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ARCHEAN STRATIGRAPHY

AND ORE RELATIONSHIPS IN THE

Chibougamau district

by

Gilles Duquette

MINERAL DEPOSITS SERVICE

QUEBEC
1970

QUEBEC DEPARTMENT OF NATURAL RESOURCES

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A critical summary based on field studies

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ABSTRACT

This paper presents a summary of the Archean column in the Chibougamau district. The principal components of the rock column are identified and new generalizations are offered concerning the stratigraphy, structure and ore associations of the various rock units. Certain of these generalizations are thought to have application in the study of other Archean zones in the Superior Province of the Canadian Shield.

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INTRODUCTION

Geographycally located in the south central part of Quebec, the Chibougamau district is bounded roughly by longitudes 74° and 76°W. and latitudes 49° and 50°N. and covers an area of some 9,000 square miles in a block that measures approximately 120 miles in east-west length and 75 miles in width. Geologically, the district lies within, and at the eastern limit of the Superior Province of the Canadian Precambrian Shield; the Grenville Front, defined as being the contact zone between the Superior and Greenville Provinces of the shield, marks the eastern limit of the district.

Although most of the lithologic units of the stratigraphic column in the Chibougamau district belong to the Archean (approximately 2.5 billion years in age), there are a few minor units which are younger in age. These younger rocks include northeasterly striking diabase dikes and a few erosional remnants of flat-lying Proterozoic sedimentary rocks.

The Archean rocks trend in a general east-west direction and dip almost vertically. They fall within the greenschist or, less commonly, the amphibolitic facies of metamorphism. Petrographically, they can be subdivided into a "Greenstone Assemblage" composed of volcanic rocks and related mafic to ultramafic intrusions and a "Granitic Assemblage" of felsic plutonic rocks.

The greenstone assemblage is by far the more economically important in the district; of the 20 metallic mines found to date (1969) in the district, 18 mines (15 copper, 2 gold and 1 zinc-silver) occur in units of this assemblage. For this reason, the Quebec Department of Natural Resources commenced a programme of detailed (500 feet equal to 1 inch) geological mapping in 1950 the objective of which was first to cover the greenstone assemblage in which the known orebodies had been outlined and, following this, to cover the adjacent areas which are underlain, as well, by rocks of the granitic assemblage. The first phase of this programme was completed in 1958 and the second one is progressing well.

In the light of information obtained to date, new generalizations can be made concerning some aspects of the lithology and structure of the Archean column in the Chibougamau district. The accompanying geological compilation map incorporates some of these generalizations. It should be mentioned at this point that the stratigraphy and structure as shown on the map have been established from rocks exposed north of Chibougamau lake, and that, consequently, the suggested interpretation becomes more uncertain as the area becomes farther removed from the type locality. This applies particularly to the large and arcuate Kreighoff-Lesueur-Rohault-Dollier township area.

STRATIGRAPHY

GREENSTONE ASSEMBLAGE

VOLCANIC AND RELATED VOLCANO-SEDIMENTARY FORMATIONS (Roy Group)

North of Chibougamau lake, the volcanic portion of the greenstone assemblage has been divided into three units named, from top to bottom, as follows:

Blondeau Formation (Duquette, P.R. 513, p. 4)
Gilman Formation (Duquette, P.R. 551, p. 5)
Waconichi Formation (Duquette, P.R. 551, p. 4)

The Waconichi Formation

If one assumes that there is no important repetition as the result of folding or faulting, this lowermost formation would be close to 40,000 feet in thickness. It consists essentially of crystal and lithic tuff with minor breccia-conglomerate and agglomerate lenses and a few mafic lava flows and associated gabbro-diorite sills.

Tuff - By far the most abundant rock type in the formation, the tuff is generally gray to green and displays good bedding everywhere, the thickness of which is, as a rule, directly proportional to the grain size. The rock can be felsic or intermediate to mafic in composition.

