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PETROLOGY, GEOCHEMISTRY AND WALLROCK ALTERATION AT OPEMISKA - A VEIN COPPER DEPOSIT CROSSCUTTING A LAYERED ARCHEAN ULTRAMAFIC-MAFIC SILL

by

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of the requirements for the degree of
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ABSTRACT

The ore deposits at the Opemiska Mine consist of several major chalcopyrite-bearing veins which transect mainly the gabbroic portions of the Ventures Sill, a layered Archean ultramafic-mafic complex near Chibougamau in northern Quebec. The Opemiska deposits yield Cu, Au and Ag, but also contain significant amounts of MoS_2, WO_3 and locally, Zn and Ni. Quartz is the most abundant non-metallic constituent. The Opemiska veins are similar in many respects to other vein Cu and Au deposits in the Chibougamau district and appear to have unusual structural and metallogenic features. Other sulphide deposits in ultramafic and volcanic rocks of the area may be metallogenically related.

The wallrocks of the Opemiska veins were studied to investigate what geochemical and mineralogical alteration has occurred as a result of vein emplacement. This approach was intended to investigate the source as well as the mode of emplacement of the different components in the veins. To accomplish this, the petrology and geochemistry of the ultramafic-mafic host rocks were studied both in the mine area and in another area 20 miles distant where there is no known vein mineralization. Analyses of major and minor elements in the whole rock as well as microprobe analyses of clinopyroxenes were utilized to investigate the crystallization history and element distribution in the host Ventures Sill.

These analyses suggest that the Ventures Sill formed by fractional crystallization of tholeiitic basalt. The intrusion was probably synvolcanic and appears to have received a number of influxes of fresh basaltic magma during formation of the lower ultramafic cumulates. The Ventures Sill is one of two or more related layered igneous "complexes" which range from dunite to quartz diorite in composition and appear to have formed by "igneous sedimentation", with expulsion of residual magma into successively higher magma chambers. The rocks have subsequently been metamorphosed to the greenschist facies.

The disseminated sulphide mineral assemblage in the Ventures Sill in the mine area consists of sulphur-rich phases, particularly pyrite, and includes millerite, chalcopyrite, pyrrhotite, pentlandite and linnaeite-group minerals. This contrasts markedly with the assemblage in the Sill remote from the mine which is distinctly sulphur-poor and includes heazlewoodite, bornite, chalcocite, digenite, and pyrrhotite as well as chalcopyrite, pentlandite, millerite and linnaeite. The geochemical results indicate that Cu, S, K_2O, H_2O and CO_2 were metasomatically introduced into the Ventures Sill wallrocks near the veins, but that SiO_2 and possibly Fe were derived locally from the walls of the veins, whereas Ni and Co appear to have originated in the ultramafic rocks. The alteration mineralogy suggests that the veins were emplaced prior to greenschist facies metamorphism in the host rocks. It is concluded that the veins formed by sub-volcanic hydrothermal activity accompanying late-stage Archean felsic volcanism and plutonic intrusion and may be temporally related to Cu-Zn mineralization in the felsic volcanics. A parallel can be drawn between this relationship and that shown between the Neogene polymetallic veins and temporally related Kuroko deposits in the Green Tuff region of Japan.

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some of the figures, and the author's wife, Sally, typed and attempted to edit the manuscript and assisted with some of the drafting. Mrs. Shirley Watt typed the second and final drafts of the thesis.

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CHAPTER I

INTRODUCTION

A. Statement of the Problem

The Opemiska deposits consist of a number of copper-bearing veins that cut across a layered Archean ultramafic-mafic intrusion known as the Ventures Sill. The veins are mined for Cu, Ag and Au contained in chalcopyrite and minor native gold. The major gangue minerals in the veins are quartz, calcite, stilpnomelane, biotite and pyrite. Pyrrhotite, magnetite, sphalerite, scheelite and molybdenite are less abundant and irregularly distributed. Pentlandite has been identified in veins crosscutting ultramafic rocks.

Ore grade mineralization is confined to the Ventures Sill, although short extensions of the vein structures, still carrying chalcopyrite, continue into the stratigraphically overlying rhyolites. Other sulphide deposits in the Opemiska Mine area (Figs. 1, 2) include: a number of Cu-Zn showings in felsic volcanic rocks, volcaniclastic and chemical sediments stratigraphically overlying the Ventures Sill; Au-Cu veins in the gabbroic Bourbeau Sill (S560, Chiboug copper zone); the conformable Astoria iron-sulphide deposit which occurs in volcanic rocks of the Gilman Formation; nickeliferous pyrrhotite-chalcopyrite "stringers" in the lower ultramafic part of the Ventures Sill. It seems probable that the spatial proximity

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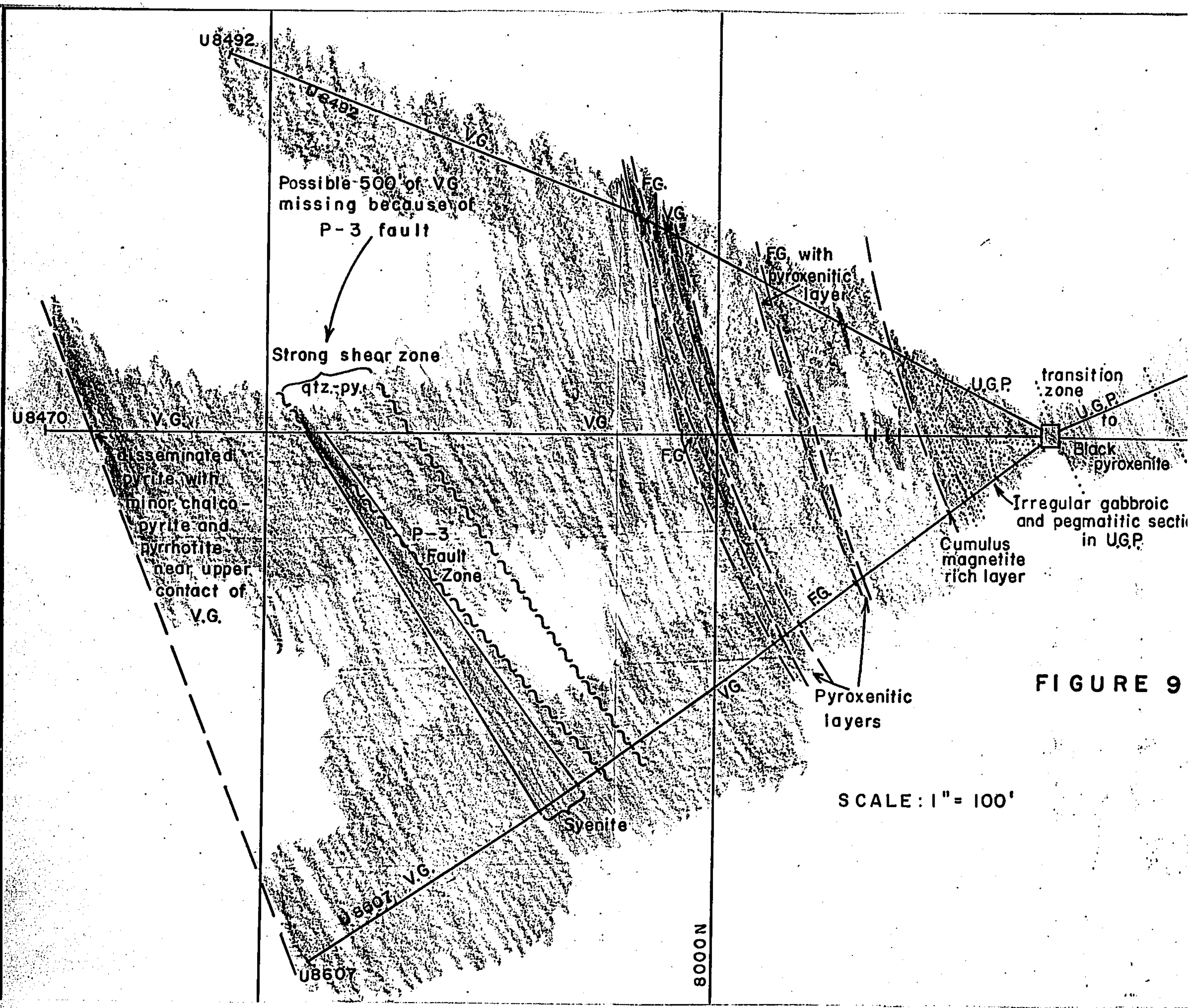
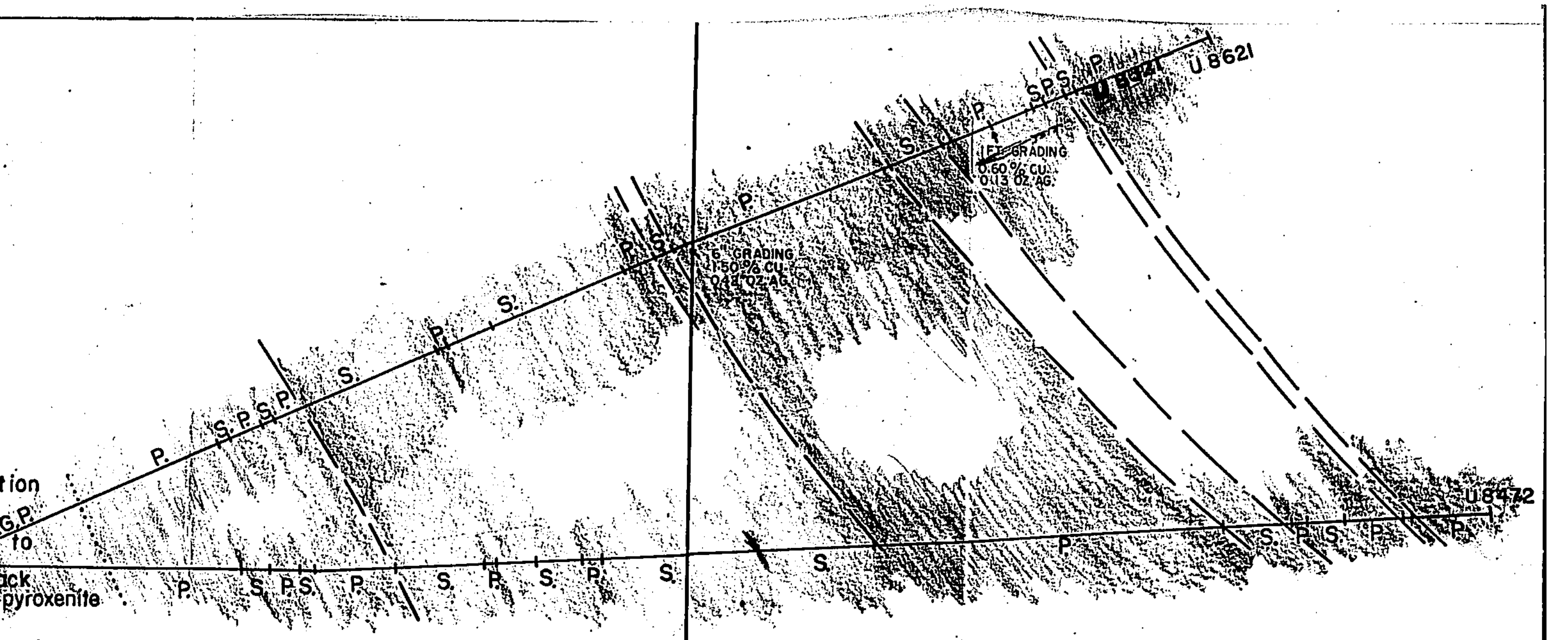


FIGURE 9

SCALE: 1" = 100'



GEOLOGICAL CROSS SECTION, SHOWING ROCK TYPES AND CORRELATIONS

SECTION 9700E, 901 DRIFT PERRY MINE

URE 9 (to accompany thesis by R.H. MCMILLAN 1972)

	▨	Syenitic Dykes
	■	Ventures Gabbro
	F.G.	Foliated Gabbro (gabbroic sections in U.G.P.)
	UGP	Upper Green Pyroxenite (pyroxenitic layers in gabbro)
Black Pyroxenite Unit	S	Dunitic, Wehrlitic Layers (now serpentine)
Black Pyroxenite Unit	▨	Clinopyroxenitic Layers
	☐	Rhyolite

of some of these various sulphide deposits results from common metallogenic factors.

The general geological setting, mineralogy and geochemistry of the Opemiska deposit suggested that it might have genetic links between three different important mineral deposit types; firstly, conformable volcanogenic Cu-Zn deposits, secondly, Cu-Ni segregations in layered ultramafic-mafic sills, and thirdly, epigenetic (endogenous) hydrothermal Cu (Mo-W) deposits. It was hoped that a study of the genesis of the Opemiska deposit would provide information regarding the partitioning of copper into these three contrasting ore types.

Study was concentrated on the wallrocks of the Opemiska veins to determine what geochemical and mineralogical alteration had occurred during vein emplacement. Six detailed underground traverses (Figs. 3-8) perpendicular to the veins but subparallel to the strike of the Sill were mapped and sampled in detail and later studied in the laboratory by petrographic and chemical analyses. In addition, two sections across the Ventures Sill were sampled and studied in order to establish the petrology and geochemistry of the host rocks remote from sulphide mineralization. One of these was in the mine area along 901 drift (Fig. 9) but remote from any known orebodies. The other was 20 miles east of the mine area near Lac Cummings (Fig. 10). Finally, surface and underground exposures and drill core from the Opemiska veins as well as the other different types of mineralization in the Opemiska Mine area were examined.

The wallrock alteration study was designed to investigate the genesis, relative timing and source of the mineral constituents from three aspects. Firstly, the three major ore types named above have different but characteristic wallrock-sulphide ore relationships. Secondly, sulphides, particularly chalcopyrite and pyrrhotite, are susceptible to plastic deformation and recrystallization under conditions of low grade metamorphism and their structural control most often appears to have resulted from the latest tectonic and/or metamorphic overprint. If a characteristic alteration mineral assemblage could be linked to ore genesis, this assemblage might survive subsequent metamorphic episodes and provide information regarding primary sulphide deposition. Thirdly, it was hoped that a geochemical study would show whether the various vein components were part of a primary magmatic mineral suite and the veins consequently some kind of magmatic segregation, or whether they were epigenetic, and if epigenetic, whether they were laterally secreted from the wallrocks or introduced from some outside source.

B. Location

The Opemiska Mine is located at Chapais (Figs. 10, 11), a small company town, 28 miles west of Chibougamau, Quebec. The town in 340 miles by road north of Quebec City and 224 northeast of Val D'Or. The CNR rail line connects Chapais and Chibougamau with other lines at Senneterre in the west and the Lac St. John area in the south. Nordair and Fecteau air services provide air links to the D.O.T. airport located a few miles south of Chibougamau. There is also a small gravel air strip immediately south of the town of Chapais.

