrrhotite Sphalerite Chalcopyrite
Baker Talc	CH-25 CH-26	Pyrite Quartz Siderite Chalcopyrite Calcite
Bateman Bay-A-Zone	CH-34 CH-52	Pyrite Quartz Chalcopyrite Calcite
Bateman Bay-C-Zone	CH-35 CH-33	Pyrite Quartz Sphalerite Chalcopyrite Calcite
Bear Bay	2	Pyrite Pyrrhotite Chalcopyrite
Campbell Chibougamau-Merrill Island	H M.C.-53 437 M.C.-53 292 M.C.-53 452 M.C.-42 473 M.C.-53 473 C.C.M.-10 C.C.M.-33 C.C.M.-14 C.C.M.-37 C.C.M.-3	Pyrite Quartz Pyrrhotite Sphalerite Chalcopyrite Calcite
Campbell Chibougamau-Cedar Bay	B-Dump CB-1	Quartz Pyrite Chalcopyrite Calcite
Campbell Chibougamau KoKo Creek	F K16A K16B KI-437 MI-423	Pyrite Quartz Pyrrhotite Chalcopyrite Calcite
Chibougamau-Kayrand	G CH-9 CH-10 CH-11	Quartz Pyrite Pyrrhotite Sphalerite Chalcopyrite Calcite Marcasite
Copper Rand-Copper Cliff Deposit	A-9 133 A-9 67 A-10 238 A-10 124.5 A-9 77	Quartz Pyrite Siderite Chalcopyrite Calcite

