

MINERALOGY OF THE LITTLE LONG LAC GOLD AREA, ONTARIO

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ABSTRACT

The mineralogy of the Little Long Lac deposits, like that of many other gold deposits of northern Ontario, is relatively simple. In the present study nine sulphides, two tellurides, two sulpho-salts, and six other metallics, including gold, have been identified in hand specimens and polished sections. In addition three supergene minerals have been observed in specimens from one mine. The latter are of interest as representing the occurrence of a shallow zone of secondary enrichment within the Canadian Shield.

INTRODUCTION

In a paper which has recently appeared (Armstrong, 1943) there are presented outlines of the general geological relationships, and discussions of the mineral paragenesis for each of seven gold mines in the Little Long Lac area. The present paper is submitted in order to supplement, in detail, the information now available concerning the mineralogy of the area.

Dr. E. L. Bruce in his several reports and papers (1935, 1936, 1939), and W. Samuel (1937), have discussed the mineralogy in general terms. A. W. Johnston (1935) and H. F. Morrow (1940) have likewise devoted some attention to the mineralogy incidental to their broader discussions of the Bankfield and MacLeod-Cockshutt mines, respectively. Professor Ellis Thomson's paper (1935) on the mineralization of the region provides important information concerning the mineralogy of the earlier prospects and developments. Further valuable data, particularly concerning the size of the mineral grains, are to be found in various reports of the Bureau of Mines, Ottawa (1935, 1936, 1937, 1939).

The information presented below has been obtained from the study of numerous hand specimens and polished sections representative of the ores from the various mines. This work was carried out at the University of Chicago in the laboratories of the Department of Geology and Paleontology, to the Chairman of which, Dr. E. S. Bastin, the writer is deeply indebted for research facilities and kindly encouragement.

MINERALOGY

The mineralogy of the area is not very complex, only twenty-one metallic minerals having been definitely identified in the present study. Since about one-third of these minerals are common to all the mines it has been considered advisable to discuss the mineralogy for the area as a

whole, rather than to consider each mine separately. Further, it is convenient to represent in tabular form the reported occurrences of the metallic minerals in the various mines. The table which has been drawn up for this purpose is as follows:

TABLE I

Metallic Minerals in the Ores	Mine						
	Hard Rock	MacLeod- Cocksutt	Little Long Lac	Magnet Consol.	Bankfield Consol.	Tombill	Jellicoe
MAJOR CONSTITUENTS							
Arsenopyrite	146	134	1256	1	12346	1	1
Pyrite	12346	12346	1256	1	12346	1	1
Gold	12346	12346	123456	1	12346	1	1
MINOR SULPHIDES							
Chalcopyrite	16	16	16	1	123	1	1
Cubanite	1						
Galena	16	1	16	1			*
Leucopyrite	1	1	1	1			
Pyrrhotite	16	1	156	1	123		1
Sphalerite	1	16	16		16	1	1
Stibnite			25				1
TELLURIDES							
Coloradoite(?)		1					
Krennerite(?)		1					
SULPHO-SALTS							
Berthierite			6				
Bournonite			125				
Grey Copper	6		16		1		
OTHER METALLICS							
Graphite	1					1	
Hematite	1	1	5				
Ilmenite	1	1	1		123	1	1
Magnetite	1	1	6		6		
Scheelite			1			**	
SUPERGENE MINERALS							
Chalcocite					1		
Limonite			6		16		
Malachite					1		

1—mineral identified in present study.

2—mineral identified by Bruce (1935).

3—mineral identified by Bruce (1936).

4—mineral identified by Bruce (1939).

5—mineral identified by Bruce and Samuel (1937).

6—mineral identified by Thomson (1935).

*—mineral reported by G. C. McCartney (personal communication).

**—mineral reported by P. E. Hopkins (personal communication).

In the following descriptions, arranged in the order in which the minerals occur in the table, the term *bleb* is used in a sense differing from the dictionary definition. The definition implies small drop-like or bubble-shaped masses. The writer uses the term to signify any very small anhedral mass within another, regardless of whether it be angular or rounded. The term, however, does not include minute regular crystal inclusions, such as are found in some sections.