C. History of the Opemiska Mine

The Opemiska deposits were discovered in 1929 by the late Leo Springer and his associates of Prospectors Airways Limited, following observation

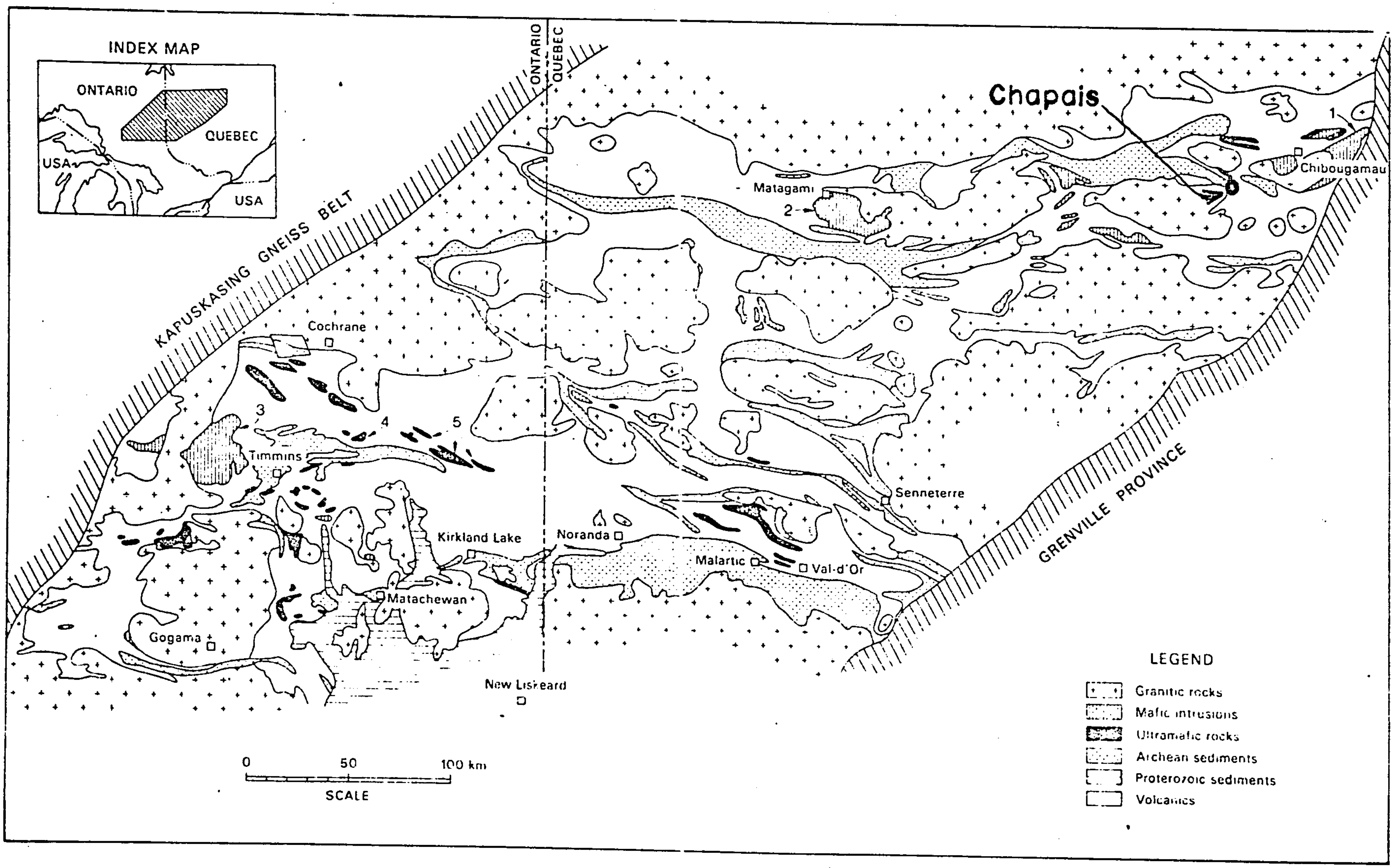


Figure 11. Geology of the Abitibi orogenic belt by Naldrett (1972) after Goodwin and Ridler (1970).

from the air of an area of dark coloured rocks in newly burned over country. Ground prospecting resulted in the discovery of three high grade, chalcopyrite-bearing veins of the Springer Vein system. After several seasons of diamond drilling and trenching financed by Ventures Ltd., a shaft was sunk in 1936, and underground exploration indicated about 280,000 tons of ore grading six percent copper ore to a depth of 500 feet. Owing to lack of transport and the prevailing low price of copper, work was suspended and the property remained dormant until 1951. In that year a new exploration program was begun which located the large No. 3 Vein, and the indicated reserves were increased to about 1 million tons. Shortly after production had started in 1954, the Perry vein system was discovered and more recently the Robitaille vein in 1962.

Production started at 400 tons per day, and has gradually been increased to the present rate of approximately 3,000 tons per day. Most of the production of the mine to date has come from the No. 3 Vein system, but at present the No. 3 Vein is nearing exhaustion, with production being shifted to the Perry veins.

Total production to the end of 1968 was 7,945, 580 tons averaging 3.12% Cu, 0.030 oz. Au and 0.464 oz. Ag per ton (Duquette, 1970). Reserves as of January, 1969 were 7,200,000 tons grading 2.90% Cu. Au and Ag contents in these reserves are considerably less than in the mined ore because, unlike the No. 3 Vein, the Perry and Robitaille vein systems that account for most of the reserves have smaller contents of precious metals.

CHAPTER II

GENERAL GEOLOGY OF THE CHAPAIS-CHIBOUGAMAU AREA

A. General Statement

The Opemiska Mine lies within but near the southeastern limit of the Superior Province of the Canadian Shield, approximately 25 miles northwest of the Grenville Front. The Archean rocks of the area constitute the easternmost extension of rocks of the Abitibi orogen (Fig. 11) of Goodwin and Ridler (1970). The Abitibi orogen is a Keewatin "greenstone" belt, composed of a synclinorium of volcanic, sedimentary and hypabyssal intrusive rocks infolded between granulites and migmatites. The orogen is the largest, southernmost and possibly youngest (Krough and Davis, 1971) of a number of east-west trending "greenstone" belts in the Superior Province. Recent radiometric age dates from zircons by Krough and Davis (1971) indicate ages of approximately 2,750 to 2,800 million years for volcanic and probably coeval granitic rocks within the Abitibi "greenstone" belt.

The geology, structure and ore relationships in the Chapais-Chibougamau district were recently reviewed by Duquette (1970), who has compiled the regional geology at 1 inch = 4 miles (Fig. 10, in pocket) based largely on detailed 1 inch = 500 ft. mapping done by the Quebec Department of Mines, and earlier Geological Survey of Canada mapping. Earlier reviews on the geology of the district were published by Norman (1948) and Graham (1957).

B. Stratigraphy

The oldest layered rocks of the area (Fig. 10) are Archean in age and have been designated as the Roy Group (Duquette, 1970), which is divided into three formations. The lowest, called the Waconichi Formation, is composed largely of pyroclastic rocks. Duquette believes the Waconichi Formation to be close to 40,000 feet thick, composed largely of crystal and lithic tuffs, minor breccia and agglomerate lenses, a few mafic lava flows and associated gabbro-diorite sills.

The second formation, the Gilman, conformably overlies the Waconichi Formation, is composed largely of mafic pillowed lavas, and is apparently 12,000 feet thick. The individual flows are mainly basaltic and average less than 200 feet thick, rarely exceeding 400 feet. This formation also contains minor felsic extrusive rocks and tuffs and is intruded by gabbro-diorite sills ranging from a few tens of feet to 1,000 feet in thickness.

The uppermost formation, the Blondeau, is composed mainly of felsic volcanic rocks and volcaniclastic sediments, and is 3,000 or more feet thick. According to Duquette (1970), the most common rock type is a grey crystal and lithic tuff composed of sodic plagioclase, quartz, white mica, carbonate, chlorite, graphite and fine felsic lithic fragments. Also included in it are lava flows, greywackes, breccia-conglomerates, graphitic argillites and cherts. Toward the base of the Blondeau there are intercalations of mafic volcanic rocks and mafic sills. Duquette includes within the Blondeau Formation the felsic rocks of the Opemiska and Pre-Opemiska Series as earlier defined in the Opemiska area by Norman

(1941) and Beach (1941). The Blondeau Formation thickens to more than 10,000 feet west of Chapais.

These Archean rocks are tightly folded and have undergone metamorphism to greenschist and locally amphibolite facies. They are unconformably overlain by relatively fresh gently dipping Lower Proterozoic clastic sediments (conglomerates, arkoses, wackes and siltstones) of the Chibougamau Formation which are considered now to be of glacial and paraglacial origin (Long, 1972, pers. comm.), and by dolomites and iron formation of the Mistassini Group.

C. Conformable Intrusive Rocks

As mentioned above, numerous gabbro-diorite sills intrude the predominantly volcanic rocks of the Roy Group. These are chemically similar to, and apparently have been folded with the volcanic rocks suggesting that they are intrusive, co-magmatic equivalents of the volcanic rocks. Some of the thicker sills show evidence of compositional fractionation, and contain quartz in their uppermost sections.

In addition to these minor sills, four thicker sills of regional extent have characteristic lithologies. The largest of these, the Lac Dore Complex is located near the base of the Gilman Formation. According to Allard (1970), its lowest exposed rocks are coarse anorthosites and anorthositic gabbros that grade upward through a layered pyroxenite-gabbro-anorthosite zone to an upper sodagranophyre zone (Allard, 1972, pers. comm.). Although the base of the intrusion is apparently not exposed, the exposed portion is about 20,000 feet thick.

According to Duquette (1970), the Roberge Sill consists of a semi-continuous series of ultramafic bodies which is exposed for 45 miles, from north of Opemiska to the Grenville Front (Fig. 10). It is 1800 feet or less in thickness. Duquette (1970) recognized "primary banding" or igneous layering (Wager and Brown, 1968) and "augite crystals poikilitically enclosing serpentinized olivine" or an olivine heteradcumulate (Wager and Brown, 1968), and suggested these rocks might be "cumulates".

The ultramafic-mafic Ventures Sill lies above the ultramafic Roberge Sill and is also concordant. This sill crops out semicontinuously for 45 miles, from north of Lake Opemiska east to the Grenville Front (Fig. 10) and also south of the Opemiska Lake Pluton. Similar rocks also crop out along the same stratigraphic horizon as far as Kreighoff township 50 miles west of Chapais. Duquette (1970) recognized two units in the Ventures Sill, an upper, coarser grained ophitic gabbro (Ventures Gabbro) locally more than 1500 feet thick, and a lower black to green pyroxenite. Although in places the Roberge and Ventures Sills are separated by a narrow band of rhyolitic rocks as in the "Rockefeller" area three miles NW of the Mine (Fig. 2), no volcanic rocks separate them at the Opemiska Mine, nor is there any evidence of chilled contacts within the ultramafic sequence. Because of this difficulty in distinguishing the Ventures and Roberge Sills at Opemiska, in this study the complete layered sequence is called the Ventures Sill and probably includes some ultramafic rocks which Duquette would have separated as belonging to the Roberge Sill.

The fourth major intrusion, the Bourbeau Sill, lies in the lower pyroclastic rocks of the Blondeau Formation, a few hundred feet stratigraphically above the Ventures Sill. It is equally as extensive as the Ventures Sill, and consists of a lower discontinuous pyroxenitic layer less than 75 feet thick, overlain by a thousand feet of feldspathic and equigranular leucogabbro, locally called epidiorite, which occasionally shows igneous lamination and layering. This unit is in turn overlain by 1200 feet of ophitic quartz gabbro which in places grades upward into a light grey sodic "micropegmatite".

D. Plutonic Rocks and Dykes

About half of the district is underlain by plutonic rocks which Duquette (1970) has divided into two suites: the first is a Tonalite-Diorite Suite composed of semi-concordant intrusions with tonalite cores and diorite rims. These intrusions are notably K-feldspar poor, similar to the Archean felsic volcanic rocks. They have been strongly deformed and are foliated parallel to the schistosity in the country rock. Duquette considers these to be conformable, laccolithic or phacolithic hypabyssal counterparts of the mineralogically similar Archean felsic lavas and contemporaneous in age with them.

The second, less abundant Granodiorite Suite, called leucocratic soda granite by Wolhuter (1968), contains moderate amounts of K-feldspar, is locally crosscutting, and lacks the prominent deformational features of the Tonalite-Diorite Suite. Duquette (1970) considers these rocks to be post-kinematic and post-Kenoran. The Opemiska Lake Pluton (Wolhuter, 1968) one mile north of the Opemiska Mine (Fig. 10) is one of these intrusions.

In both the Opemiska and Chibougamau mines, there are numerous mafic to felsic porphyry dykes occupying structures both parallel to and oblique to the ore-bearing structures, and those in the Opemiska Mine are discussed further below. Proterozoic diabase dykes are the latest igneous intrusions in the area.

E. Structure

Brown (1970) suggests that three sets of folds may be present, one having northwest to north-trending axial traces, a second with east to east-southeast traces, and the third a northeast trace. The most important of these are the east to east-southeast trending folds which swing northeasterly (Fig. 10) near the Grenville-Superior boundary and are probably Kenoran in age. Brown (1970) considers the northeasterly trending set to be slip folds at least partly kinetically related to the large northeast trending faults (Fig . 10) in the area and to be the youngest of the three fold sets.

Duquette (1970) and others (Brown, 1970; Graham, 1957; Norman, 1948) have recognized three major directions of regional shearing and faulting: a northeast set, a west-northwest set, and a north set. The northeast set is apparently the youngest and has affected both Archean and Proterozoic layered rocks. Two important examples of this set are closely spatially associated with both the Chibougamau area vein copper deposits and the Opemiska deposits. Although no ore is present in the structure itself, in the Chibougamau area all twelve mines occur on either side of, and within 4,000 feet of the Dore Lake Fault (Fig. 10). Similarly, at Opemiska the Campbell Lake (Gwillim Lake) Fault cuts through the south side of the property (Figs. 1, 10). It is a chlorite-carbonate-quartz shear zone measuring up to several hundred feet in width and has a steep southerly dip. The Campbell Lake fault has a left-hand strike displacement of approximately one mile, but Brown (1970) has presented detailed structural and petrofabric evidence which indicates that the latest movement was right-handed. Although the latest movement along the northeast fault set is clearly post Archean, it is not known how long faulting was active.

The second set of faults trends west to northwest, has right-handed displacements, is commonly intruded by dykes and is host to some of the

Opemiska veins and most of the Chibougamau veins except the Henderson and Portage Lake deposits. There is less agreement as to the relative age and regional extent of this set. Duquette (1970) and Graham (1957) consider them pre-Kenoran, whereas Brown (1970) and Norman (1948) consider that in the Opemiska Mine area these faults formed as subsidiary or conjugate fractures during late movement of the northeast trending Campbell Lake fault. Some of the disagreement over the age of movement on these faults is because regional correlations have been attempted on fractures which may be local in extent and also because there has probably been recurring movement along these faults. Nonetheless, the fact that the west-northwest set is occupied by various dykes and ore deposits which are in turn sheared and faulted suggests that this set is early relative to the northeast set.

Duquette (1970) recognizes a third set which strikes slightly east of north, dips east, and has a left-handed displacement. At the Norbeau gold deposit one of these fractures is occupied by a gold-bearing quartz vein; a second example of this set is the Mistassini Lake Fault (Fig. 10). In addition to the above transverse faults, there are a number of strike faults with very large displacements. Duquette (1970) states that some of the largest of these occur within or at contacts of the ultramafic rocks.