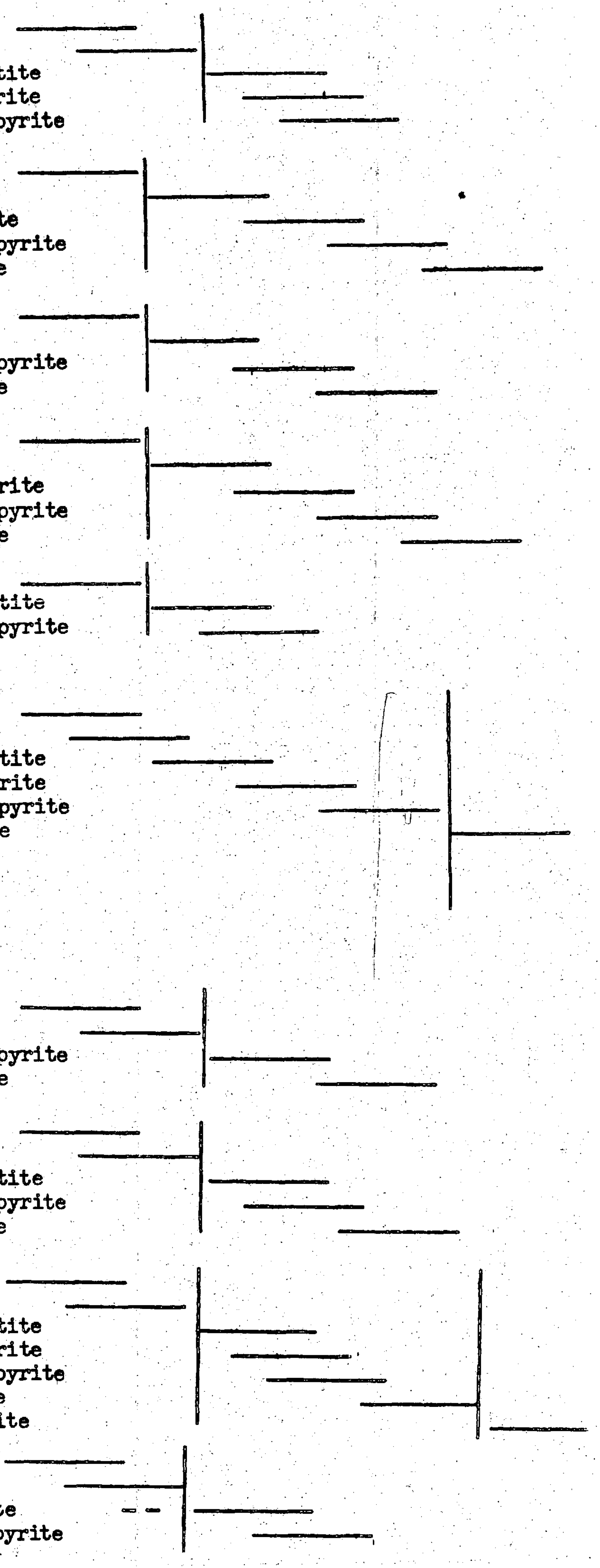

Table 3 - DESCRIPTION OF THE MAJOR PYRITE-PYRRHOTITE-CHALCOPYRITE DEPOSITS IN THE CHIBOUGAMAU DISTRICT

LL ROCK	STRIKE OF DEPOSIT	DIP OF DEPOSIT	PLUNGE	AVER.LENGTH (feet)	AVER.WIDTH (feet)	TYPE OF DEPOSIT	MINERALIZATION	WALL ROCK ALTERATION	EXPLORATION WORK
ered rthosite i dikes	W.-end N80W E.-end N45W	Vertical	-	2700	500 ft. Level 8-25 ft.	Pods and Stringers	Py.,Po.,Cp.,minor Sl., Carb., Qtz.	Ser.,Chl., Qtz., Carb.	Surface D.Drilling Shaft sinking
"	N60W	"	-	-	Variable	"	"	"	Surface D.Drilling
"	N60W	"	-	-	"	"	"	Chloritoid & other minerals	"
c Sauvage ult zone	NW	"	-	-	"	"	Py.,Cp.,Sid.,Qtz.	Ser.,Chloritoid,Chl.,Qtz.	Surface Trenching-Diamond Drilling
tered orthosite d dikes	N60-70W	60-70S	-	500	"	"	Py.,Cp.,Qtz.,Carb.,etc.	Carb.,Ser.,Clay minerals	Surface D.Drilling
"	E.-end N45W W.-end N70W	60S to Vertical	Westerly	700	"	"	Py.,Cp.,Po.,minor Sl.,Qtz., Ser.,Cal.	Ser.,Chl.,Carb.,Qtz.,Talc	Surface D.Drilling Shaft Sinking Underground Development
"	N45W	Vertical to steeply dipping N.	-	N.-zone 900 S.-zone 500	N.-zone 20.3 S.-zone 11.4	"	"	"	Surface D.Drilling
"	N45W	Vertical to steeply dipping N.W.	-	700	Variable	"	"	"	Surface Trenching-Diamond Drilling, Shaft Sinking Underground Development
"	-	"	-	-	"	"	"	"	"
"	-	Low Dip	-	-	"	Massive	"	"	"
"	N80W	Vertical to steeply dipping N.	70W	1700	12-30 feet	Pods and Stringers	Py.,Cp.,minor Po.,Carb., Qtz.,minor Sl.	Ser.,Chl.,Carb.	Surface D.Drilling Shaft Sinking Underground Development
Altered Gabbro	W.-end N80E E.-end N80E	80S	W.-end W. E.-end E.	-	5-50 feet	"	"	Sid.,Ser.,Chl.,Chloritoid, Qtz.	
t.wall- lt.gabbro .wall- ransition	Variable	80S	-	-	Variable	"	"	"	Surface D.Drilling
ltered northosite nd dikes	N60W	Vertical	-	500	Variable	Disseminations	Py.,Po.,minor Sl.,Cp.,Qtz., Carb.	Ser.,Chl.,Carb.,Qtz.,Talc	Trenching Surface D.Drilling
hear zone t anortho- ite-Gabbro ontact	N80W	-	-	700	"	Pods and Stringers	Py.,Cp.,minor Sl.,Carb.	Chl.,Talc,Chloritoid, Carb.	Surface D.Drilling Shaft Sinking Underground Development
ltered northosite d dikes	N60W	70SW	-	900	20	"	Py.,Cp.,Carb.,minor Po., minor Sl.	"	"

Table 3 - DESCRIPTION OF THE MAJOR PYRITE-PYRRHOTITE-CHALCOPYRITE DEPOSITS IN THE CHIBOUGAMAU DISTRICT

NAME OF MINING PROPERTY	ZONE	WALL ROCK	STRIKE OF DEPOSIT	DIP OF DEPOSIT	PLUNGE	AVER.LENGTH (feet)	AVER.WIDTH (feet)	TYPE OF DEPOSIT	MINERALIZATION	WALL ROCK ALTERATION
Bateman Bay Mining Co.	A	Altered Anorthosite and dikes	W.-end N80W E.-end N45W	Vertical	-	2700	500 ft. Level 8-25 ft.	Pods and Stringers	Py.,Po.,Cp.,minor Sl., Carb., Qtz.	Ser.,Chl., Qtz., Carb.
	B	"	N60W	"	-	-	Variable	"	"	"
	C	"	N60W	"	-	-	"	"	"	Chloritoid & other miner
Baker Talc	Main	Lac Sauvage Fault zone	NW	"	-	-	"	"	Py.,Cp.,Sid.,Qtz.	Ser.,Chloritoid,Chl.,Qtz
Bouzan Chibougamau Mines	Main	Altered Anorthosite and dikes	N60-70W	60-70S	-	500	"	"	Py.,Cp.,Qtz.,Carb.,etc.	Carb.,Ser.,Clay minerals
Campbell Chibougamau Mines	Main	"	E.-end N45W W.-end N70W	60S to Vertical	Westerly	700	"	"	Py.,Cp.,Po.,minor Sl.,Qtz., Ser.,Cal.	Ser.,Chl.,Carb.,Qtz.,Tal
	KoKo Creek	"	N45W	Vertical to steeply dipping N.	-	N.-zone 900 S.-zone 500	N.-zone 20.3 S.-zone 11.4	"	"	"
Campbell Chibougamau Mines (Cedar Bay)	A	"	N45W	Vertical to steeply dipping N.W.	-	700	Variable	"	"	"
	Sulphide	"	-	"	-	-	"	"	"	"
	Flat Vein	"	-	Low Dip	-	-	"	Massive	"	"
Chibougamau Jaculet Mines	No. 1	"	N80W	Vertical to steeply dipping N.	70W	1700	12-30 feet	Pods and Stringers	Py.,Cp.,minor Po.,Carb., Qtz.,minor Sl.	Ser.,Chl.,Carb.
	No. 2	Altered Gabbro	W.-end N80E E.-end N80E	80S	W.-end W. E.-end E.	-	5-50 feet	"	"	Sid.,Ser.,Chl.,Chloritoi Qtz.
	No. 3	Ft.wall-alt.gabbro H.wall-Transition	Variable	80S	-	-	Variable	"	"	"
Chibougamau Kayrand Mines	Main	Altered Anorthosite and dikes	N60W	Vertical	-	500	Variable	Disseminations	Py.,Po.,minor Sl.,Cp.,Qtz., Carb.	Ser.,Chl.,Carb.,Qtz.,Talc
Copper Rand Mines	Copper Cliff	Shear zone at anorthosite-Gabbro contact	N80W	-	-	700	"	Pods and Stringers	Py.,Cp.,minor Sl.,Carb.	Chl.,Talc,Chloritoid, Carb.
	Eaton Bay	Altered Anorthosite and dikes	N60W	70SW	-	900	20	"	Py.,Cp.,Carb.,minor Po., minor Sl.	"