MAJOR CONSTITUENTS

Arsenopyrite (FeAsS). Arsenopyrite has been recognized in polished sections representative of each of the seven mines in the area. In nearly all the sections examined it was the first mineral to crystallize, commonly having assumed lath-, diamond-, or needle-shaped euhedral outlines. In sections from several mines, especially Hard Rock and Bankfield, the grains of arsenopyrite are bounded on two sides by crystal faces, the remaining boundary being more irregular. Such crystals, known as skeleton crystals, characteristically formed where arsenopyrite replaced wall-rock minerals. The crystal faces are an automorphic replacement of the minerals of the wall-rock; the irregular boundary is a contact where replacement is incomplete. Where arsenopyrite is not automorphic it very commonly occurs as granular aggregates, which may be up to 10 mm. in diameter.

The larger crystals and aggregates of grains are commonly broken by fractures; in the aggregates, individuals may be pried away from their neighbors. Lath-shaped crystals are often fractured transversely, the fractures being filled by quartz, carbonate, or metallica. Where fracturing has been complex the arsenopyrite may have a brecciated appearance. Replacement of the walls by the "healing" mineral is common, but in many specimens the opposite walls along fractures match perfectly.

The arsenopyrite crystals average about 0.5 mm. in diameter, but the size varies within wide limits. Tiny euhedra surrounded by pyrite are 0.01 mm. or less in longest dimension; larger lath-shaped crystals are as much as 4 mm. long. The proportion of arsenopyrite in the ores is also variable. Polished sections of some sulphide ores contain very few crystals of arsenopyrite, less than two or three per cent. A specimen of massive arsenopyrite ore from Magnet Consolidated is more than ninety per cent arsenopyrite, the remainder being largely quartz.

The crystallizing power of the arsenopyrite is strong enough to inhibit the growth of contemporaneous inclusions. Later replacements are, however, rather common in some sections. Where arsenopyrite is in great excess over pyrite, pyrrhotite and chalcopyrite may occur as small rounded or irregular blebs in the arsenopyrite. The lack of any regular

arrangement of these inclusions precludes the possibility that they are products of exsolution. In sections where the period of deposition of arsenopyrite is overlapped by that of pyrite, the latter may occur as small euhedral crystals within the arsenopyrite.

Pyrite (FeS_2). Pyrite, like arsenopyrite, was found in specimens from all the mines in the area. Although not constant in its relations to the other minerals, especially quartz and arsenopyrite, it usually exhibits the regular outlines of sectioned cubes or pyritohedra. In vuggy specimens from Hard Rock, MacLeod-Cockshutt, and Little Long Lac mines pyrite encrusts quartz or calcite crystals as clusters of minute euhedra. Although pyrite often shows a strong tendency to assume its crystal outlines, later fracturing or replacement have commonly destroyed what may have been euhedral crystals. As in the occurrences of arsenopyrite, pyrite frequently forms aggregates of anhedral grains, and in some specimens it occurs as narrow veinlets.

Fractures in pyrite are commonly filled with quartz or calcite, sometimes with chalcopyrite. Bruce (1935, p. 39) has figured a specimen from the Little Long Lac mine in which pyrite has been brecciated and cemented with bournonite. The writer had available no specimens showing this condition; the closest similarity was brecciated pyrite cemented with quartz. As in the arsenopyrite, fracture walls may or may not be replaced by the fillings; many examples of both conditions were observed. In general, the pyrite is less fractured than the arsenopyrite, for the most part as a result of its position in the paragenetic sequence. The contrast may be due, in part, to the crystal habit and greater brittleness of the arsenopyrite.

Pyrite crystals are extremely variable in size. The smallest can be seen only with the high powers of the microscope; the largest measured, from the Number 2 vein system at Hard Rock, were just over 30 mm. in diameter. Under such conditions it is difficult to set an average, but for individual crystals, as seen in polished sections, the average diameter approximates 1 mm. The average size of the aggregates of anhedral grains is somewhat in excess of this figure, 2 to 3 mm. being representative. The proportion of pyrite to the other metallics and to the gangue minerals is extremely variable. A specimen from Hard Rock, of iron formation almost completely replaced by sulphides, contains arsenopyrite and two-millimeter diameter pyrite grains in about equal proportions.