The felsic variety, with quartz and sodic plagioclase representing more than three quarters of the rock volume, is the more common tuff. These two minerals are relatively fresh and euhedral although, in places, fragments of these mineral grains are visible. Such fragments are as a rule extremely angular and are believed to have been derived from collision between originally well-formed crystals. Other minerals present, by order of abundance, are chlorite, white mica, calcite or/and dolomite, and graphite. Where schistose, the tuff looks very much like a sheared quartz and feldspar porphyry. In the more massive variety one commonly sees angular blocks, up to 8 inches across, of chert-like tuff set in a haphazard fashion in a crystal tuff matrix.

Next in abundance is a very thinly laminated tuff carrying up to 40 per cent chlorite along with much plagioclase and very little or no quartz. This rock is obviously intermediate to mafic in composition and, where schistose, can easily be mistaken for a sheared andesite or basalt. This laminated tuff is particularly abundant at the very top and in the lowermost 10,000-foot section of the Waconichi Formation. As one

proceeds north across the formation and into higher grade metamorphic conditions, the contained chlorite is seen to be gradually replaced by hornblende needles.

Breccia-conglomerate - The breccia-conglomerate is essentially made up of pyroclastic material containing local concentrations of pebbles made up of leucodacitic porphyry and fine-grained granite(?). It is abundant in the core of the formation and is best exposed along the east shore of Sauvage lake in Vienne township (see the following section on Blondeau Formation).

Agglomerate - The agglomerate seems to be concentrated in the uppermost beds of the formation. It forms lenses which are very few number and are characteristically loaded with bombs of leucodacite porphyry measuring up to one foot in length. Having a long-to-short axis ratio of up to 10 or more, the bombs confer to the lenses a strong foliation which is everywhere oriented parallel to the local schistosity. Moreover, inasmuch as they weather white, these bombs stand in strong contrast to the enveloping dark-green chloritic matrix.

Flows and sills - Scattered throughout the Waconichi Formation are a few mafic lava flows and associated gabbro-diorite sills that are petrographically similar to those present in the overlying Gilman Formation which will be described in the following section. They are dominant, however, in the lower 10,000-foot section of the Waconichi Formation.

As yet, no type locality has been selected for the Waconichi Formation. It may be suggested, however, that the section following the Albanel road, east of Waconichi Lake, could be used as a provisional, if not a definitive type section. This section should also be compared and perhaps supplemented by part of the sequence exposed along Sauvage lake where granite-like and porphyry pebble conglomerates are found.

The Gilman Formation

Conformably above the Waconichi Formation and following a zone of interlayering, these lies a 12,000-foot sequence of well-pillowed lavas referred to as the Gilman Formation. Seldom exceeding 400 feet in thickness, individual flows have been calculated to measure, on the average, less than 200 feet in thickness. Composition-wise, they range from an andesite to a basalt. As a rule, the upper two-thirds and the lowest part of a flow are aphanitic to very fine grained, whereas the remaining central portion shows a fine- to medium-grained texture. Amygdules, vesicules, varioles, flow lines, and brecciated tops are present in many

flows, but pillows are the most common primary structures. These pillows occur in the upper portion of the flows and locally make up one-half of the volume of the individual flows.

The pillows are elongated everywhere parallel to the local bedding; in general their short axis id one foot in length, whereas the long one is about three feet. Characteristically, the top of a pillow is limited by a convexly curved surface, and the bottom is marked by rather flat surfaces showing a single, small and downward-pointing, V-shaped depression. The latter feature may be viewed as the result of sagging of the original spherical pillows when coming to rest on older ones. There is commonly a concentration of small (1/10inch) carbonate amygdules at the summit of the pillows. Such agmidules are also locally abundant at the top (upper 20 feet or more) of some pillowless flows, forming what is called "vesicular tops". The nearly constant presence of a thin band (usually less than 5 feet in thickness) of felsic tuff between each flow is most useful for determining the thickness of individual flows.