F. Ore Deposits

The location, tonnage, grade and general geology of the Chibougamau area ore deposits is summarized on Duquette's map (Fig. 10). Copper is by far the most important mineral product and occurs in a number of different mineral deposit types that are briefly outlined below.

i) Chibougamau Veins

The most important ore deposits are the veins at Opemiska and along the northwest shore of Lake Chibougamau (Fig. 10), all of which are similar in bulk mineralogy and occur as veins crosscutting Archean layered sills. The Chibougamau vein deposits have been studied by Jeffrey (1959), Miller (1957), Raychaudhuri (1960) and Vollo (1959), and include the Copper Cliff, Jaculet, Copper Rand and Bouzan deposits of Patino Mining Corporation; the Cedar Bay, Kokko Creek, Henderson, Campbell Chibougamau and Merill Island Mines of Campbell Chibougamau Mines Ltd., and the Chib-Kayrand, Quebec Chibougamau Goldfields and United Obalski deposits. All these occur in the layered Dore Lake anorthosite, and while most occupy northwest trending shear zones, the Henderson and Portage deposits occur in southeast dipping, northeast trending shear zones. The veins contain pyrrhotite, chalcopyrite, pyrite, sphalerite, quartz, chlorite, sericite and calcite. Less common metallic minerals include magnetite, arsenopyrite, cobaltite, galena, cubanite, pentlandite, hematite and native gold. Other gangue minerals include actinolite, siderite, ankerite, epidote, apatite, chloritoid, allanite and tourmaline. The shear zones which the veins occupy have also been intruded by numerous dykes ranging from mafic to felsic in composition. The deposits are all within four miles of the Chibougamau Tonalite-Diorite Pluton, and all have been affected by severe post ore deformation. Significant secondary (supergene) minerals (native copper, chalcocite, iron oxides and copper carbonates) are present 800 feet and more below surface at the Henderson Mine.

ii) Other Copper and Gold Veins

The Bruneau deposit, a few miles northeast of Chibougamau (Fig. 10), consists of two veins which carry chalcopyrite, pyrite, pyrrhotite, quartz, calcite and epidote. The veins strike northwest and north-northwest, and cut across east trending Archean basic volcanic rocks, gabbro sills and minor clastic sediments. North-south trending quartz-feldspar porphyry dykes are common throughout the area.

The Norbeau gold deposit, four miles northeast of Chibougamau (Fig. 10) is a 2.5 to 8 foot wide quartz vein crosscutting the Bourbeau sill. The vein strikes northeast, dipping 50°SE, and carries pyrite and minor arsenopyrite.

The Key Anacon deposit is a series of steep east-west trending veins cutting a diorite-gabbro sill 28 miles south of Chibougamau (Fig. 10) and less than one mile from the Grenville Front. The host sill is 400 to 600 feet thick and has intruded mafic volcanic rocks of the Gilman Formation. Felsic dykes occupy structures subparallel to the ore. The vein walls are chloritized and silicified, and minor sericitization occurs in the felsic dykes. The veins contain pyrite, pyrrhotite and chalcopyrite with the gold occurring as free gold in quartz. Minor sphalerite and galena are also present.

iii) Porphyry Type Deposits

Kirkham (1972) believes that "porphyry copper" type mineralization is present in the Chibougamau area. The Garth Lake deposit, south of Chibougamau townsite contains traces of copper and molybdenum in a large area of metasomatic rocks containing up to ten percent pyrite. A second property, the Talbot, is located southwest of Chibougamau Lake within the Chibougamau Tonalite-Diorite Pluton. Here Kirkham (1972) reports a stockwork of quartz-carbonate veinlets containing chalcopyrite, magnetite and pyrite, with some potash feldspar alteration associated with the veining. A third deposit, the Grandroy, northeast of Chibougamau (Fig. 10), also has features which are common in "porphyry copper" deposits. The deposit is a vein stockwork in a small stock apparently satellitic to the Chibougamau pluton. In addition to chalcopyrite and pyrite, molybdenite, magnetite and specular hematite are present in narrow quartz veinlets. Other gangue and alteration minerals include K-feldspar, carbonate, sericite and chlorite. Extensive pyritization occurs in the volcanic rocks for 1,500 feet west of the mine.

iv) Zinc-Lead-Copper Deposits

The Coniagas Zn-Pb-Ag deposit, located near Desmaraisville approximately 60 miles west of Chapais (Fig. 10), is stratiform and occurs in felsic volcanic rocks near the contact between the Blondeau and Gilman Formations. The sulphide minerals include pyrite, pyrrhotite, sphalerite, chalcopyrite and galena. The sulphides show evidence of shearing and deformation and the deposits have been folded.

The Tache Lake Zn-Au deposit, located 3 miles northwest of Chibougamau (Fig. 10), occurs in serpentine and pyroxenite near felsic tuffs at the base of the Blondeau Formation. Pyrrhotite, sphalerite and minor chalcopyrite are the major sulphides and occur in veins cutting the ultramafic rocks.

In addition to the Coniagas and Tache Lake deposits, numerous small copper-zinc showings occur in the felsic tuffs at the base of the Blondeau Formation, including the M(8-5) zone at the Opemiska Mine described below.

v) Copper Deposits in the Proterozoic Sediments

Copper mineralization occurs in both the Chibougamau Series clastic sediments and Mistassini Series dolomites. Arkose and greywackes of the Chibougamau Series north of Waconichi Lake contain small zones of disseminated pyrite, pyrrhotite and chalcopyrite which grade up to 2% copper across one to two feet. Copper mineralization is also found associated with small veinlets of carbonate and quartz cutting these sediments.

The Icon Mine, 32 miles northeast of Chibougamau (Fig. 10), occurs in dolomitic carbonates of the Mistassini series which are in fault contact with Grenville gneisses immediately to the east. The enclosing fine grained dolomites are argillaceous and graphitic and commonly contain radiating iron sulphide nodules and possible stromatolitic structures. The ore is chalcopyrite which occurs as lenses in dilatant zones cutting a conformable coarse grained dolomite-quartz rock. The coarse dolomite-quartz rock forms a stratiform horizon roughly 10 feet thick and has large euhedral quartz crystals up to two feet in diameter.

vi) Other Mineral Deposits

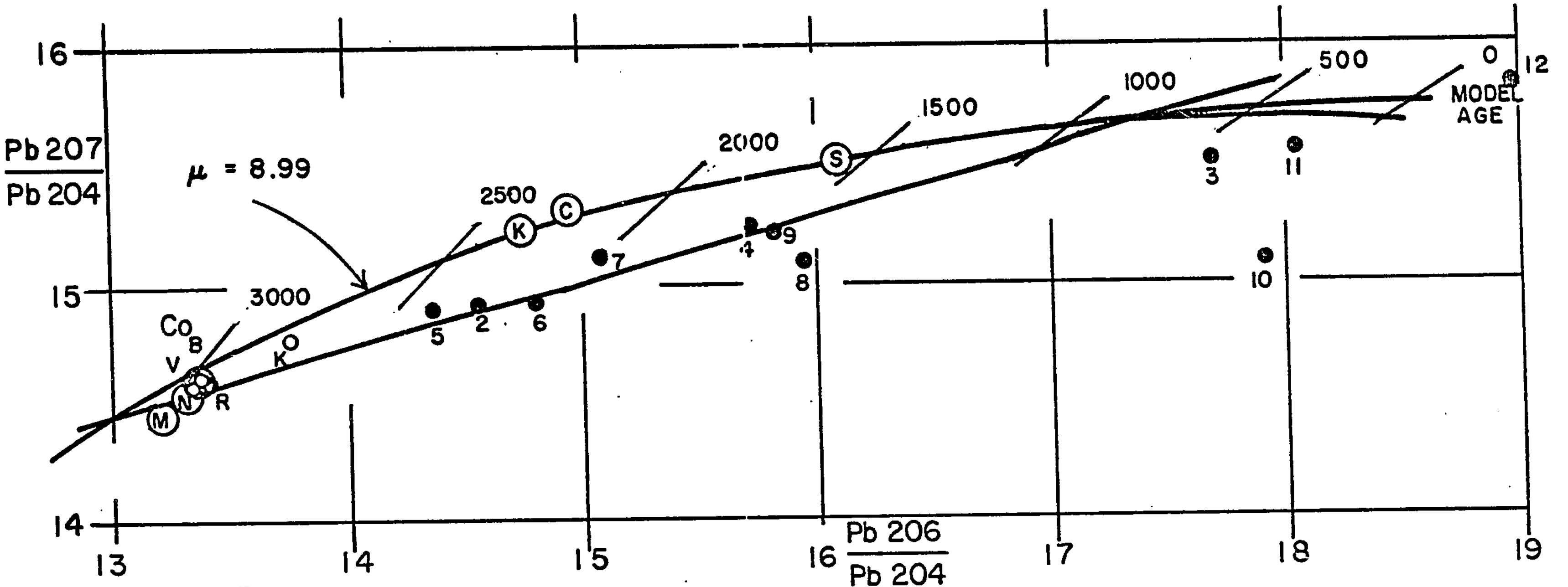
The Dore Lake anorthosite complex contains segregations of vanadiferous, titaniferous magnetite and ilmenite in a number of locations, two of which are of possible economic interest (Fig. 10). The ultramafic rocks of the Roberge Sill contain crysotile asbestos in places (Fig. 10), and Ekstrand (1972) notes occurrences of nickel as "low-grade occurrences in serpentinized ultramafic rocks (approximately background content of nickel)" near Chibougamau, although he does not name specific locations.

G. Lead Isotope Data

Lead isotope analyses (Appendix V) done by the Geological Survey of Canada on samples collected from the Chibougamau and Opemiska Veins by J. M. Franklin in 1965 are plotted in Fig. 12. Other results shown for comparative purposes are from Roscoe (1965) and Kanasewich (1968).

The results do not fall into a linear plot, thus preventing a simple interpretation. However, the strongly anomalous character of the leads suggests a two-(or multi-) stage age. A tentative anomalous lead line (Fig. 12) has been drawn based on a consideration of the Archean age of the host rocks and a possible date for secondary emplacement. Geologically, a Grenville Age for secondary emplacement seems the most probable because of the post Aphebian northeast trending fractures which are closely associated with both the Chibougamau and Opemiska deposits, and because there was a major tectonic-intrusive-metamorphic event nearby at that time.

FIGURE 12 LEAD ISOTOPE DATA FROM THE OPEMISKA AND CHIBOUGAMAU AREA MINES



I ● Large Circles Roscoe 1965
- M Mattagami
- N Noranda
- K Kirkland Lake Pb-Zn veins
- C Cobalt area veins
- S Sudbury Basin
- Co Coniagas

Small Circles Kanasewich 1968
- V Val d'Or
- B Bdrvue
- R Renabie
- K Kerr Addison

Solid Circles Opemiska and Chibougamau veins (Appendix V)

CHAPTER III

PETROGRAPHY OF THE VENTURES SILL

A. General Statement

The rock units in the Ventures Sill are mineralogically and texturally similar to those found in other layered complexes such as the Skaergaard, Bushveld and Stillwater Intrusions which are now generally regarded as having formed largely by igneous sedimentation (Wager and Brown, 1968; Jackson, 1967). The terminology of Wager and Brown (1968) and Jackson (1967) has been used in the petrographic descriptions. Mineral identification is based on detailed petrographic examination, supplemented by X-ray diffraction analyses; some of the latter were conducted on mineral concentrates of the less abundant minerals. The main rock units and their mineralogy in the two sections studied are shown in Fig. 13.

B. Lower Green Pyroxenite

The Lower Green Pyroxenite is about 100 feet thick and forms the lowest mappable unit in the Ventures Sill. Unfortunately this unit is poorly exposed both in outcrop and in mine workings: nevertheless, the section studied here from hole 8583 (Fig. 13), is considered representative. The unit is not exposed in the Lac Cummings area.

The rock is greenish-grey, massive, structureless medium-grained clinopyroxenite. Dark flecks visible in drill core are seen in thin

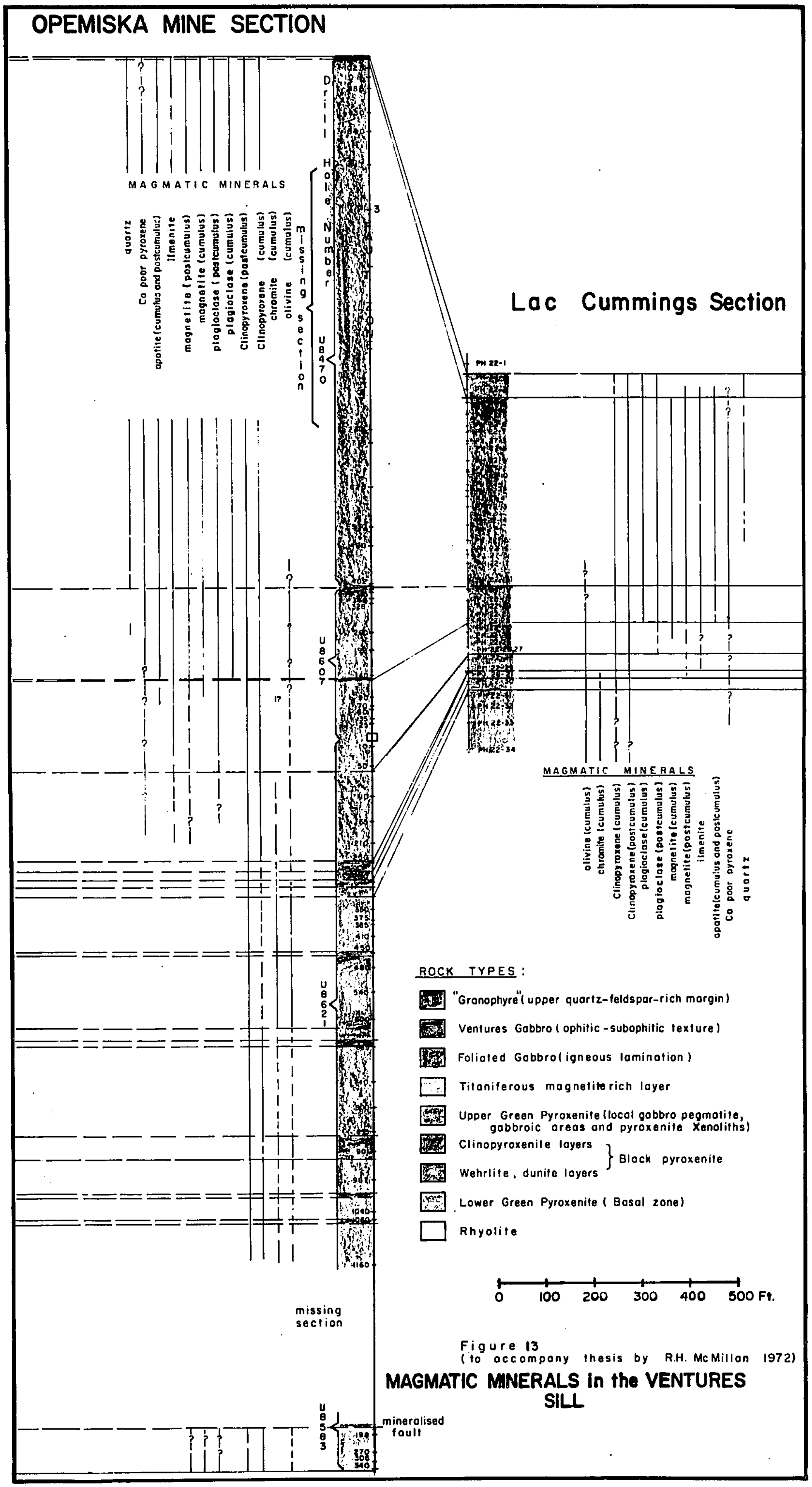


Figure 13
(to accompany thesis by R.H. McMillan 1972)

MAGMATIC MINERALS in the VENTURES SILL

section to be brown pleochroic amphiboles, possibly uralitized pyroxenes. Distinction of this unit from clinopyroxenite layers in the overlying Black Pyroxenite is often difficult and although the contacts between the two units are conformable, they are commonly faulted and some are mineralized with sulphides. Brown (1970) described breccia dykes composed of fragments of pyroxenite up to six inches in a pyroxenite matrix mainly near the top of the unit in outcrop at the eastern end of the property. The contact of the Lower Green Pyroxenite with rhyolite is sharp with little evidence of chilling. Veinlets of amphibole extend into the rhyolite close to the contact.