Pyrite commonly contains inclusions of other minerals, metallics and quartz. Arsenopyrite occurs as euhedral grains and rarely as rounded blebs. These are a result of the prior crystallization of arsenopyrite; the rounded blebs are probably due to replacement action of the later pyrite. Quartz, where earlier than pyrite, is generally present as euhedral crys-

tals, doubly terminated needles being common. Rounded or irregular inclusions of chalcopyrite and pyrrhotite, usually less than 0.1 mm. in size, are characteristic of much of the pyrite. In many instances they have replaced pyrite along channels of easy access formed by the contact with arsenopyrite or quartz, or by minute cracks in the pyrite. Sphalerite blebs are less common than pyrrhotite and chalcopyrite. In some sections these are associated with the other two, in others the sphalerite forms minute replacement blebs unconnected with either pyrrhotite or chalcopyrite. In none of the sections examined were the inclusions arranged in any regular order; it is unlikely, then, that they have formed as a result of unmixing from solid solution.

Gold (Au). Gold was observed in polished sections from each of the mines. Hand specimens of "high grade" from all but Hard Rock show free gold, sometimes in spectacular amounts. In some, the gold is associated with quartz, generally greyish in color and fairly well fractured. One specimen from Magnet Consolidated shows gold associated with calcite; and in one from Tombill the gold occurs in a blue-black quartz vein near the contact with a black argillite-like greywacke. Gold visible in the hand specimens forms delicate films, leaf-like or dendritic, along fractures in the quartz. In some specimens the gold is more robust, forming aggregates with the characteristic hackly feel.

In the polished sections gold occurs as blebs and veinlets in quartz and in the sulphides. It is associated with galena in sections from MacLeod-Cockshutt, Little Long Lac, and Magnet Consolidated. A section from the latter mine shows a veinlet of galena and gold, in which gold is auto-morphic against the galena.

In polished sections of average ore the gold occurs as blebs which vary in size from less than 10 to as much as 100, rarely 200 microns, in longest dimension. In some sections only two or three such blebs were observed, in others the number is higher. A specimen of pyritic ore from MacLeod-Cockshutt contains seventeen tiny blebs in an area of about 100 sq.mm. A somewhat larger specimen of similar ore from Hard Rock contains nineteen blebs. In neither of these specimens is gold visible except under high power.

Gold in the finely-divided state occurs as inclusions, but in sections of high grade ore it is itself seen to contain inclusions, galena and chalcopyrite being most common. Very minute specks of other minerals, too small for optical or etch tests, were observed in some sections. These may be of telluride nature, as in sections from the 210 Quartz Vein at MacLeod-Cockshutt. Inclusions of galena are rounded and are probably contemporaneous with the gold. Chalcopyrite inclusions are generally auto-morphic, thus indicating their position in the paragenetic sequence.

The very minute blebs of gold present in the sulphides and gangue of average ore were distinguished from chalcopyrite by careful observations of color, surface texture, and behavior under crossed nicols. Even the smallest grains are bright yellowish-orange against chalcopyrite, and the surface of such grains has a rather granular or roughened appearance, probably a result of the softness of the gold. The gold of these inclusions does not seem to show any preference for pyrite over arsenopyrite; where more gold is associated with pyrite, it is very largely due to the fact that there is more pyrite than arsenopyrite in the section. The same holds true for arsenopyrite. M. H. Haycock, reporting the results of grain analyses of a number of polished sections of MacLeod-Cockshutt ore, in a personal communication to H. F. Morrow (1940, p. 26) stated that 67 per cent of the gold was in pyrite, the remainder in the gangue. The present study indicates that the proportion is about even, gold generally being found wherever the solutions have had easiest access. The presence of tiny gold inclusions in pyrite or arsenopyrite unconnected with the gangue by cracks or other visible channels, suggests the possibility that the gold may be contemporaneous with the sulphides. In such cases great care must be taken to determine whether or not most of the gold in that particular section occurs in the gangue, that is, is late gold. Consideration must also be taken of the third dimension; many supposedly unconnected blebs were seen to conform to one or more crystal outlines on the mineral in which they occur. This gold, then, may well have come in along a channel normal to the plane of the section. Some of the gold merely fills open spaces; in other specimens, or even in parts of the same specimen, the gold may be a replacement of sulphides or gangue minerals.