Gabbro-diorite sills, assumed to be intrusive equivalents of the enclosing lava flows, are present at various stratigraphic horizons in the Gilman Formation. They range from a few tens of feet to about 1,000 feet in thickness. The largest ones generally show evidence of crystal fractionation inasmuch as they carry quartz grains in their uppermost sections only.

In the northwest quarter of Roy township, the cuts on the road leading to Waconichi lake afford a nearly continuous section of the Gilman Formation. It would be logical to use this segment of the road as type locality for the formation.

The Blondeau Formation

Above the Gilman Formation lies a sequence of felsic pyroclastic rocks called the Blondeau Formation. This formation, interlayered at its base with the Gilman Formation, is more than 3,000 feet thick in the area north of Chibougamau lake, where it bears strong lithological similarities to the felsic fraction of the Waconichi Formation. Indeed, the most widespread rock type is a gray crystal and lithic tuff consisting essentially of sodic plagioclase, quartz, white mica, carbonate, chlorite, graphite and tiny rock fragments of felsic composition.

Included in the Blondeau Formation are lenses of breccia-conglomerate containing some granite-like pebbles and a more abundant quantity of porphyritic rhyolite or of light-colored porphyritic dacite pebbles. The lenses are particularly abundant at the latitude of Blondeau lake, where the pebbles measure up to 10 inches across and, for the most part, are of the "rhyolite or dacite" variety. This type of pebbles may represent fragments of beds of crystal tuff that would have slumped shortly

after deposition. In fact, the breccia-conglomerate lenses of the Blondeau Formation, as well as those of the Waconichi Formation, may be viewed as being essentially intraformational accumulations in which some explosive material would have been added. The provenance of the granite-like and true porphyry pebbles, particularly abundant in some of the lenses of the Waconichi Formation, is more problematic owing to the fact that these pebbles may be the product of either, or both, erosional and explosive processes. The intraformational nature of the majority of the conglomerate lenses in the Waconichi and Blondeau Formations is indicated by the fact that the conglomerate-breccia locally fills scour channels and contains abundant angular and non-oriented fragments of a fine-grained tuff clearly derived from underlying beds and possibly transported by turbidity-like currents. Depositional conditions of this sort would also be in accord with the fact that many contemporaneous deformational structures and graded series are seen in the vicinity of such lenses.

As a type locality for the whole Blondeau Formation, it is recommended to use the exposures along the 3,700-foot segment of the main road located immediately north of the regional synclinal axis shown on Map 1521 of the Q.D.N.R. (P.R. 513).

It is worth mentioning at this point that the distribution of rocks and fold axes in the Chibougamau district clearly indicates that the above three formations are of regional extent. The pyroclastic rocks of the Waconichi Formation can be traced in an east-west direction for some 80 miles; they may possibly extend beyond the Grenville Front at the eastern limit of the district. The upper two formations, on the other hand, can apparently be followed not only strikewise along the whole length of the Chibougamau district and beyond, but can also be correlated with a fair degree of certitude with like units exposed south of the Opémisca Lake and Chibougamau Lake felsic plutons.

In the writer's mind, the Blondeau Formation is correlative with Norman's and Beach's Opémisca and Pre-Opémisca "Series". Such a correlation would be untenable if the granite-like pebble conglomerates mapped by these two geologists in Lévy and Daubrée townships and at Deux Orignaux and La Trêve lakes indicate that an angular unconformity separates the two "Series". Detailed studies conducted by Wolhuter (1962) in the southeast quarter of Daubrée township have shown the possible inadequacy of Norman's and Beach's interpretation. Indeed, instead of finding a basal conglomerate along the presume angular unconformity, Wolhuter observed a series of granite-like and porphyry-like pebble conglomerate lenses, lithologically similar to those in the Blondeau Formation, distributed stratigraphically within a thickness extending several hundreds of feet above and below the presumed angular unconformity. Of perhaps greater significance is the fact that Wolhuter saw only one lens truncating the underlying rocks. This made him conclude that the "angular relationship" could easily be explained by the presence of a minor local intraformational unconformity. Keeping in

mind Wolhuter's results in Daubrée township, the writer is inclined to think that the outcrops of granite-like pebble conglomerate at Deux Orignaux and La Trêve lakes can also be interpreted as marking the presence of local intraformational unconformities rather than a single angular unconformity separating the "Series".