Polished thin sections show that the rock contains greater than 90 percent partially uralitized clinopyroxene in equant to prismatic grains that range in diameter from .2 to 2 mm. but average about .5 mm. Chromite and secondary skeletal ilmenite after primary titaniferous magnetite are other minor "magmatic" minerals. Round pseudomorphs averaging .4 mm. in diameter composed of unoriented actinolite and fine secondary magnetite form about 20 percent of specimen 8583-306 and are apparently secondary after magmatic olivine. Secondary minerals in the Lower Green Pyroxenite include brown and pale green actinolite which comprises 50 percent or more of the rock, calcite and chlorite. Feldspar was not seen in any section.

C. Black Pyroxenite

This unit is composed of clinopyroxenite and serpentinized dunite and wehrlite. At the mine it is approximately 1200 feet thick. In the Lac Cummings area, only the top 200 feet of the unit is exposed, but the textures and primary igneous features are much better preserved than

Fig. 14. Sharp contact between brown-weathering serpentine (above) and grey-weathering clinopyroxenite in Black Pyroxenite at Opemiska. (Location: 800 ft. north of east end of Campbell Lake)

Fig. 15. Well layered olivine clinopyroxenite in the Lac Cummings section. Layering is marked by negative weathering serpentinized olivine pseudomorphs. (Location: 5 ft. S. of PJ28-2, Fig. 13)

in comparable rocks of the mine area.

The rocks of the Black Pyroxenite unit have been divided into two subunits: clinopyroxenite which contains less than 15 percent olivine pseudomorphs, and wehrlite-dunite which contains greater proportions of olivine pseudomorphs. In the mine area, contacts between clinopyroxenite and wehrlite-dunite are commonly sheared (Fig. 14), whereas in the less altered rocks near Lac Cummings, primary igneous contacts are more common. The upper contact of the Black Pyroxenite unit with Upper Green Pyroxenite is gradational. In the Lac Cummings area, primary igneous layering (Fig. 15) is well preserved, the layers ranging from less than an inch to a number of feet, in which case individual layers constitute mappable units (Fig. 13). Some narrow layers show both mineral and size grading. The dunitic and wehrlitic rocks are olivine and possibly clinopyroxene cumulates and commonly have post-cumulus clinopyroxene poikilitically enclosing olivine (olivine heteradcumulate, Wager and Brown, 1970). The individual poikilitic clinopyroxene crystals are up to three inches in diameter (Fig. 16).

The clinopyroxenite is dark grey in outcrop. The serpentinized olivine pseudomorphs weather readily to form round pits (Fig. 15) with a rusty colour. In fresh hand specimens the clinopyroxenite ranges from dark to light greenish grey, is subequigranular, medium-grained and the olivine pseudomorphs form black, highly magnetic patches.

In polished thin sections the mineralogy is simple. Clinopyroxene is most abundant and ranges in diameter from .3 to 50 mm., averaging about .7 mm. Pseudomorphous olivine is next in abundance and occurs most commonly as round grains, many of which are poikilitically included in large clinopyroxene crystals. Grain size ranges from .2 to 2 mm., but

Fig. 16. Large clinopyroxenite crystals poikilitically enclosing serpentinized olivine (olivine hetradcumulate) in the Lac Cummings section. (Location: PH22-30, Fig. 13)

Fig. 17. Gabbro pegmatite and gabbro "nodules" in feldspathic Upper Green Pyroxenite at Opemiska. (Location: 102 ft. E. of L.P. 9633, 901 Drift)

averages approximately .4 mm. Most of the pseudomorphs are round, although a few of the coarser ones have elliptical outlines. Chromite is the only other magmatic mineral, and occurs as an accessory associated with olivine. The chromite crystals are finer grained than the associated olivine, octahedral in outline, and commonly rimmed and veined by secondary magnetite. In transmitted light they are completely opaque. Alteration of the clinopyroxene is much less evident in the Black Pyroxenite than in the other units of the Ventures Sill, although there is invariably some uralitization. The pseudomorphs after olivine are composed of minor magnetite with mesh textured serpentine or talc or less commonly with unoriented amphibole. Some specimens contain calcite. The slight difference in colour between the black and the green pyroxenites is apparently due to the higher content of green amphibole in the latter.

D. Upper Green Pyroxenite

The Upper Green Pyroxenite is about 200 feet thick in the mine area and about a third as thick near Lac Cummings (Fig. 13). Its upper contact with the Foliated Gabbro is sharp, marked by the abrupt appearance of cumulus plagioclase and titaniferous magnetite in the gabbro. Although most of the unit is structureless, some specimens have an igneous lamination. In the mine area, the Upper Green Pyroxenite is almost identical to the Lower Green Pyroxenite, the main difference being slightly coarser grain size in the former. Local gabbroic areas occur where intercumulus plagioclase comprises up to 50 percent of the rock (Figs. 17, 18) and titaniferous magnetite up to 8 percent. Also associated with the feldspathic patches are nodules of coarse grained gabbro (Fig. 17), gabbro pegmatites

Fig. 18. Large angular xenolith of clinopyroxenite in feldspathic Upper Green Pyroxenite at Opemiska. Feldspathic pyroxenite near contacts of xenolith is locally very feldspar rich. (Location: 153 ft. E. of L.P. 9539, 901 Drift)

Fig. 19. Rhythmic, mineral graded layering in Foliated Gabbro in the Lac Cummings section. Layers are marked by clinopyroxene-magnetite-rich bottom and feldspar-rich top with a sharp contact against the overlying layer. (Location near sample PH22-21, Fig. 13)

(Fig. 17) and xenoliths of pyroxenitic rock (Fig. 18). Irregular coarse gabbro pegmatites are present in the Upper Green Pyroxenite in the Lac Cummings area, but the other features were not seen, possibly because of less exposure.

E. Foliated Gabbro

The Foliated Gabbro has derived its name from its prominent igneous lamination. In some specimens a lineation is present within the plane of lamination. Most of the unit is coarse grained and homogeneous, but rhythmic layering is very prominent in some areas (Fig. 19). Each layer has a pyroxene-magnetite rich base and a plagioclase-rich top, and layers range from a few inches to almost a foot in thickness. A few gabbroic layers texturally similar to the Ventures Gabbro are up to 1 foot thick (Fig. 9). The base of the unit normally has a six inch to one foot thick band composed of thirty to forty percent cumulus titaniferous magnetite octahedra, with the remainder clinopyroxene. Narrow layers rich in cumulus magnetite also occur above this basal layer within the Foliated Gabbro. In the mine area, layers of pyroxenite up to 20 feet thick occur within the Foliated Gabbro (Fig. 9).

In polished thin sections, the three main magmatic minerals are plagioclase, clinopyroxene and titaniferous magnetite. The plagioclase crystals are elongate, up to 4 mm. in length and .7 mm. in width, with most about half this size. The plagioclase is euhedral in contrast to the interstitial plagioclase present in some of the Upper Green Pyroxenite. The plagioclase has been saussuritized and is now albite, containing epidote, zoisite, sericite and calcite as alteration minerals. The clinopyroxene is also cumulus, and slightly coarser than the plagioclase.

Extensive postcumulus overgrowth has occurred on the clinopyroxene, resulting in subhedral to anhedral grain outlines. Titaniferous magnetite, ranging from .3 to .8 mm. in size is common and has minor postcumulus overgrowths. Occasional isolated plates of ilmenite are possibly magmatic in origin. Apatite is an abundant accessory and occurs both as fine inclusions in feldspar and coarser prisms up to .1 mm. thick aligned in the plane of the igneous lamination. Pseudomorphs composed of randomly-oriented, fine-grained actinolite or chlorite may be after either olivine or a calcium-poor pyroxene and occupy interstices between cumulus plagioclase and clinopyroxene.

Metamorphism of the rock has resulted in partial uralitization of the primary clinopyroxene, 50% or more in the mine area, but much less in the Lac Cummings area. Albitization of plagioclase and partial alteration of ilmenite to rutile, sphene and leucoxene has also occurred. Primary magnetite has been completely removed from the Lac Cummings rocks except in the titaniferous magnetite-rich cumulate at the base of the unit, leaving only skeletal ilmenite, whereas at Opemiska the magnetite is usually preserved. Other metamorphic minerals in the rock include epidote, calcite and stilpnomelane. Biotite is common in the Opemiska area.

F. Ventures Gabbro

The Ventures Gabbro isreadily distinguished by its ophitic to subophitic texture and coarse grain size. It is about 1200 feet thick near the mine, and about 400 feet thick at Lac Cummings (Fig. 13). Although it is generally uniform, locally the rock has a mottled appearance (Fig. 20) with irregular patches relatively rich in mafic minerals. The lower contact against Foliated Gabbro is abrupt, and marked by a change in

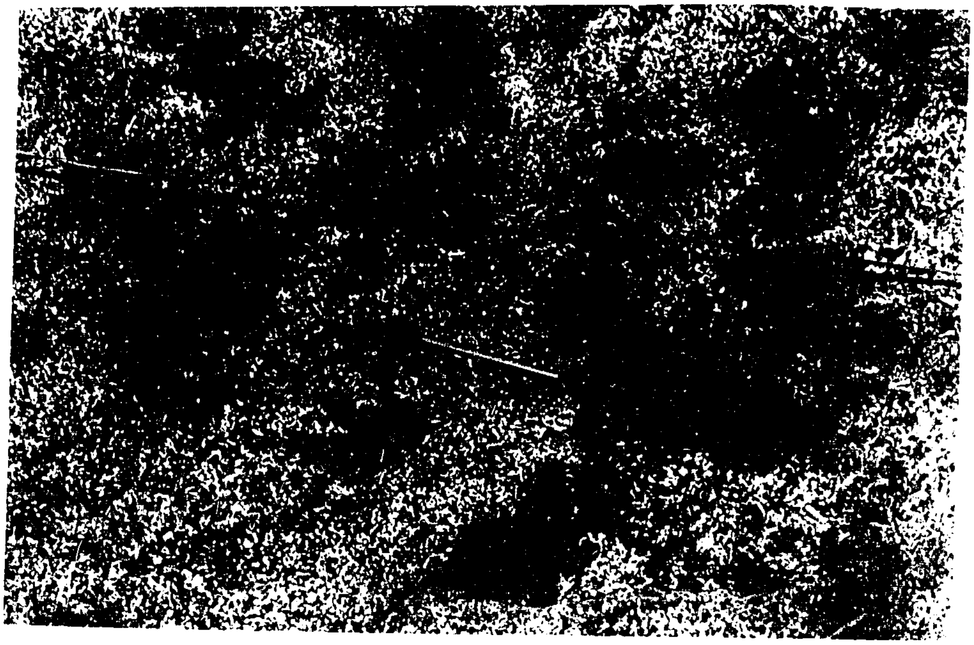


Fig. 20. Irregular mafic "clots" in feldspathic Ventures Gabbro at Opemiska (Location: 6 ft. E. of L.P. 9539, 901 Drift)

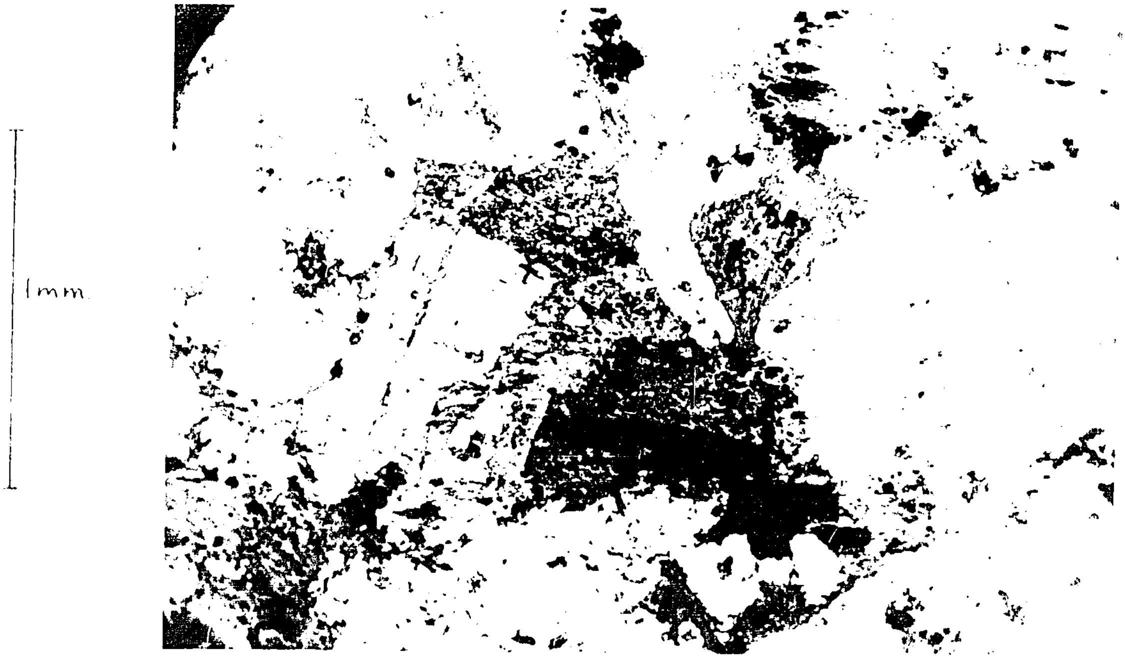


Fig. 21. Oriented actinolite and magnetite pseudomorphous after calcium-poor-pyroxene in ophitic Ventures Gabbro at Opemiska. White areas are saussuritized plagioclase. (Specimen OG24-12; transmitted light, x21)

texture and grain size.