MINOR SULPHIDES

Chalcopyrite (CuFeS_2). In most of the specimens available, chalcopyrite occurs in minor amounts as anhedral blebs in sulphides or gangue. In five of the sections examined, of which two were from MacLeod-Cockshutt, two from Bankfield, and one from Tombill, chalcopyrite is the important sulphide.

Few examples of chalcopyrite with crystal outlines were observed. The most common occurrence of the mineral is as blebs in pyrite and arsenopyrite, as described above under those minerals. In several sections, however, chalcopyrite occurs as a fracture filling in pyrite and arsenopyrite. Several places were found where it is automorphic against the calcite of the gangue, and it has been mentioned above that it occasionally presents crystal faces against gold. In the sections where sphalerite occurs in fairly large masses, chalcopyrite is found as blebs in the sphalerite. These are further discussed under that mineral.

The blebs of chalcopyrite in pyrite and arsenopyrite are small, usually less than 100 microns in diameter. Irregular areas of chalcopyrite in quartz or carbonate gangue are larger and measure as much as 1000 microns. In the specimens containing an average amount of chalcopyrite there is less than one per cent of the mineral. In the five sections mentioned above, chalcopyrite forms more than 90 per cent of the surface area.

The age relations between pyrite, quartz, and chalcopyrite are well illustrated by the Tombill specimen in which chalcopyrite conforms to crystal outlines of quartz, pyrite, and arsenopyrite. Except for one occurrence of cubanite, and those cases in which chalcopyrite is so abundant that it has surrounded earlier crystals, the mineral contains no inclusions.

Cubanite ($\text{Cu}_2\text{S} \cdot \text{Fe}_4\text{S}_5$). In one section from Hard Rock a pinkish-cream mineral occurs as a slender lath in a chalcopyrite bleb in pyrite. The strong anisotropism, color, and association with chalcopyrite and pyrrhotite established its identity. It was much too small to identify positively by microchemical or etch methods.

Galena (PbS). Galena was identified in polished sections from Hard Rock, MacLeod-Cockshutt, Little Long Lac, and Magnet Consolidated. From each of the latter two mines it is represented in only one section; it was identified in six from the 210 Quartz Vein at MacLeod-Cockshutt. The mineralogy of the Magnet Consolidated specimen, from the drag-fold on the 1080-foot level, except for the presence of arsenopyrite, closely resembles that of the MacLeod-Cockshutt specimens which contain no arsenopyrite. It is possible that the ore bodies are similar in nature and origin.

In the Little Long Lac specimen galena is associated with calcite and chalcopyrite. It is automorphic against the calcite, but conforms to the chalcopyrite. In the other specimens galena is associated with gold, both occurring as blebs and veinlets in fractures in the quartz. The relations between galena and gold indicate that the two minerals are contemporaneous; segmented veinlets are common in which the contacts between gold and galena are quite smooth. There is nothing to suggest replacement of the one mineral by the other.

An euhedral lath-shaped telluride occurs as an inclusion in one of the sections from MacLeod-Cockshutt. This is the only mineral inclusion other than gold, except for places where galena has grown around quartz or pyrite crystals, that has been observed.

Leucopyrite (Fe_3As_4). In sections from the four easternmost mines of the area leucopyrite has been identified, associated closely with arsenopyrite, pyrrhotite and pyrite. It occurs as dendritic rods in a manner

almost identical with that illustrated by G. C. Ridland (1941, fig. 13) and also as small prisms, similar to those mentioned in his descriptions of the mineral. The best examples of the present occurrence were seen in one section from Magnet Consolidated, in which the leucopyrite is intergrown with pyrrhotite as dendrites. In the same section it occurs with pyrite as short curved prisms, and with arsenopyrite in dendritic form; it is later than both arsenopyrite and pyrite. In sections from the other three mines the proportion of short prisms to dendrites is about one to one.

The dendrites average 200 to 300 microns in length; the shorter prisms are much less, about one-tenth the length of the dendrites. The amount of leucopyrite in any section is considerably less than one per cent.

The identification of the mineral was based upon its optical properties combined with the peculiar manner of growth. Etch tests were run on some of the specimens, the results agreeing closely with those given by Short (1940, p. 161).