Pending evidence to the contrary, the writer feels justified in proposing a correlation of the rocks of the Blondeau Formation with those of the Opémisca and Pre-Opémisca "Series" outcropping east and west of Chapais. If such a correlation is valid, the Blondeau Formation in the area west of Chapais would have a thickness close to 10,000 feet.

Genesis of the Coniagas and Taché Lake Zinc Deposits

Associated with some of the felsic members of the above three formations, important stratiform deposits of massive sulfides have been outlined in various parts of the Chibougamau district. Quite characteristically these masses carry, as essential minerals, pyrite and pyrrhotite with which variable quantities of sphalerite and chalcopyrite are found. To date, however, only one such deposit turned out to be exploitable. Reference is made here to the zinc-silver orebody which is located just west of Bachelor lake in Lesueur township and which has been mined out by Coniagas Mines during the 1961-1967 period. According to the writer's interpretation of the local stratigraphy, this deposit would lie near the Gilman-Blondeau formational interface. It must be stressed, however, that this is far from being an established fact.

Lithologically, texturally and structurally speaking, the Coniagas orebody looks very much like other well-known stratiform zinc ore deposits in the Superior province, such as the Mattagami Lake, Texas Gulf, East Sullivan, Lake Dufault, Normetal and Deldona deposits, as well as some others in the Appalachians, namely the Buchans, Brunswick, Solbec and Cupra ore deposits. Because all these sulfide orebodies are now generally considered as volcano-exhalative deposits it seems reasonable to propose a similar hypothesis in ragards to the genesis of the Coniagas deposit. Thus sulfide deposition at Coniagas may be seen as an event older than the Kenoran period of folding. Such an age relationship is in accord with the folded nature of the Coniagas sulfide lenses and with the occurrence in some of these lenses of a crush conglomerate made up of felsite pebbles set in massive sulfides. These pebbles, here seen as being derived through the shearing and fragmentation of thin felsitic tuffs which were originally interbedded with layers of massive sulfides, have always been described erroneously as bombs of an agglomerate whose matrix had been completely replaced by sulfides.

Another massive sulfide deposit worth mentioning is the one explored by Taché Lake Mines just north of Berrigan lake in McKenzie township. Located stratigraphically at the very bottom of the Blondeau Formation,

this deposit carries, apart from sphalerite veinlets, appreciable quantities of gold-bearing iron sulfides. The sulfide distribution (veins) and the wall-rock alteration (heavy chloritization) are reminiscent of the features which characterize the mineralized chimneys underlying the typical stratiform volcano-exhalative sulfide deposit. If such an interpretation is correct, one should search for a stratiform zinc-gold deposit in the vicinity of the known Berrigan lake deposit. It is worth mentioning that the best horizon to explore for that purpose is perhaps the pyroclastic band flooring the Bourbeau Sill. Indeed, north of the Opémisca and Chibougamau lakes, as well as in Lévy township, the largest stratiform zinc (and copper) sulfide deposits practically all occur along that horizon which likely bears witness to a major metallogenic epoch.

INTRUSIVE FORMATIONS

The greenstone assemblage includes not only volcanic and related volcano-sedimentary rocks but also a great variety of conformable intrusive bodies which are mafic to ultramafic in composition. These rocks were emplaced prior to the Kenoran period of folding and may be regarded in relation with the mafic lavas and the ultramafic rocks of the district as the product of a single cycle of igneous activity.