In polished thin section, the mineralogy of the rock is very similar to that of the Foliated Gabbro, with minor differences. Quartz constitutes up to 5% of the upper portions of the unit (Fig. 13), and has two habits. Mostly it forms megascopically visible interstitial grains up to 2 mm. in diameter. In the uppermost parts, it occurs as myrmekitic intergrowths in the adcumulus rims around plagioclase. The quartz is commonly partially replaced by stilpnomelane along grain boundaries. Zircon occurs as minute inclusions in some of the mafic minerals. As in the Foliated Gabbro, biotite and magnetite are absent in the Lac Cummings section, but the other magmatic and metamorphic minerals are the same in both areas. Titaniferous magnetite occurs as coarse irregular intergrowths with clinopyroxene in contrast to the separate cumulus grains of magnetite in the Foliated Gabbro. Pseudomorphs after calcium-poor pyroxene, either orthopyroxene or pigeonite, were recognized in interstitial areas between plagioclase and clinopyroxene in the mine area and are composed of numerous parallel fine amphiboles with intervening linear patches of fine secondary, non-titaniferous magnetite (Fig. 21). Similar pseudomorphs after calcium-poor pyroxene are present in the Lac Cummings area, but without the secondary magnetite.

In the Lac Cummings area and in parts of the Opemiska area, a zone containing approximately one percent disseminated pyrrhotite and minor chalcopyrite has been recognized near the top of the Ventures Gabbro below the "Granophyre". This zone is up to 20 feet wide, is clearly recognizable in the field and can be traced along strike.

G. "Granophyre"

This rock is present at the top of the Ventures Gabbro in the Lac Cummings area where it is up to 50 feet thick, but is thin and poorly developed in the mine section. It is composed mainly of medium-grained, hypidiomorphic-granular altered plagioclase and quartz. Compared to Ventures Gabbro it contains relatively minor altered pyroxene and skeletal ilmenite, which is pseudomorphic after titaniferous magnetite. Locally, myrmekitic intergrowths of quartz and plagioclase are very prominent. Cobaltinitrite staining for K-feldspar was negative in all samples.

H. Sulphide Distribution

Although the silicate and oxide mineralogy and textures at Opemiska and in the Lac Cummings area are similar, there are strong contrasts in the sulphide mineralogy which are important in the interpretation of the wallrock geochemistry and genesis of the Opemiska veins. The sulphide minerals were identified by detailed microscopic examination both in air and oil, supplemented by X-ray powder camera photography and some microprobe analyses. The results are presented in Fig. 22.

i) Lac Cummings Section

Although the sulphur content is very low in rocks of the Lac Cummings Section (Fig. 31) a few grains of sulphide minerals were identified in every section examined and form the basis for a three-fold division into nickel-rich, copper-rich and iron-rich facies (Fig. 22).

The nickel-rich sulphides occur only in the ultramafic rocks. Heazlewoodite forms very fine grained flecks which occur as inclusions in secondary magnetite and as disseminated grains, some with pseudohexagonal outlines. In polished section, heazlewoodite grains are pale yellow,

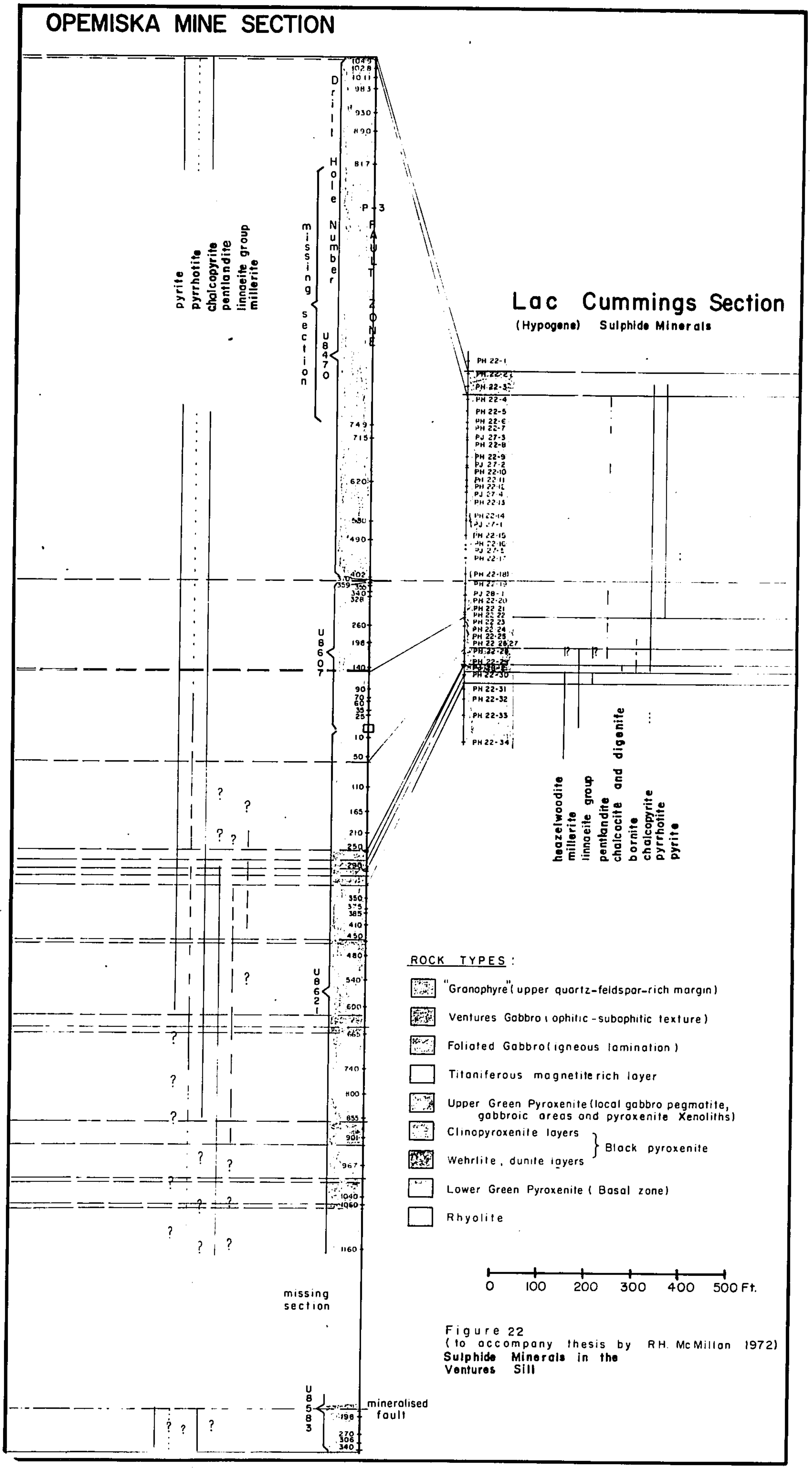


Figure 22
(to accompany thesis by R.H. McMillan 1972)
Sulphide Minerals in the Ventures Sill

with weak anisotropism and are difficult to distinguish from both pentlandite and linnaeite group minerals. The identification of heazlewoodite was confirmed by X-ray powder camera photography from samples PH22-30 and PH22-31, and electron microprobe analysis of sample PH22-30. Linnaeite, intermixed with heazlewoodite, was identified in the X-ray powder pattern of sample PH22-30. The pattern showed weak doublet peaks at 1.66 Å and 1.82 Å with two distinct peaks at 2.85 Å and 3.34 Å. Millerite is clearly identifiable in the polished section due to its yellow colour and distinctive strong anisotropism. Its presence was also confirmed by X-ray powder photography in sample PH22-31. Some of the millerite is clearly "supergene" and is replacing heazlewoodite along grain boundaries and fractures judging from its association with secondary oxides. However much of it appears to be "hypogene", for it is present as fine inclusions in unfractured magnetite (Fig. 23) grains or as fine disseminated material not associated with any oxide-bearing fractures. Pentlandite is found at the top of the ultramafic rocks (Fig. 23), and in some specimens chalcopyrite is intergrown along pentlandite cleavage planes. X-ray diffraction confirmation of both these minerals, with the intergrown texture, was obtained in specimen PH22-28.

A zone containing copper-rich sulphide minerals occurs at the top of the ultramafic rocks, partially overlapping, but mainly above rocks containing the nickel-rich sulphide suite. In sample PJ28-2 (Fig. 23) chalcocite and digenite are intergrown with bornite, occurring both as fine disseminated grains and inclusions in magnetite. Bornite-chalcopyrite intergrowths have similar habit. Both bornite and chalcopyrite were confirmed in X-ray powder photographs in sample PH22-29. Minor amounts

Fig. 23. Chalcopyrite-bornite, bornite-digenite, pentlandite-millerite intergrowths and individual grains included in secondary magnetite at base of copper-rich sulphide zone in Lac Cummings section. (Sample PJ28-2b; reflected light, oil immersion, 250x)

Fig. 24. Pentlandite with intergrown chalcopyrite in talc-serpentine-carbonate veinlet in serpentinized dunite at Opemiska. Pyrrhotite also present. (Sample 8621-540; coated with carbon, transmitted and reflected light, oil immersion, x150)

of chalcopyrite continue upwards throughout the Ventures Gabbro. Chalcopyrite was also seen as minute inclusions in one ultramafic specimen (PH22-33).

Pyrrhotite is the predominant iron-rich sulphide in the Foliated and Ventures Gabbros where it is associated with minor chalcopyrite and rare pentlandite "flames". It is absent in the ultramafic rocks that contain the nickel- and copper-rich sulphide minerals. It occurs as fine to coarse disseminated grains and is also commonly intergrown with skeletal ilmenite, replacing magnetite. One minute pyrite grain in sample PH22-17 was the only pyrite observed in more than forty samples.

A minute inclusion of a mineral tentatively identified as enargite occurs as an inclusion in magnetite in specimen PH22-33. The mineral is brownish to violet with a distinct reflection pleochrism in oil, and strong yellow to violet anisotropism. Marcasite is common as a "supergene" replacement of a pyrrhotite. The native metals, awaruite and copper, were sought but are apparently lacking.

ii) Opemiska Mine Section

The most notable contrast between the Lac Cummings and the Opemiska sections (Fig. 22) is the abundance of pyrite and the absence of heazlewoodite and the copper-rich sulphides, bornite, digenite and chalcocite in the Opemiska section. The three distinctive "facies" of sulphide minerals in the Lac Cummings section are not present in the Opemiska area, and pyrite, pyrrhotite and chalcopyrite are found throughout the section in all rock types (Fig. 22). Sulphides are also more abundant than in the Lac Cummings Section.

Narrow veinlets containing sulphide grains are found in all rock types in the Opemiska Section. In the gabbros, the sulphide assemblage in both veinlets and wallrocks is identical. In the ultramafic rocks, however, the sulphur-and iron-rich sulphides predominate in the veinlets. In these rocks, pyrite occurs only in the veinlets; pyrrhotite, chalcopyrite, pentlandite and linnaeite-group minerals are present in both veinlets and disseminated in the rock. Millerite was only seen disseminated in the rock.

Texturally, the disseminated sulphides usually occur intergrown with secondary minerals, included within secondary magnetite, or as isolated fine granules. They are also found as fine flecks along cleavages in primary clinopyroxene or feldspar and replacing the magnetite portion of primary magnetite-ilmenite intergrowths.

Pyrite in the gabbroic rocks is euhedral, but in the talc and serpentine veinlets that cut the ultramafic rocks it is commonly ragged and irregular. Identification of pyrite in serpentine in specimens 8621-350 and 8621-440 was confirmed by X-ray powder camera patterns, and by electron microprobe analyses in the former. Pyrrhotite is much less abundant than pyrite in the gabbroic sections of the Sill, but becomes equally, or more, abundant in the ultramafic portions.

Pentlandite is the most common nickel sulphide in rocks of the Opemiska section, and was found only in ultramafic rocks, occurring both as disseminations and in crosscutting veinlets (Fig. 24). X-ray powder camera patterns confirmed the presence of pentlandite in both veinlets and as disseminations in samples 8621-480, 540 and 901.

Linnaeite-group minerals are the next most abundant nickel minerals, and are very difficult to distinguish optically from pentlandite in polished thin section. X-ray powder photography confirmed their presence as intergrowths with pentlandite in small veinlets in specimens 8621-480 and 901 (Figs. 25, 26). Partial microprobe analyses of the linnaeite for Fe, Ni and S suggests that 8621-480 is close to true linnaeite in composition. It is pinkish cream in colour, compared to a yellowish hue in the associated pentlandite. The linnaeite grains are rimmed and cut by lamellae of pentlandite (Fig. 25) and both occur associated with pyrrhotite, pyrite and chalcopyrite in a small carbonate vein cutting serpentine. In specimen 8621-901, another linnaeite-group mineral occurs intergrown with pentlandite in a serpentine veinlet (Fig. 26). In this case, the linnaeite occurs as fine, irregular, lamellar-shaped structures cutting the pentlandite host. Microprobe analysis for Ni, Fe and S suggest a composition richer in nickel and thus closer to siegenite. The linnaeite (siegenite) intergrowths have a slightly whiter colour than the associated pentlandite. Linnaeite was also confirmed by microprobe as a small isolated grain associated with a cluster of chalcopyrite and pentlandite grains in specimen 8621-350.

Chalcopyrite was identified optically throughout the sill in the Opemiska Mine both in small veinlets and as disseminations. In two specimens chalcopyrite occurs intergrown along cleavage planes in pentlandite (Fig. 24). Millerite was observed both as small laths intergrown with pentlandite and as disseminated grains in two samples. A small, isolated, highly reflecting, white, isotropic grain associated with pyrrhotite and chalcopyrite in pyroxenite (sample 8621-855) was tentatively identified

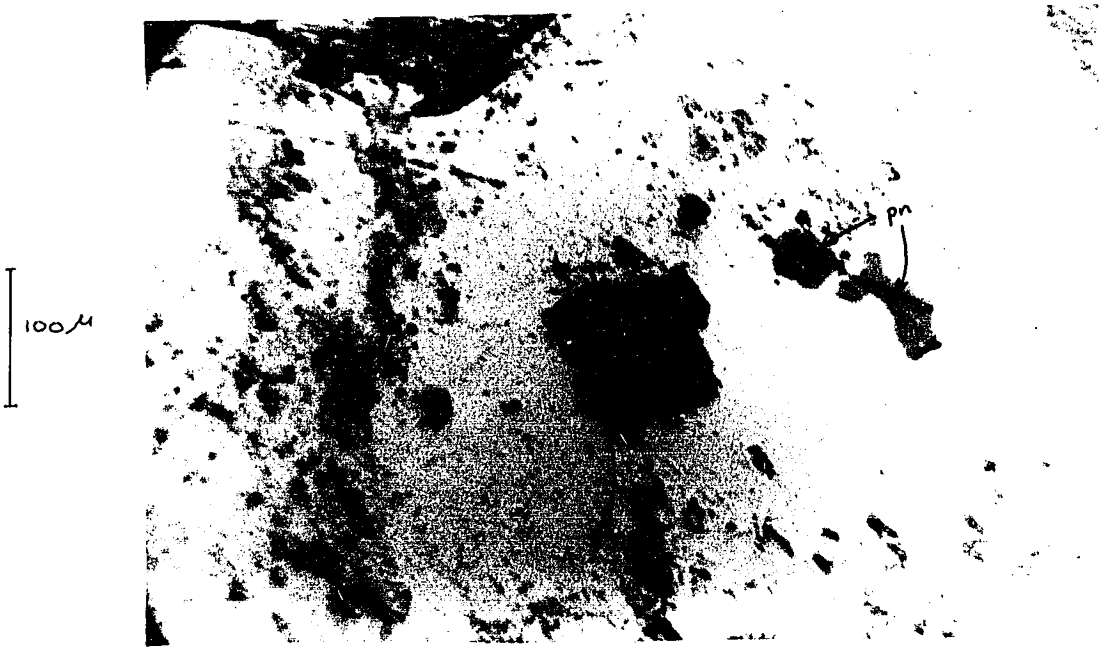


Fig. 25. **Linnaeite intergrown with and replaced along rims by pentlandite in carbonate veinlet cutting serpentinized dunite at Opemiska. Pyrite and pyrrhotite are also present in veinlet. (Sample 8621-480; coated with carbon, transmitted and reflected light, x96)**

Fig. 26. Pentlandite with intergrown linnaeite (siegenite) in serpentine veinlet cutting serpentinized dunite at Opemiska. (Sample 8621-901; coated with carbon, transmitted and reflected light, x96)

as cobaltite. Partial microprobe analysis confirmed the presence of cobalt and sulphur, and the relative insignificance of iron and nickel.