Pyrrhotite (FeS_{1+}). With the exception of Tombill, pyrrhotite was found in polished sections from all the mines in the area. It is probable that more sections of the Tombill ore would have revealed its presence there also. In only one specimen, from a diamond-drill intersection of the West ore zone at MacLeod-Cockshutt, was pyrrhotite present in more than minor amounts.

Pyrrhotite commonly occurs as blebs and veinlets in pyrite, arsenopyrite, and the gangue minerals. The blebs are rounded or irregular in outline, in some places conforming to the crystal outlines of the mineral in which they occur. A few specimens were noted in which pyrrhotite is automorphic against chalcopyrite or carbonate, but no single crystals of pyrrhotite were observed. In some specimens pyrrhotite occurs as fairly large grains in the quartz or other gangue minerals. Such large pyrrhotite masses may contain small replacement blebs of chalcopyrite. The mutual age relationships of chalcopyrite and pyrrhotite are uncertain, but it is probable that the latter is the older. This is suggested by the fact that, where pyrrhotite occurs as blebs in pyrite, chalcopyrite commonly occupies a peripheral position in the inclusion, apparently having replaced the pyrrhotite along its contact with pyrite. These facts are in accord with Schwartz's (1937) observations that the two minerals are in part contemporaneous, but with most of the chalcopyrite somewhat later than the pyrrhotite. An interesting occurrence is as minute ovoid blebs in the magnetite of the iron formation ore from the Hard Rock mine.

Sphalerite (ZnS). Sphalerite was identified in specimens from all but the Magnet Consolidated mine. It is possible that additional sections from that mine would indicate its presence in those ores also.

The mineral occurs in pyrite and arsenopyrite as minute blebs similar to those of pyrrhotite and chalcopyrite. It also occurs as larger masses in the gangue. Wherever it occurs in the larger masses it characteristically contains rounded or ovoid, sometimes angular, minute inclusions of chalcopyrite arranged in a regular manner, possibly along certain crystallographic directions in the sphalerite. These blebs are believed to be ex-solution blebs—a view to which support is lent by their regular arrangement. Even the largest sphalerite areas measure only slightly more than 1 mm. across, so that the amount in a section, as of the other minor sulphides, is generally less than one per cent.

The smaller blebs of sphalerite in pyrite and arsenopyrite are difficult to identify positively. The optical properties have been used to a great extent. It was found that, using the highest power dry objective and ocular combination, with a high intensity lamp and nicols completely crossed, the yellowish brown internal reflection which characterizes the mineral was well brought out.

Stibnite (Sb_2S_3). This mineral was identified in only one section, one which came from the Jellicoe mine. It was recorded by Bruce (1935, p. 40) from the Little Long Lac mine, but none was found in the present material.

In the single occurrence stibnite is associated with chalcopyrite and arsenopyrite; it is later than both those minerals. The mottled appearance, as suggested by Short (1940, p. 114), is probably a result of the radiating, prismatic structure. It may, however, be due to polysynthetic twinning which, under certain conditions, gives an appearance of undulatory extinction as noted by Schneiderhöhn and Ramdohr (1931, p. 79).

The mineral forms a small area 0.2 mm. wide, and 0.9 mm. long. The action of the etch reagents so damaged the specimen as to make it useless for photographic purposes. The identification of the mineral is based on its optical character and its reactions with the standard etch reagents.

TELLURIDES

In his investigation of the mineralogy of the 210 Quartz Vein at MacLeod-Cockshutt, Morrow (p. 39) obtained a positive test for tellurium. The satisfactory identification of tellurides has not been possible in the present study, although especial care was taken with all suspected minerals. Only in the polished sections from the MacLeod-Cockshutt 210 Quartz Vein were there observed any possible tellurides. In these sections however, occur three minerals which may be tellurides.

A lath-shaped, creamy-white mineral associated with galena may be *Krennerite* (Au, Ag) Te_2 . This mineral is anisotropic, but the high reflectivity of the surrounding galena prevented identification of the colors.

Continuous scratches of about equal depth cross both minerals, indicating the hardness of the lath-shaped mineral to be somewhat less than the value C assigned to krennerite by Short. Etch tests would have destroyed the section; as a result, the identification as krennerite is not to be regarded as definite.