Mafic Intrusions

Although present at various stratigraphic horizons in the greenstone assemblage, the mafic intrusions are most abundant in the andesite-basalt sequence of the Gilman Formation and in the lower pyroclastic beds of the overlying Blondeau Formation. Dioritic to gabbroic in composition, they all occur as silt-like bodies and are regarded as hypabyssal equivalents of the mafic lavas. Some of the sills have a uniform composition throughout, whereas others are composed of different rock types that grade into one another and range in composition from that of a peridotite to that of a white micropegmatite. In the latter type of sills there is everywhere an orderly arrangement of the various lithological units with ultramafic rocks at the bottom and felsic ones at the top. This distribution, which is clearly the result of gravitational differentiation during crystallization, is best displayed in the larger sills such as the "Lac Doré complex", the "Ventures Sill" and the "Bourbeau Sills".

Lac Doré complex

This complex, which is the largest layered mafic intrusion in the whole district, occurs at the very bottom of the Gilman Formation. It is composed of an anorthositic suite of rocks curving around the northeast end of Chibougamau lake. According to Allard (1967) the exposed section of this complex is over 12,000 feet thick and is made up, from bottom to top, of the following units: meta-anorthosite, gabbroic meta-anorthosite, anorthositic metagabbro, metagabbro, magnetite-rich metagabbro and metapyroxenite, tonalite and mylonitized gabbro (chilled margin?). Since the lowermost

(stratigraphically) exposed unit is everywhere an anorthosite and not, as one would expect, a sequence of rocks such as dunite, peridotite, norite, etc., the writer believes that a large part (bottom) of the Lac Doré complex lies hidden somewhere, presumably below the Chibougamau pluton (see composite cross-section on the accompanying map). It is also interesting to note that regional mapping indicates the Lac Doré complex to be a possible correlative with the anorthositic complex exposed in La Ronde township, some 15 miles east of Desmaraisville. If so, the Lac Doré complex would have a length of close to 100 miles.

Ventures Sill

This sill lies stratigraphically at the very bottom of the Blondeau Formation. Best exposed in Lévy township, where it is the host rock of the Opemiska Copper Mines orebodies, it has been traced to the west, into Daubrée township, over a strike length exceeding 12 miles. It also crops out north of Opémisca lake from where it can be followed right up to the Grenville Front, some 30 miles farther east. It may also be correlative with like rocks present in the central part of Kreighoff township, some 50 miles west of Chapais. Thus the Ventures Sill has a regional extent comparable and possibly even greater than that of the Lac Doré complex.

Throughout its length, the Ventures Sill is seen to be made up of two units: an upper, coarse-grained ophitic gabbro (Ventures gabbro) locally more than 1,500 feet thick and a lower, black to green pyroxenite up to 1,800 feet thick. In underground workings at the Opémisca mine, the lower 200- to 500-foot section of the "Ventures" gabbro and the upper 300-foot portion of the pyroxenite show widespread rhythmic layering caused by a cyclic repetition of thin bands of gabbro and pyroxenite (Derry, 1955). Such interlayering clearly indicates that both units have probably been derived from a single magmatic intrusion which has differentiated in situ.

Bourbeau Sill

The Bourbeau Sill occurs in the lower pyroclastic rocks of the Blondeau Formation and thus, stratigraphically, a little above the Ventures Sill. It has been traced for some 25 miles across the central part of McKenzie, Roy and McCorkill townships, north of Chibougamau lake. It shows, in its thickest section, the following lithological sequence: at the bottom, a discontinuous peridotite layer less than 75 feet thick; next above, a feldspathic and equigranular leucogabbro unit, some 1,100 feet thick, in which primary foliation and rhythmic layering can occasionally be seen; and, in the upper part, an ophitic quartz gabbro layer, more than 1,200 feet thick, which locally grades upwards into a light gray sodic micropegmatite. From the evidence at hand, the Bourbeau Sill could be correlative with the canoe-shaped body of mafic rocks exposed in central Cuvier and Barlow townships, with the two bands of similar rocks bordering the regional synclinal axis west of Chapais and some of the mafic rocks in

Kreighoff township. If so, it would extend over a strike length exceeding one hundred miles and would therefore constitute, like the Lac Doré complex and the Ventures Sill, one of the best horizon markers in the whole district.