CHAPTER IV

GEOCHEMISTRY OF THE VENTURES SILL

A. General Statement

Detailed study was made of the comparative geochemistry of the Ventures Sill in the Lac Cummings and Opemiska areas in order to provide a basis for determining the changes in chemistry which might have accompanied emplacement of the Opemiska veins. The whole-rock analyses provide data on the geochemistry of the rocks, and together with the microprobe analyses on the pyroxenes and the petrographic information, have been used to reconstruct the crystallization history of the Sill. Details of the procedures used in sample preparation and analytical techniques are presented in the Appendix.

B. Major-Element Abundances in the Whole Rock

The whole-rock analyses of Ventures Sill rocks are presented in Fig. 27.

The two analyses of Lower Green Pyroxenite are quite similar to the clinopyroxene analysis of sample 8583-270 shown in Fig. 36. The small differences in SiO_2 and TiO_2 are probably due to the presence of minor altered olivine and titaniferous magnetite in the rock. The higher alumina in the rock analysis possibly reflects the former presence of minor plagioclase. The very low Al_2O_3 and high MgO and CaO in the rock

Figure 27. Table Showing Whole Rock Analyses of Various Opemiska Rocks (Ventures Sill Rocks arranged in ascending stratigraphic order)

			SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O*	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	NiO	Total	L.O.I.
Ventures Sill Rocks	Ventures Gabbro	8470-983	47.80	14.27	17.90	5.74*	7.12	3.76	.84	2.05	.26	.26			100.00	2.48
		8470-930	48.22	15.00	17.28	2.42*	10.00	3.05	1.30	2.14	.36	.23			100.00	.68
		8470-890	48.38	12.60	16.85	3.70*	11.27	4.21	.80	1.78	.16	.25			100.00	2.60
		8470-890A	48.01	12.63	17.05	3.70*	11.19	4.21	.77	1.79	.40	.25			100.00	2.65
		8470-715	54.00	13.32	18.12	3.21*	3.18	5.08	.89	1.69	.24	.27			100.00	3.20
		8470-620	52.86	13.87	18.21	3.24*	4.62	5.04	.72	.85	.33	.26			100.00	1.23
		8607-370	56.57	15.06	12.46	2.33*	5.25	5.94	.41	1.65	.16	.17			100.00	.36
	Foliated Gabbro	8607-359	45.84	9.47	27.21	6.10*	6.50	1.98	1.01	1.13	.28	.38			100.00	1.70
		8607-328	46.25	14.00	18.83	6.40	7.26	4.17	.63	1.94	.26	.26			100.00	1.28
		8607-140	41.67	12.26	20.22	9.16	9.29	4.09	.95	2.02	.15	.19			100.00	1.28
	Upper Green Pyroxenite	8621-10	50.23	3.27	10.66	18.35	15.84	.43	.17	.65	.10	.22	.02	.06	100.00	.60
	Black Pyroxenite	8621-165	50.22	2.45	9.76	20.39	15.95	.01	.05	.52	.10	.19	.28	.08	100.00	.90
	Wehrlite	8621-290	44.72	2.08	13.38	29.57	8.92	0.00	.04	.40	.09	.30	.32	.18	100.00	9.00
	Lower Green Pyroxenite	8583-340	50.40	3.23	10.96	18.52	14.85	.98	.13	.56	.07	.23		.07	100.00	1.70
		8583-270	51.23	3.92	9.15	17.82	16.10	.88	.10	.49	.08	.16		.07	100.00	1.14
	Inter. to Mafic Dykes	OG24-9	57.57	16.94	6.57	5.63*	7.39	4.35	.81	.43	.21	.10			100.00	.60
		OH25-10	44.65	14.42	8.15	10.17	10.57	7.80	2.89	.84	.39	.12			100.00	4.25
	Silicified Syenite Porphyry	OG10-4	75.40	16.28	1.16	1.33*	1.35	3.60	.67	.15	.04	.02			100.00	.50
	Syenite Porphyry	7294-1190	66.85	14.79	1.13	1.73*	8.30	6.31	.58	.12	.15	.04			100.00	5.86
		9031-510 & 533	69.95	15.83	1.63	1.78*	2.45	7.43	.74	.13	.04	.02			100.00	1.08
	Rock Standards	AGV-1@	60.45	17.71	6.61	1.51°	4.97	4.15	2.95	1.07	.49	.09			100.00	1.00
		AGV-1+	60.10	17.35	6.91	1.51°	5.07	4.41	2.95	1.10	.50	.10			100.00	1.34
		T-1@	64.27	16.43	5.73	1.85°	5.02	4.65	1.27	.56	.13	.09			100.00	1.56
		T-1+	64.00	16.55	5.94	1.85°	5.19	4.39	1.24	.57	.17	.10			100.00	1.60

X. Na_2O analyzed by flame emission spectroscopy

* MgO analyses with asterisks analyzed by atomic absorption spectroscopy

@ Submitted as unknown samples

\+ Ignited powder compositions based on Flanagan (1969) and Ingamells and Suhr (1963)

° MgO analyses from the above published analyses

analyses clearly indicate that the Lower Green Pyroxenite does not represent a frozen contact phase of parental basaltic magma.

The analyses of the wehrlite and Upper Green Pyroxenite are what one would expect from the petrography (Chapter III). In the Foliated Gabbro, there is a sharp rise in Al_2O_3 and Na_2O, due to the appearance of abundant cumulus plagioclase. The sharp drop in SiO_2 and abrupt increase in Fe_2O_3 and TiO_2 are due in part to the appearance of abundant titaniferous magnetite. The decrease in MgO is due to a combination of the appearance of the above two cumulus minerals, as well as cryptic variation in the clinopyroxene. The increase in P_2O_5 reflects the appearance of cumulus apatite.

C. Minor Element Abundances in the Whole Rock

All of the minor element analyses were done by the Quebec Department of Natural Resources and have been presented in Figs. 30-35. The analytical methods together with their advertised precision are presented in Appendix III. Control was provided by sending as an unknown a replicate check sample from sample OG23-14 in every twelfth to fifteenth sample, as well as by sending several known analysed standards. These results are presented in Fig. 28 together with the statistics on the reproducibility of the replicate samples and the published results of the standard rock samples.

The average content of some of the elements in the gabbroic rocks has been calculated and is presented in Fig. 29. These provide a basis for subsequent comparison of the alteration effects in the walls of the Opemiska veins in Chapter VI.

Figure 28. Table Showing Data and Statistics on the Replicate and Check Analyses Sent as Unknowns to the Quebec Department of Natural Resources

Date	Sample Number	S ppm	S %	K_2O %	Mn ppm	Mn %	Co ppm	Cu ppm	Ni ppm	Ag ppm	Zn ppm	Cr ppm
4-12-70	9 (W1)		.04					88		.6	76	
	W1 (F)	130						110		.06	82	
4-12-70	7 (OH18-3)		.12					42		.7	94	
	10 (OH18-3)		.15					47		1.0	98	
23-2-72	OH18-3		.10	.28	1950		75	40	38	.6	100	8.4
28-6-71	OG16-12 (BR-503)		.05	1.44	1510		68	63	290		140	180
	BR-503 (R)	467.5		1.36	1600		50	72	270	0.2-1	160	420
19-11-71	OG23-33 (T1)		.02	1.06		.94	26	67	19	.7	150	15
	OG28-15 (T1)		.01	1.08		.17	35	51	20	.6	160	180
24-2-72	PH22-32a (T1)		.01	--			39	40	n.d.	n.d.	159	--
	T1 (T)		.01	1.24			13	47	13	<1	190	24
28-6-71	OF29-12*		.50	.75	2676		64	72	29	n.d.	120	23
	OG16-13*		.30	.77	1980		62	70	29	.9	120	23
	OG21-28*		.32	.75	2010		67	85	22	.4	120	10
19-11-71	OG23-14		.35	.66		.43	60	76	21	.8	120	6.3
	OG23-34*		.33	.67		.42	54	82	21	.8	110	4.5
	OG24-25*		.41	.65		.42	59	100	23	n.d.	120	4.8
	OG28-14*		.35	.63		.42	64	82	21	.4	120	4.8

Figure 28 ...... continued

Date	Sample Number	S		K_2O %	Mn		Co ppm	Cu ppm	Ni ppm	Ag ppm	Zn ppm	Cr ppm
		ppm	%		ppm	%						
23-2-72	OH14-18*		.36	.78	1950		63	65	22	.8	120	9.5
	OH21-29*		.35	.80	2050		65	60	22	.7	110	8.8
24-2-72	OH25-15*		.35	.80	2100		67	70	28	n.d.	120	10.0
	8607-400*		.36	.76	2000		66	80	24	.5	120	7.8
	8621-1200*		.34	.78	2000		64	70	27	.6	110	13.0
	8470-1105*		.34	.78	2100		63	60	29	.5	120	19
	8583-506*		.35	.80	2100		69	65	24	n.d.	120	69
	PH22-35*		.39	.80	2300		71	85	27	.7	130	59
	PJ28-3*		.34	.82	2200		73	70	26	.6	120	13
	OH5-8*				1500		70	68	24	.6	140	12
	OH20-5a*				1550		74	74	24	.7	230	12
	OH21-8*				1740		66	78	24	1.0	160	7.8
	OH24-21*				1540		72	70	28	1.0	170	10
	$\bar{x}$		.36	.75	2435		65.7	74.1	24.8	.68	130.0	16.4
	σ		.05	.06	957		5.0	9.7	2.9	.19	28.1	17.2
	R.S.D.%		13.8	8.2	39.0		7.6	13.0	11.6	27.5	21.6	105
	N		16	16	20		20	20	20	16 (n.d. omitted)	20	20
	$\bar{x}$				1987					.61	124.7	
	σ				300					.23	15.8	
	R.S.D.%				15.0					37.7	12.6	
	N				16					20	19	
					(19-11-71 samples omitted)					(n.d. assigned .3)	(230 omitted)	

Code: -

* OG23-14 replicate samples
F Fleischer 1969
R Recommended value, Roubault et al., 1968
T Thomas, 1961

Figure 29. Table Showing Average Content of Various Elements in Opemiska and Lac Cummings Gabbroic Rocks

	Opemiska Area						Lac Cummings					
	n	Mean	σ	n	Mean	σ	n	Mean	σ	n	Mean	σ
K_2O%	12	.87	.49	20	.79	.41	19	.30	.12	23	.26	.15
S%	12	.67	1.23	20	.45	.98	19 18 17	.10 .08 .06	.13 .04X .06*	23	.09	.12
Mn p.p.m.	12	2146	538	20	2127	600	19	2163	350	23	2030	437
Co p.p.m.	12	61	21	20	74	30	19	71	14	23	74	14
Cu p.p.m.	12	79	85	20	104	130	19	34	22	23	30	22
Ni p.p.m.	12	40	22	20	41	39	19	22.4	3.7	23	38.8	41.6
Ag+ p.p.m.	12	.9	.6	20	.8	.5	19	1.0	.2	23	.9	.2
Zn p.p.m.	12	130	66	20	125	57	19	131	42	23	122	44
	Ventures Gabbro			V.G. + Foliated Gabbro			Ventures Gabbro			V.G. + Foliated Gabbro		
Samples used in calculation	8470 - 402, 490, 530, 620, 715, 749, 817, 890, 930, 983, 1011, 1028			as before + 8607 - 140, 198, 260, 328, 340, 355, 359, 370			PH22 - 4 to 17 PJ27 - 1 to 5			as before + PH22 - 19 to 22		

X Excludes one sample from sulphide rich layer at top of Ventures Gabbro (PH22-4)

* Excludes two values outside 3 σ

\+ n.d. treated as 0.03 p.p.m.

i) Potassium

In the Lac Cummings section (Fig. 30) potassium appears to be controlled by plagioclase distribution, insofar as no K-feldspar was observed. The K_2O content rises from near zero in the ultramafic rocks to .08 percent in the pegmatitic portion of the Upper Green Pyroxenite, falling to half this value in the Foliated Gabbro and rising to an average of .30 percent through the Ventures Gabbro. K_2O then falls to less than .10 percent in the "Granophyre".

In the Opemiska Section, the pattern is generally similar but numerous anomalously high values in the gabbroic rocksraise the average for comparable sections of Ventures and Foliated Gabbro to approximately three times that of the Lac Cummings Section (Fig. 29). The specimens with anomalously high K_2O content contain above average amounts of secondary biotite and sulphides.

ii) Sulphur

In the Lac Cummings section (Fig. 31), sulphur content is low in the ultramafic rocks where the nickel-rich sulphide assemblage occurs. It rises to a small peak of approximately .09 percent where the copper-rich sulphide assemblage occurs, falling off again until the iron-rich sulphide assemblage begins in the gabbroic rocks. Throughout the Foliated and Ventures Gabbros, sulphur distribution is rather erratic, reflecting the occurrence of sulphides as fine sparse particles, with occasional sulphide-rich patches.