A pinkish-gray, isotropic mineral associated with, and of approximately the same hardness as galena, is tentatively identified as *Coloradoite* (HgTe). The grains are too small to afford an accurate basis for etch reaction.

The third mineral could not be even tentatively identified, and is referred to as *Mineral X*. The color is somewhat greenish-yellow; under crossed nicols this varies through shades of blue as the stage is rotated. The hardness is about the same as that of galena, B. As with the other two minerals, etch tests could not be made without loss of the sections.

SULPHO-SALTS

Bournonite ($\text{Cu}_2\text{S} \cdot 2\text{PbS} \cdot \text{Sb}_2\text{S}_3$). This mineral was identified in several hand specimens and in one polished section from the Little Long Lac mine. In the former it occurs as irregular veinlets and blebs associated with chalcopyrite in quartz. In the polished section it occurs as irregular blebs in pyrite; at one place the bournonite appears to be automorphic against chalcopyrite, but the relation is uncertain. In general the mineral is not automorphic, but conforms to the surrounding minerals, or to the walls of the fractures in which it may occur.

The identification of bournonite in the polished section was based on its optical character and reaction to the standard etch reagents. In the hand specimens the somewhat conchoidal fracture, brittleness, low hardness, metallic luster, and steel-grey color and streak served to identify the mineral.

Grey Copper ($5\text{Cu}_2\text{S} \cdot 2(\text{Cu},\text{Fe})\text{S} \cdot 2\text{As}_2\text{S}_3$). This mineral was identified in polished sections from Little Long Lac and Bankfield. The circumstances of its occurrence suggest that it may also be present in most of the other mines. It occurs as very small rounded and irregular blebs in pyrite and arsenopyrite.

The close similarity in color between grey copper and sphalerite may have resulted in some misidentification. Grey copper is somewhat lighter in color, and does not have the yellowish-brown internal reflection noted for sphalerite. Etch reactions were inconclusive because of the minuteness of the inclusions. It is possible that, when dealing with such small grains, electrolytic action, inhibiting the normal reactions, may be set up within the drop of reagent.

OTHER METALLICS

Graphite (C). Flakes of graphite were identified in polished sections from Hard Rock and Tombill. The Tombill graphite is visible along seams in a hand specimen containing a high proportion of chalcopyrite. The association of graphite seams with chalcopyrite is not uncommon in some of the mines of the Canadian Shield. A polished section containing graphite shows short flakes of a brownish-grey mineral, soft, and negative to all reagents. Careful observation was made to ascertain whether there were four or only two extinctions per revolution. The mineral extinguished only twice in 360 degrees, so is graphite rather than molybdenite. The graphite in the Hard Rock sections occurs as very small brownish flakes, distinctly anisotropic. They are regularly arranged with longest dimensions parallel in a sheared dark greywacke. Their similarity to the mineral called graphite in the Tombill section indicates their identity.

The origin of the graphitic carbon is an interesting, but conjectural matter. The associated rocks are sediments, and it is possible that the graphite is of organic origin, derived from primitive organisms.

Hematite (Fe_2O_3). Hematite was positively identified in polished sections of ore from MacLeod-Cochshutt. In the best specimen, magnetite-bearing iron formation has been folded and has fractured parallel to the bedding. In this fracture two-millimeter euhedra of pyrite have crystallized, preserving their outlines against quartz. The quartz-pyrite contact has served as an effective channel for the ingress of solutions which deposited hematite. In some places, separating the hematite from pyrite, is a thin band of a transparent mineral exactly like quartz, but having a reddish color in obliquely reflected light. It is probably jasper.

The hematite forms narrow bands 0.1 mm. in width, having minutely irregular contacts with quartz or jasper and pyrite. In other specimens, in which the hematite was identified by similarity with that already described, it occurs as rounded inclusions, or as arborescent and irregular replacements of pyrite. The hematite in the quartz-pyrite veinlet in folded iron formation carries some inclusions of pyrite and magnetite. The magnetite was probably caught up from the wall rock; the pyrite is euhedral and represents material around which the hematite has grown.