Ultramafic Intrusions

These intrusions, which roughly correspond to Smith's Ultrabasic Complex (1960, p. 15), are concordant masses of gray clinopyroxenite and serpentinized peridotite and dunite. Except for the possible occurrence of a thin and discontinuous band 20 miles west of Chapais and a few other smaller bodies, all these masses are confined to an east-west-trending belt that extends from the northern tip of Opémisca lake to the Grenville Front, a distance of 45 miles. Although the various lithological bands of ultramafic rocks of the belt have, to date, been interpreted as being separate intrusive bodies, recent detailed mapping by the author has shown that most of these separate bands occur along the same stratigraphic horizon and at a position equivalent to the contact line between the Gilman and Blondeau Formations or, more precisely, immediately below the Ventures Sill horizon. Thus, most of the ultramafic bodies in Chibougamau would belong to a single sill nowhere exceeding 1,800 feet in thickness. That sill is here referred to as the "Roberge Sill".

Some of the largest ultramafic bands constitutive of the Roberge Sill have a well exposed pyroxenitic rim and a drift- or water-covered metaperidotitic core. These rocks commonly exhibit a primary banding, defined by textural or mineralogical variations, which parallels the local foliation in the adjacent country rock. Most of them are believed to be "cumulates". In some of the peridotites, for instance, serpentinized olivine grains are commonly poikilitically enclosed in pyroxene crystals.

Petrologically the Roberge Sill appears to be intimately related to the Ventures and Bourbeau Sills. As mentioned previously, this sill (peridotite-pyroxenite) lies immediately below the Ventures Sill (pyroxenite-gabbro) which is, in turn, a little below the Bourbeau Sill (gabbro). Such an orderly lithological sequence can, of course, be fortuitous but it more likely indicates a strong magnetic relationship between the three sills. It is possible, for instance, to view the Roberge Sill as having been derived through crystal fractionation of a basaltic magma which would have been, in its early stage of crystallization, expelled slightly higher up into the volcanic pile leaving behind olivine and pyroxene cumulates. The squeezed out liquid could then have collected into a new chamber, to day represented by the Ventures Sill from which it would have been, before final consolidation, expelled once again into a still higher chamber corresponding this time to the Bourbeau Sill. Obviously, in such a process, some fresh basaltic magma could have been added to the residual liquids while moving from one chamber to another.

GRANITIC ASSEMBLAGE

The rocks of the "Granitic Assemblage" are most important from a point of view of volume, as they underlie more than one half of the Chibougamau district. Petrographically, most of them belong either to a tonalite-diorite or to a granodiorite suite of rocks.

THE TONALITE-DIORITE SUITE

Most of the large granite bodies in the Chibougamau district are made up of rocks of the tonalite-diorite suite, with tonalite predominating in the core and diorite in the rims. Quite characteristically, the tonalite-diorite intrusions conform to the regional structures of the enclosing country rock. They show, in addition, good gneissic and cataclastic structures produced, respectively, by the alignment of mafic minerals (biotite, chlorite, hornblende) and the granulation and elongation of quartz grains. These structures, which are parallel to similar structures in the adjacent country rock, indicate that most of the intrusions were probably emplaced into the volcanic pile as concordant bodies (laccoliths, phacoliths, etc.) at a time prior to the Kenoran period of folding. Moreover, being essentially oligoclase granites with very little perthite or microcline, these intrusions are rather similar mineralogically to the district pyroclastic rocks and may be viewed therefore as their hypabyssal counterparts.

The Chibougamau pluton (Allard, 1969, p. 4), underlying lake Chibougamau, is an excellent example of the Tonalite-Diorite Suite.