The Opemiska section (Fig. 31) contains many erratic high values, with an average of 4-6 times higher S (Fig. 29) than comparable rocks in the Lac Cummings section. Low or "background" values are similar in

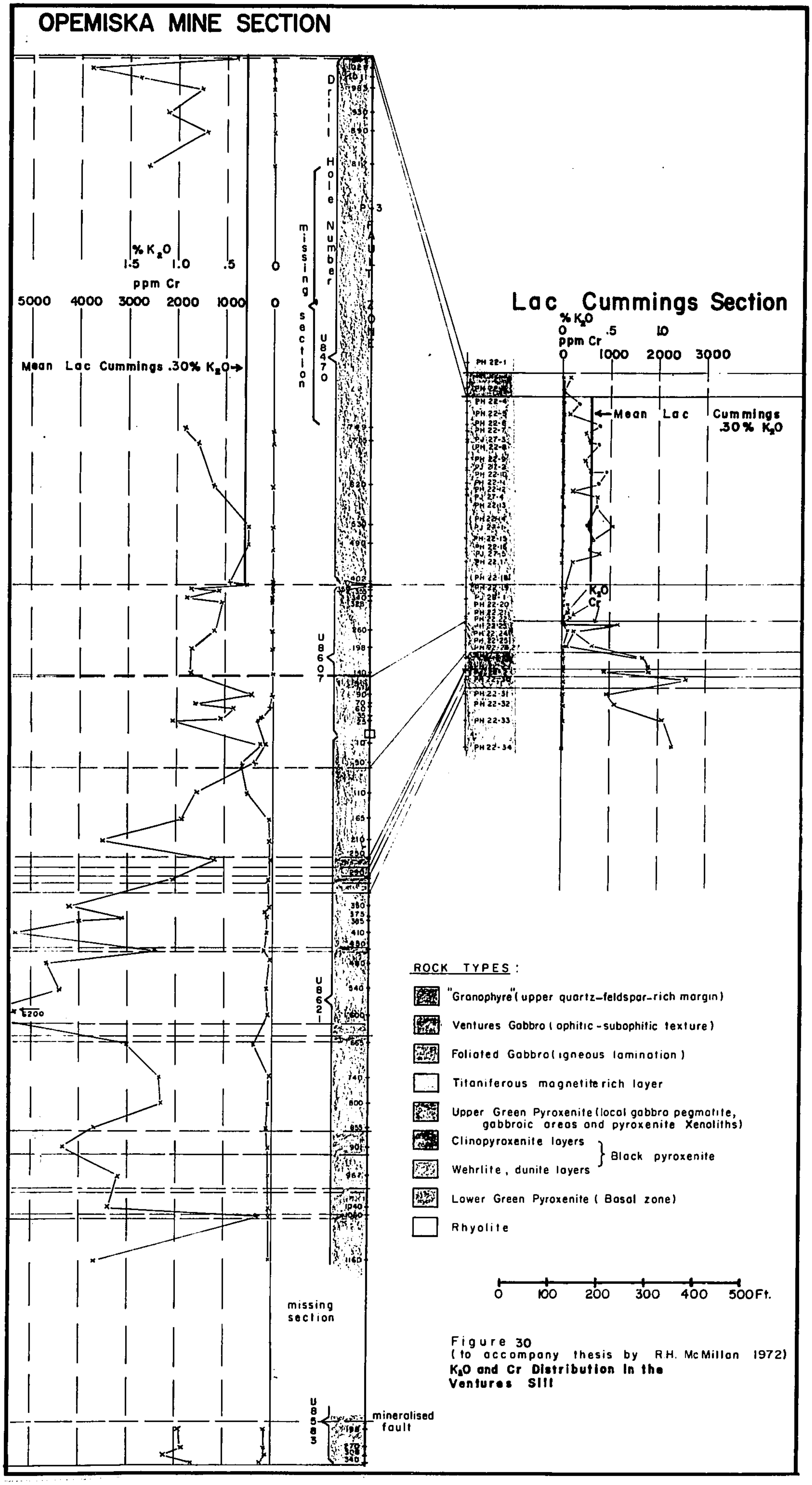


Figure 30
(to accompany thesis by R.H. McMillan 1972)
K_2O and Cr Distribution in the Ventures Sill

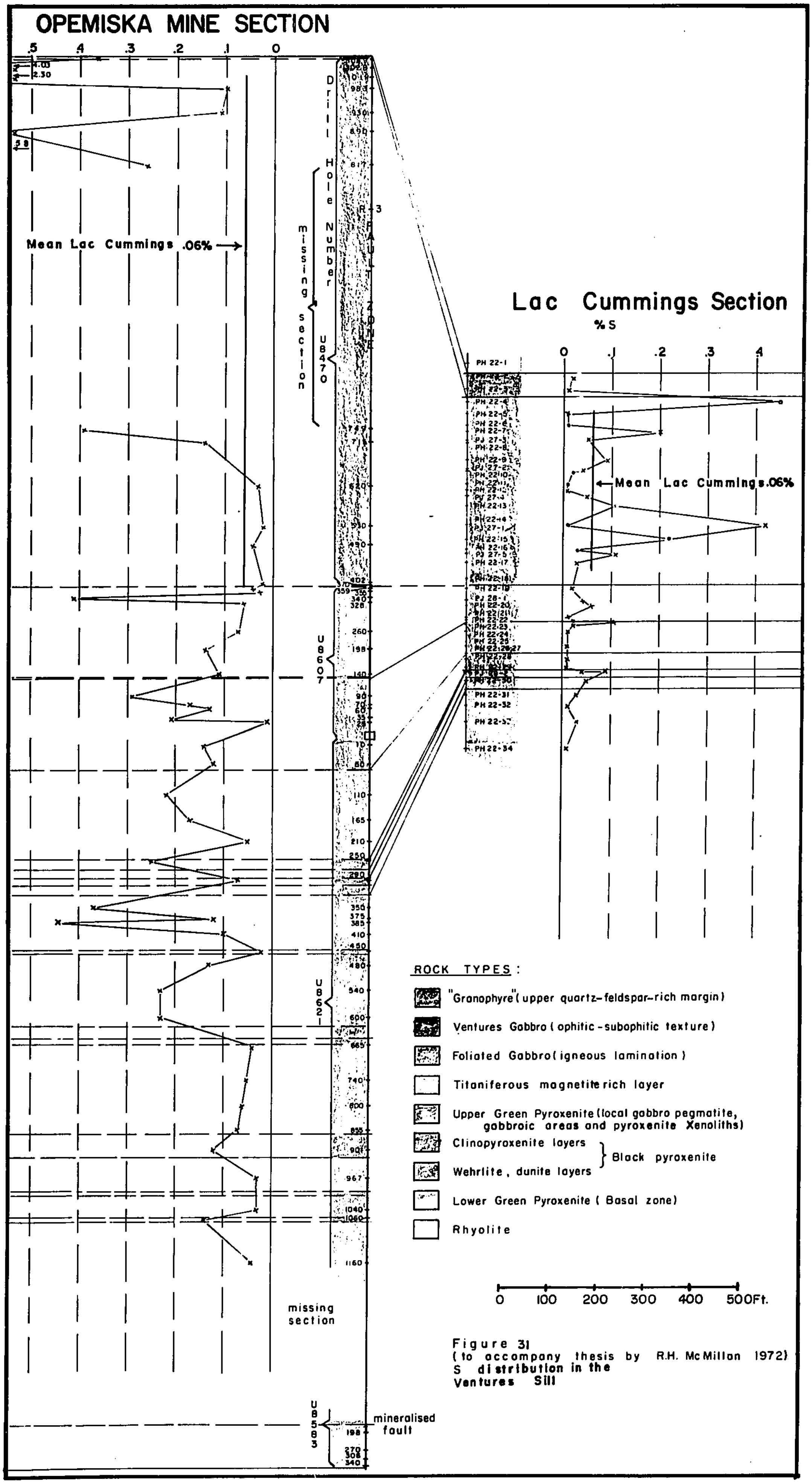


Figure 31
(to accompany thesis by R.H. McMillan 1972)
S distribution in the
Ventures Sill

both areas. In the gabbroic rocks of the Opemiska section there is a close correspondence between samples with anomalously high S and K_2O content.

iii) Copper

In the Lac Cummings section (Fig. 32), copper content in the olivine-rich ultramafic rocks near the base of the section is negligible, but rises to 200 parts per million in the uppermost Black Pyroxenite, where the copper-rich sulphides occur. The copper content then decreases until it again rises to a peak at the magnetite-rich layer at the base of the Foliated Gabbro where the iron-rich sulphide zone begins. It falls off again through the Foliated Gabbro until the Ventures Gabbro, where it averages 34 ppm, never exceeding 80 ppm.

This distribution contrasts strongly with that in the Opemiska section, where although the lower values are similar, there are many erratic high values, many of which are coincident with high K_2O and S content in the same samples. In the Opemiska section, the average copper values for comparable gabbroic rocks are two to three times that of the Lac Cummings section (Fig. 29).

iv) Silver, Zinc, Nickel, Cobalt, Manganese, Chromium

The poor precision of the silver analyses (Fig. 28) make any statements about silver distribution speculative at best. The poor correlation between the Ag analyses (Fig. 33) and Cu analyses is particularly strange in view of their apparent coherence in other studies (Wager and Brown, 1968, p. 199).

In the lower parts of the Ventures Sill in the Lac Cummings Section, the content of zinc is less than 100 ppm (Fig. 33), rising to an average of 131 ppm in the Ventures Gabbro, perhaps reflecting its preference

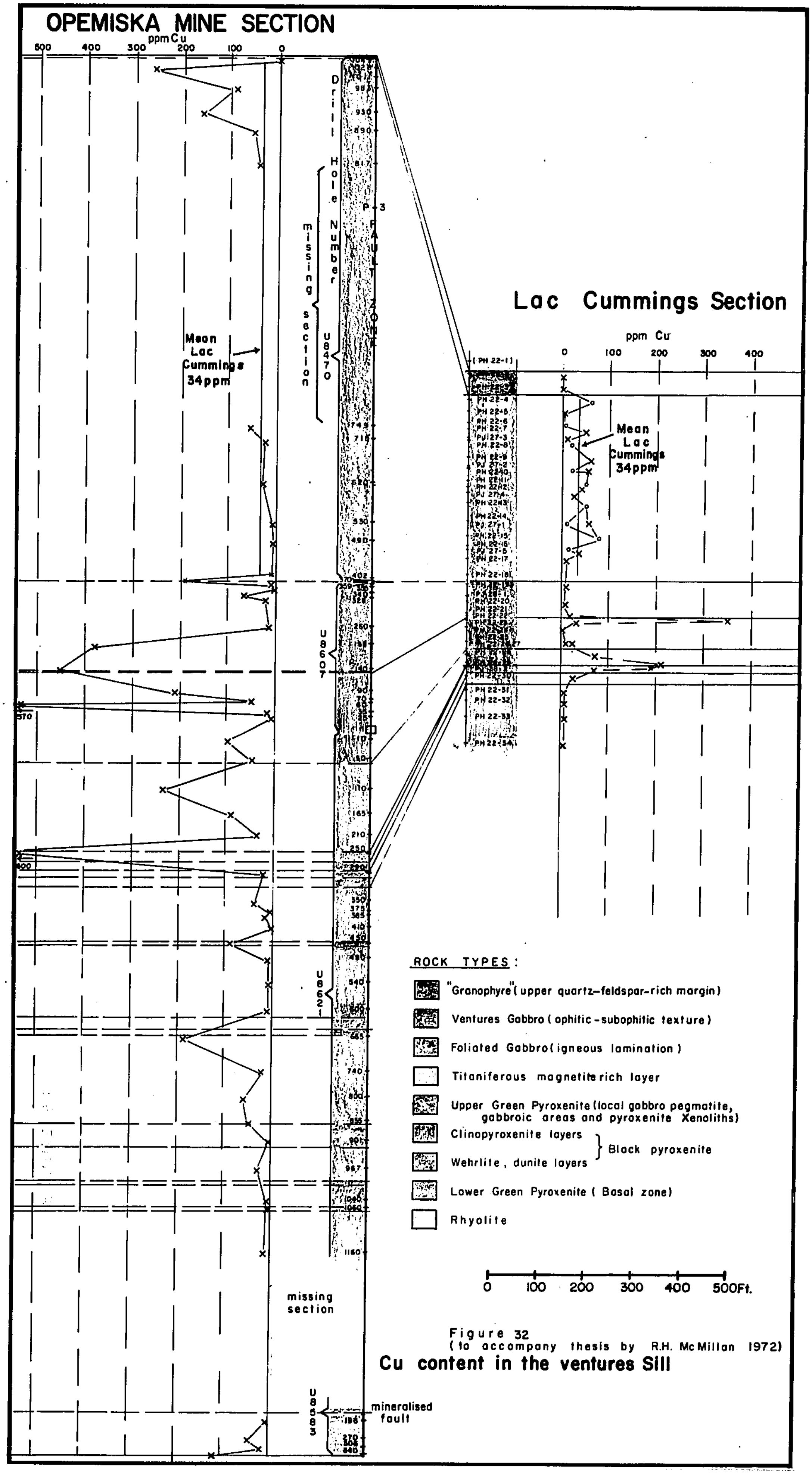


Figure 32
(to accompany thesis by R.H. McMillan 1972)
Cu content in the ventures Sill

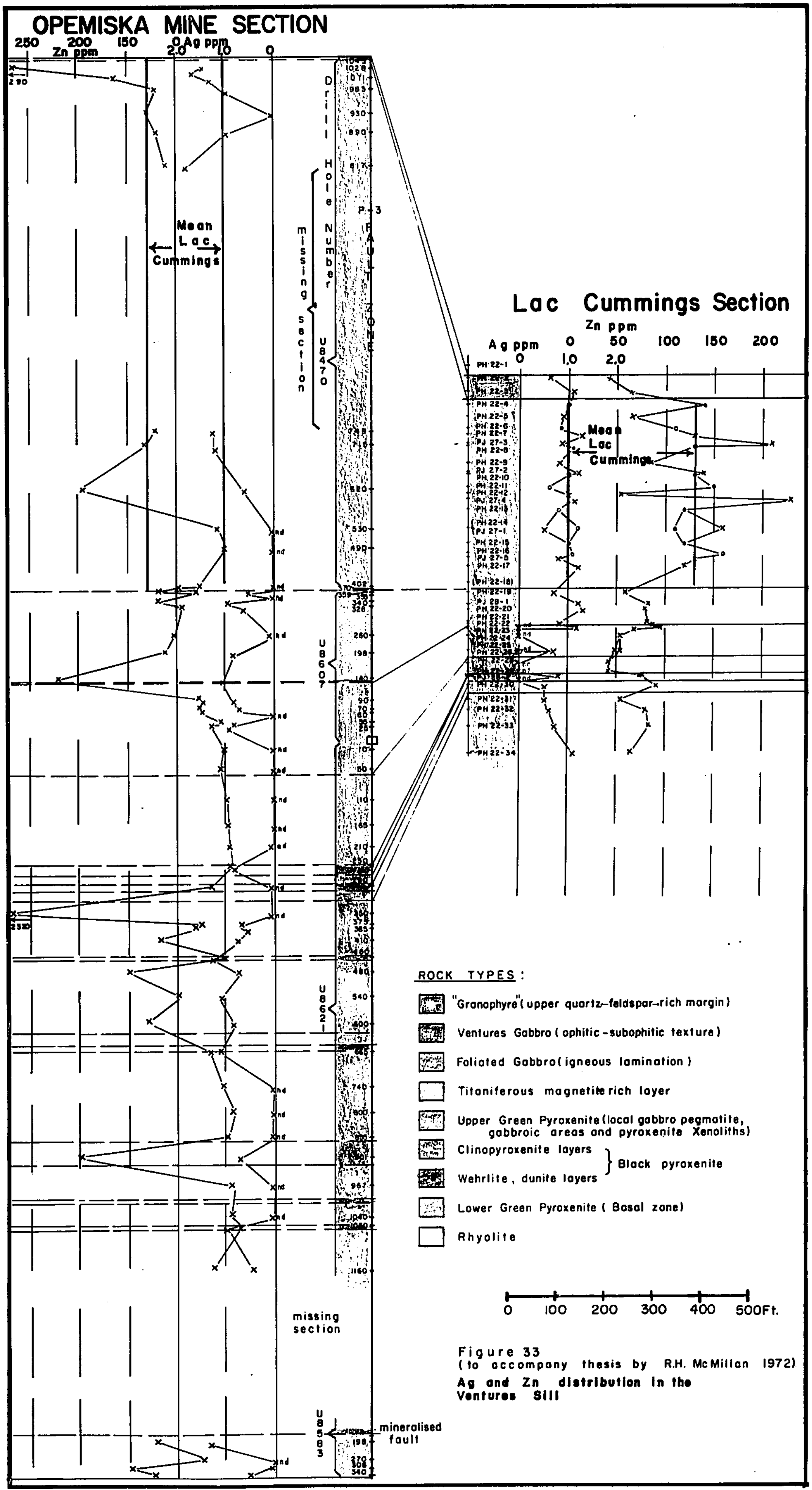


Figure 33
(to accompany thesis by R.H. McMillan 1972)

Ag and Zn distribution in the Ventures Sill

for magnetite as a host mineral (Wager and Brown, 1968, p. 200). Zinc may be present as fine sphalerite, as in a basic intrusion in Missouri (Desborough, 1963), but none was identified in the Lac Cummings Section. There are no clearly definable differences in zinc distribution between the Lac Cummings and the Opemiska sections.