Hematite was identified by its optical and chemical properties. It is negative to all the standard etch reagents; and in vertically reflected light is distinctly bluish against pyrite. It is not strongly anisotropic under crossed nicols, but with a high intensity lamp shows bright red internal reflection.

Ilmenite (FeTiO_3). A mineral, the description of which answers most

closely to that of ilmenite, occurs in polished sections from all the mines but Magnet Consolidated. It occurs as irregular grains in the gangue, and as veinlets cutting pyrite or arsenopyrite. In some specimens it may form as much as one per cent of the section, but in general is considerably less. Larger masses measure up to 0.5 mm. in diameter; smaller grains are less than 0.1 mm.

The identification of the mineral was based on the following criteria: Color—Grey, lighter than sphalerite, sometimes having a brownish tinge. Hardness—Very hard, cannot be scratched by a sharp needle with pressure. Optically—Distinctly anisotropic through shades of grey and brownish-grey, two extinctions per revolution. Under only one nicol the mineral shows a strong reflection pleochroism through light gray and brownish-grey. Internal reflection varies from slight to distinct, with colors of yellow-brown to red-brown. The characteristic twinning lamellae are irregularly spaced. These lamellae show up well under polarized light, or better under crossed nicols. Chemically—Negative to all standard etch reagents.

Magnetite (Fe_3O_4). Magnetite occurs in conspicuous amounts in specimens and polished sections of ore from the Hard Rock No. 2 and No. 30 vein systems, and from the MacLeod-Cockshutt North and South ore zones. Small grains of an isotropic grey mineral in sections of ore from most of the other mines are possibly magnetite, but their identity is uncertain. Euhedral crystals of magnetite are not uncommon, but in general the mineral forms irregular grains. In one of the Hard Rock specimens the magnetite grains almost everywhere conform to quartz outlines.

The grains are small, usually less than 0.05 mm. in diameter. Larger areas of magnetite are composed of aggregates of individual grains, some of which are euhedral, others irregular. Where magnetite forms a conspicuous part of a section it may be 25 per cent, or in some specimens more than 60 per cent, of the polished area. Where it occurs in only minor amounts it is less than one per cent.

The magnetite in the specimens from Hard Rock and MacLeod-Cockshutt is part of the original iron formation which has not been replaced by the later sulphides. It is probable that any magnetite in other sections is also earlier than the ore minerals, being either detrital or formed in the unaltered rock prior to the sulphide mineralization.

Scheelite (CaWO_4). Although it has not been possible for the writer to study the relationships of this mineral, it is included herein for the sake of completeness. Available information indicates the occurrence of scheelite at Little Long Lac and, in minor amount, at Tombill. In one specimen, from the former mine, scheelite occurs as small bunches and segments in

quartz veinlets. It was not observed in any of the polished sections studied.

MAJOR NON-METALLICS

Quartz (SiO_2). Quartz occurs as euhedral crystals, veinlets, and irregular masses in specimens from all the mines in the area. It is the most abundant gangue mineral; in nearly all the specimens occupying a considerable proportion of the area of the section. It was one of the earliest minerals to crystallize, the period of its deposition sometimes being long continued so that it forms small euhedral crystals in vuggy quartz veins. Later ages of quartz were seen where the narrow quartz veinlets have cut through existing minerals. In general, the quartz is similar to that of other areas, showing considerable variation in color from white "bull" quartz, through shades of grey, to the blue-black quartz of the Tombill specimen noted in the discussion of gold. The degree of fracturing sustained by quartz is also variable; some, which is badly shattered, contains considerable free gold. Some quartz is rather sugary, in other specimens it is almost chalcedonic. Jasper, a variety of quartz, was observed in sections from MacLeod-Cockshutt where it is associated with hematite in quartz-pyrite veinlets.

Calcite (CaCO_3). Calcite is second only to quartz in quantity as a gangue mineral. It was observed in sections from all the mines reported upon. Generally one of the last minerals to crystallize, it conforms to the crystal outlines of all but gold, against which it is occasionally automorphic. It is a common constituent of the wall rock, but occurs also in the quartz veins. In some specimens calcite crystallized prior to quartz; it occurs at the contact of the quartz veins with the wall rock, and is automorphic against quartz except where it has been replaced. Calcite was found in some vuggy quartz veins where it was deposited upon euhedral quartz crystals. In one specimen from Little Long Lac calcite forms rhombohedral crystals deposited directly upon light grey arkose, clusters of minute pyrite crystals were in turn deposited on the calcite. In many specimens late fractures are filled with narrow quartz-calcite veinlets, or with veinlets of calcite alone. Some specimens show calcite which is of possible secondary (supergene) origin.