THE GRANODIORITE SUITE

The rocks of the granodiorite suite carry large amounts of both oligoclase and potassic feldspar and form bodies fewer in number and generally much smaller in size than those of the tonalite-diorite suite. Commonly showing highly irregular outlines, being in many places elongated across the trend of the local country rocks and carrying very little evidence of mechanical deformation, they may very well represent post-kinematic (post-Kenoran) intrusive rocks. A good example is the granodiorite pluton outcropping on both sides of the Vienne-Blaiklock township line. Unfortunately, this intrusion has not yet been dated by radiometric means. Another good example would be the Opémisca pluton underlying Opémisca lake and recently studied by Wolhuter (1968).

COPPER ORE GENESIS

In spite of the fact that the rocks of the granitic assemblage do not carry important concentrations of base-metal sulfides, they are, nevertheless, locally mineralized (e.g. Grandroy deposit, Roy twp.) and appear to have played an important role in the formation of the deposits found in the greenstone assemblage.

Considering that virtually all copper ore occurring within the Doré Lake complex lies along or near dike material issued from the nearby Chibougamau Lake Pluton (tonalite-diorite) and considering also that the Pluton emplacement and the sulfide mineralization can be interpreted as being pre-folding (Kenoran) events, one can conclude with a fair degree of certitude that copper mineralization in the Doré Lake-Chibougamau Lake basin is genetically related to the Chibougamau pluton.

A genetic relationship could also exist between the Opémisca Copper Mines orebodies and the adjacent granodioritic Opémisca pluton. Indeed, the sulfide zones of the Ventures Sill are contained, in all cases, in late structures of post-Kenoran age which, as mentioned previously, also appears to be the age of the granodioritic plutons in the district. In addition, some of the Opemisca ore zones carry scheelite and molybdenite or syenitic and granodioritic material logically all derived from the nearby Opémisca pluton.

STRUCTURAL GEOLOGY AND COPPER ORE RELATIONSHIPS

FOLDING

The regional structure of the Chibougamau district can be viewed as a synclinorium comprising a series of isoclinal and symmetrical folds plunging a few degrees east or west (see composite diagrammatic cross-section on accompanying map). The synclinorium, which is more than 120 miles long and 50 miles wide, was probably formed during the Kenoran period of folding, some 2.5 billion years ago. To the east, it includes the Chibougamau anticline bordered by two major synclinal structures (the Chibougamau and Chapais synclines) the axes of which are about 20 miles apart; to the west, it consists of a single syncline issued from the merging of these two synclines. To the south, the rock distribution would indicate the presence of a large anticline the axial trace of which, although not yet located with accuracy, would be parallel to those of the above folds.

As it is commonly the case in the Superior Province, a gross correlation between lithology and folding exists in the Chibougamau district. Thus, major anticlinal zones are usually underlain by rocks of the granitic assemblage, and the intervening synclinal zones are occupied by rocks of the greenstone assemblage.

The rocks of the greenstone assemblage generally show a well-developed, nearly vertical schistosity which is oriented parallel to the axial plane of the regional folds. Moreover, it is not uncommon to find crenulations that plunge steeply down the dip of these schistosity planes. This warping of the schistosity along nearly vertical axes, coupled with the frequent changes of plunge direction of the regional and near-horizontal fold axes, as evidenced by the abundant canoe-shaped structures in the

district, lead one to infer that during or after the Kenoran period of folding the rocks of the greenstone assemblage were subjected to strong compression working in a general east-west direction. Such cross-folding could account for the two large, nearly vertical folds which have been outlined in the north-central part of Daubrée township and in the southwest part of Lévy in which are located the Opemisca Copper Mines orebodies. It would also be compatible with such an interpretation that these two structures be downward pointing conical folds.

SHEARING AND FAULTING

Three major directions of shearing or fracture are known in the Chibougamau district. Several strike faults have also been mapped.

NORTHEAST SET

A first set of shears and fractures strikes northeast and includes several regional faults such as the Gwillim Lake fault, the Doré Lake fault and the McKenzie Narrows fault.