SUPERGENE MINERALS

Minerals of supergene origin are neither common nor important in the Little Long Lac area. A single polished section from Bankfield kindly loaned the writer by Ellis Thomson, contains chalcocite, limonite, and malachite. Bruce (1935, p. 49) noted an oxidized zone at this mine ex-

tending to depths varying from two and one-half to ten feet. It is probable that the polished section examined came from this zone. Economically the occurrence is unimportant, but from the scientific point of view it is interesting as representing one of the few oxidation zones recorded in the Canadian Shield.

Chalcocite (Cu_2S). Replacement veinlets in chalcopyrite and pyrite are composed of limonite and a soft, blue-grey mineral identified as chalcocite. Limonite forms the medial portion of the veinlets, chalcocite being found on either side. The replacement origin of the chalcocite is indicated by its very irregular contact with the primary minerals. Its supergene character is suggested by the numerous transverse cracks which may represent shrinkage due to drying from a colloidal state.

Limonite (hydrated iron oxides). Limonite occurs in replacement veinlets cutting chalcopyrite and pyrite, and as clusters of radiating needles (goethite?) associated with the same minerals. Thomson (p. 40) recorded it as occurring fairly commonly as tiny veinlets or small inclusions in the gangue or other iron minerals. In addition to the section from Bankfield, a mineral identified as limonite was observed in several sections where it is the latest mineral present. It occurs as a hard grey mineral appearing grey by vertically reflected light.

Malachite ($\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$). A mineral occurring as clusters of radiating needles, grey by vertically reflected light, but brilliant green under crossed nicols or obliquely reflected light, was identified as malachite. It is later than limonite and chalcocite, which form a rim separating it from the unaltered chalcopyrite from which it was derived. Malachite is present in only minor amount, less than five per cent, in the one section in which it was observed.

CONCLUSION

The above extended descriptions of the metallic and major non-metallic minerals of the Little Long Lac area supplement the writer's earlier paper which is concerned, for the most part, with their age relationships. As a result of the study of the major sulphides the writer allocates the deposits to Lindgren's upper hypothermal, or lower mesothermal, zone. Instrumental observations made by F. Gordon Smith, at the University of Toronto, on pyrite from the Hard Rock mine indicate that it crystallized at temperatures lying within the range suggested for those zones.

REFERENCES

- ARMSTRONG, H. S., *Econ. Geol.*, **38**, 204 (1943).
BRUCE, E. L., *Ontario Dept. Mines, Ann. Rept.*, **44**, [3], (1935).

- , *Ontario Dept. Mines, Ann. Rept.*, **45**, [2], 118 (1936).
———, *Econ. Geol.*, **34**, 357 (1939).
———, AND SAMUEL, W., *Econ. Geol.*, **32**, 318 (1937).
CANADA, *Bureau of Mines*, No. **771**, 114 (1935).
———, *Bureau of Mines*, No. **774**, 4 (1936).
———, *Bureau of Mines*, No. **785**, 36 (1937).
———, *Bureau of Mines*, No. **805**, 156 (1939).
———, *Bureau of Mines*, No. **806**, 18 (1939).
JOHNSTON, A. W., Unpub. M.Sc. thesis, Dept. of Geol., Queen's Univ. (1935).
MORROW, H. F., Unpub. M.A. thesis, Dept. of Geol., Queen's Univ. (1940).
RIDLAND, G. C., *Econ. Geol.*, **36**, 45 (1941).
SCHNEIDERHÖHN, H., AND RAMDOHR, P., *Lehrbuch der Erzmikroskopie*, II (1931).
SCHWARTZ, G. M., *Econ. Geol.*, **32**, 31 (1937).
SHORT, M. N., *U. S. Geol. Surv., Bull.*, **914**, (1940).
THOMSON, ELLIS, *Univ. Toronto Studies, Geol. Ser.*, **38**, 37 (1935).