The Gwillim Lake fault, which has been traced over a minimum distance of 60 miles, runs vertically through the Opemisca Copper Mines property where it is represented by a chlorite-carbonate-quartz shear zone measuring up to several hundred feet in width. A left-hand strike separation of the order of 1 mile has been observed at this locality.

The Doré Lake fault, some 9 miles east of the Gwillim Lake fault, consists of a sericite (paragonite)-chlorite-quartz-carbonate shear zone that passes through the Lac Doré complex and dips to the west at an average angle of 55 degrees. Because all the copper mines in the Doré Lake - Chibougamau Lake area occur on either side and within 4,000 feet of this fault, it has always been regarded as one of the most important structural features related to the deposition of copper ore in the district. New evidence indicates, however, that faulting and shearing could have taken place a long time after the period of copper mineralization in the Doré Lake area.

The McKenzie Narrows fault is considered by some geologists (Graham, p. 17) as being the northerly extension of the Doré Lake fault. At McKenzie narrows, just north of Portage island, this fault is represented by a nearly vertical shear zone measuring several hundred feet in width and carrying chlorite, sericite, quartz, carbonate, and locally talc, as essential minerals. The volcanic rocks adjacent to the fault show a right-hand strike separation of the order of 1 mile.

It is worth mentioning that the important copper orebodies at the Portage and Henderson mines, located along the east shoreline of Portage island, are contained in a shear zone striking parallel to the Doré Lake fault but dip 45° to the east.

WEST-NORTHWEST SET

A second set of shears strikes west-northwest. These are steeply dipping and closely spaced zones of intense shearing and carbonatization as well as of sillicification and of sulfide mineralization. Individual shears vary in width, pinch and swell, forming lenticular zones of all sizes. It must be noted that most copper orebodies in the Doré Lake basin occur along such west-northwest-striking shears. According to some geologists, these ore-bearing shears represent complementary structures to the Doré Lake fault. Although a structural relationship may exist between these shears and that fault, it does not follow necessarily that shearing along those zones in a pre-ore event. In fact it is more likely a post-ore event, first because the sulfides in those shears appear everywhere to be highly deformed as evidenced by slickensides and recrystallization, and secondly because all major ore zones in the Doré Lake area regain a nearly vertical orientation when the host anorthositic sill (Lac Doré complex) is rotated to its pre-folding position. These facts, to the writer's mind, are strong arguments in favor of an hypothesis calling for sulfide deposition as a pre-folding (pre-Kenoran) event. For instance, sulfide deposition could have taken place shortly after the emplacement of the dikes related to the Chibougamau pluton and along essentially the same, nearly vertical tension fractures as the one already used by the dikes. These fractures would have developed in the anorthositic sill then roofing flatly the recently emplaced Chibougamau pluton. On the other hand, the rotation, tilting and shearing having affected not only the sulfide-bearing zones but also every other nearby fracture and fault such as the Doré Lake fault would be, according to this hypothesis, events contemporaneous with the Kenoran and/or a younger period of deformation.

NORTH SET

A third set of shears strikes a little east of north and commonly shows a left-hand strike separation. The gold-bearing quartz veins exploited by Norbeau Mines in McKenzie township are good examples of this set. Here, the nature of the slickensides in the quarts material and the angular relationships between the quartz veins (dipping about 45° east) and the wall-rock schistosity (vertical) tend to prove that the Norbeau veins are lying along thrust faults later converted to normal faults. Such an interpretation would, of coarse, become untenable if one were to prove that mineralization took place before the regional folding. The Mistassini Lake fault in Bignell and O'Sullivan townships and the swarm of parallel breaks in Rinfret and McCorkill townships marking the contact zone between the Superior and Grenville Provinces are also grouped in this third set of shear zones. It is well to note that these Grenville Front fractures and fault are clearly younger than the Kenoran period of folding.

STRIKE FAULTS

Several strike faults (or bedding faults) with very large displacements have been mapped in the area. Some of the largest strike faults occur at the contact of, or within ultramafic rocks.

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