Nickel distribution (Fig. 34) in both areas is similar and, as expected, Ni content is highest in the ultrmafic rocks, dropping to an average of 22.4 ppm. in the Ventures Gabbro. A slight rise in nickel content to slightly more than 50 ppm is discernible in the top 150 feet of the Ventures Gabbro in the Opemiska section, but not in the Lac Cummings section. Throughout the rest of the Sill, higher nickel values correspond closely to the abundance of olivine, reaching maxima of 2,000 to 2,500 ppm. in the dunitic layers, and falling to about 500 ppm. in the clinopyroxenite layers. Some relatively high nickel values from samples low in the Foliated Gabbro probably reflect the former presence of olivine.

Cobalt (Fig. 35) shows similar distributions in both the Lac Cummings and Opemiska sections and is highest in the olivine-rich rocks in both areas. The cobalt values then decrease through the pyroxenite, rise again to a peak of 145 ppm. in the titaniferous-magnetite rich layer at the base of the Foliated Gabbro, and thereafter fluctuate at an average of about 71 ppm. in the gabbroic rocks. This distribution is consistent with the data of Wager and Brown (1968, p. 180) which suggests that the highest concentrations of cobalt occur in olivine, followed closely by magnetite and ilmenite, with considerably less in pyroxene or plagioclase.

Although the relative standard deviation of the Mn analyses (Fig. 28) taken as a whole is very poor, if the results of November 19, 1971

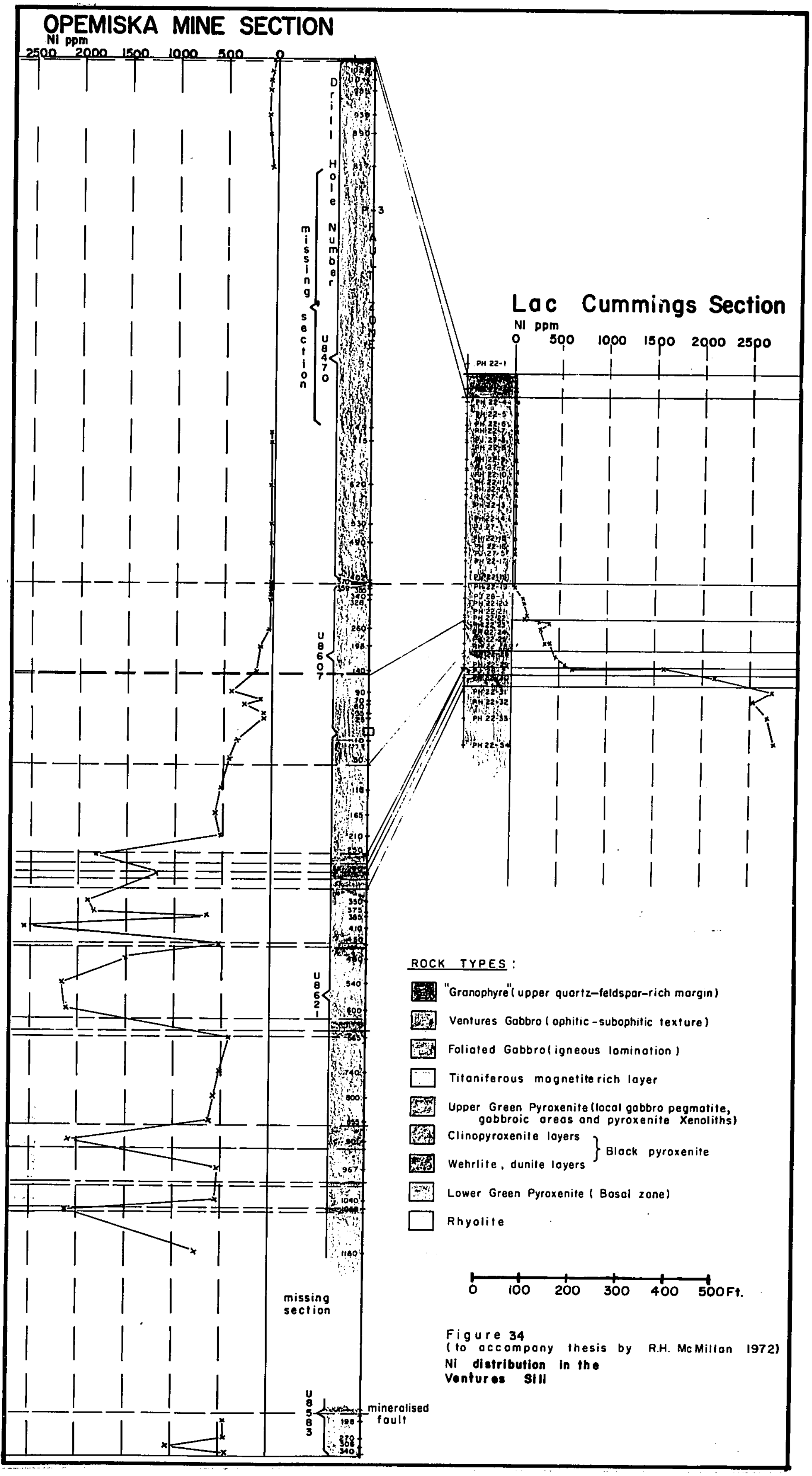


Figure 34
(to accompany thesis by R.H. McMillan 1972)
Ni distribution in the Ventures Sill

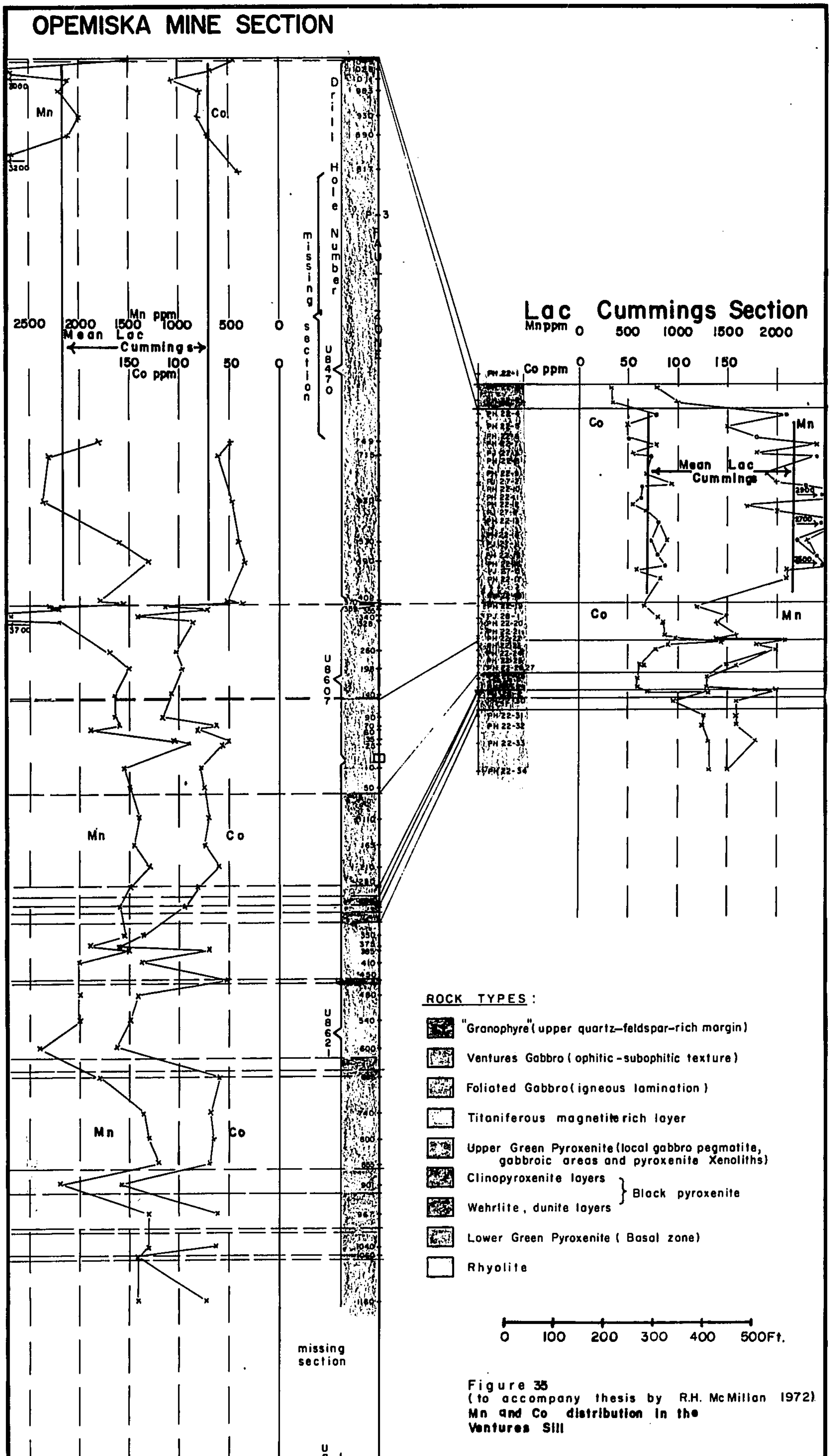


Figure 35
(to accompany thesis by R.H. McMillan 1972)
Mn and Co distribution in the Ventures Sill

are removed, the variance is reasonable. The results presented in Fig. 35 and the ones used in the alteration diagrams (Figs. 3 to 8) are from the group with the small standard deviation. The other results have not been presented. Manganese distribution closely parallels that of cobalt, reflecting its preference for the same minerals as cobalt. Despite this close correlation, manganese is richer in the Ventures Gabbro than the serpentinites, whereas the converse is true for cobalt.

Although the low precision in the Cr analyses for the low-Cr gabbroic rocks (Fig. 28) has prevented their use in the alteration diagrams (Figs. 3 to 8), in the ultramafic rocks the results are probably sufficiently accurate to allow comment. The highest chromium values are found in the olivine-rich layers, where cumulus chromite is relatively abundant (Fig. 30). Cr_2O_3 is also high in the pyroxenitic layers, where it occurs mainly in the pyroxenes and not in a separate mineral species.

D. Major Element Abundances in Clinopyroxene

Microprobe analyses of clinopyroxenes were utilized to investigate fractionation trends in the rocks of the Ventures Sill. In the case of the Ventures Gabbro, it was hoped that in the absence of textures unique to cumulus rocks, the analyses would indicate if the rock was in fact of cumulus origin. In the ultramafic rocks it was hoped that they would clarify whether the repetition of some of the olivine-rich layers was due to new injections of magma, or to some other factor. The analyses together with the structural formula for each sample are presented in Fig. 36.

The MgO/FeO ratios in clinopyroxenes (Fig. 37) illustrate the cryptic variation well. The iron enrichment trend which is clearly evident in

Figure 36. Table Showing Microprobe Analyses and Structural Formulae of Ventures Sill Clinopyroxenes

	Sample		PH22-5 (a)		PH22-8 (b)		PH22-14 (c)		PH22-18 (d)		PH22-21 (e)		PH22-24 (f)		PH22-29 (g)
	SiO_2		50.02		50.08		50.19		50.14		51.59		50.23		52.45
	TiO_2		.91		.81		.90		.70		.41		.86		.30
	Al_2O_3		1.05		1.24		1.44		.81		1.80		2.26		1.01
	FeO*		22.68		19.18		13.33		23.50		12.84		9.60		7.24
	MgO		5.64		7.87		10.55		4.22		13.29		13.43		17.16
	CaO		19.92		19.80		21.21		19.28		18.87		20.61		20.95
	Na_2O		.26		.24		.35		.38		.50		.50		.33
	Cr_2O_3		.01		.02		.07		.00		.00		.23		.36
	MnO		.47		.36		.23		.39		.20		.11		.11
	Total		100.99		99.60		98.27		99.42		99.50		97.83		99.91
Z	Si	2.000	1.966	2.000	1.962	2.000	1.949		2.005	2.000	1.954	2.000	1.923		1.942
	Al		.049		.057		.066		.038		.080		.102		.044
	Ti		.027		.023		.026		.021		.012		.025	2.000	.008
	Cr		---		.001		.002		.000		.000		.007		.011
	Mg		.330		.460		.611		.251		.750		.766		.947
	Fe*	1.995	.746	1.993	.629	1.994	.433	1.963	.785	2.012	.407	2.016	.307	2.034	.224
X + Y	Mn+		.016		.012		.008		.013		.006		.004		.003
	Ca		.839		.831		.883		.826		.766		.845		.831
	Na		.020		.018		.026		.029		.037		.037		.024
No. of analyses	grains		3		2		1		2		2		2		3
	points		9		4		3		5		2		3		6

* Fe total expressed as FeO in wt. percent

Figure 36 ...... continued

Sample	8621-10 (h)	8621-165 (i)	8621-290 (j)	8621-665 (k)	8621-740 (l)	8583-270 (m)
SiO_2	52.51	52.05	52.89	53.01	52.76	53.65
TiO_2	.44	.35	.40	.28	.28	.31
Al_2O_3	1.27	1.02	.94	.99	.97	.97
FeO*	9.08	6.72	5.87	6.86	6.00	6.53
MgO	16.69	17.11	17.95	17.34	17.15	16.96
CaO	20.53	20.70	21.44	21.08	21.29	21.28
Na_2O	.20	.26	.31	.24	.34	.33
Cr_2O_3	.09	.40	.75	.66	.50	.45
MnO	.04	.01	.01	.09	.11	.14
Total	100.85	98.62	100.56	100.55	99.40	100.62
Z	2.000	2.000	2.000	2.000	2.000	2.000
Si	1.936	1.946	1.936	1.946	1.953	1.963
Al	.055	.045	.041	.043	.042	.042
Ti	.012	.010	.011	.008	.008	.009
X + Y	2.029	2.024	2.022	2.025	2.021	2.013
Cr	.003	.012	.022	.019	.015	.013
Mg	.917	.953	.979	.949	.946	.925
Fe	.280	.210	.180	.211	.186	.200
Mn	.001	---	---	.003	.003	.004
Ca	.811	.829	.841	.829	.845	.834
Na	.014	.019	.022	.017	.024	.023
No. of analyses: grains	3	2	3	2	3	3
No. of analyses: points	6	4	5	3	8	7

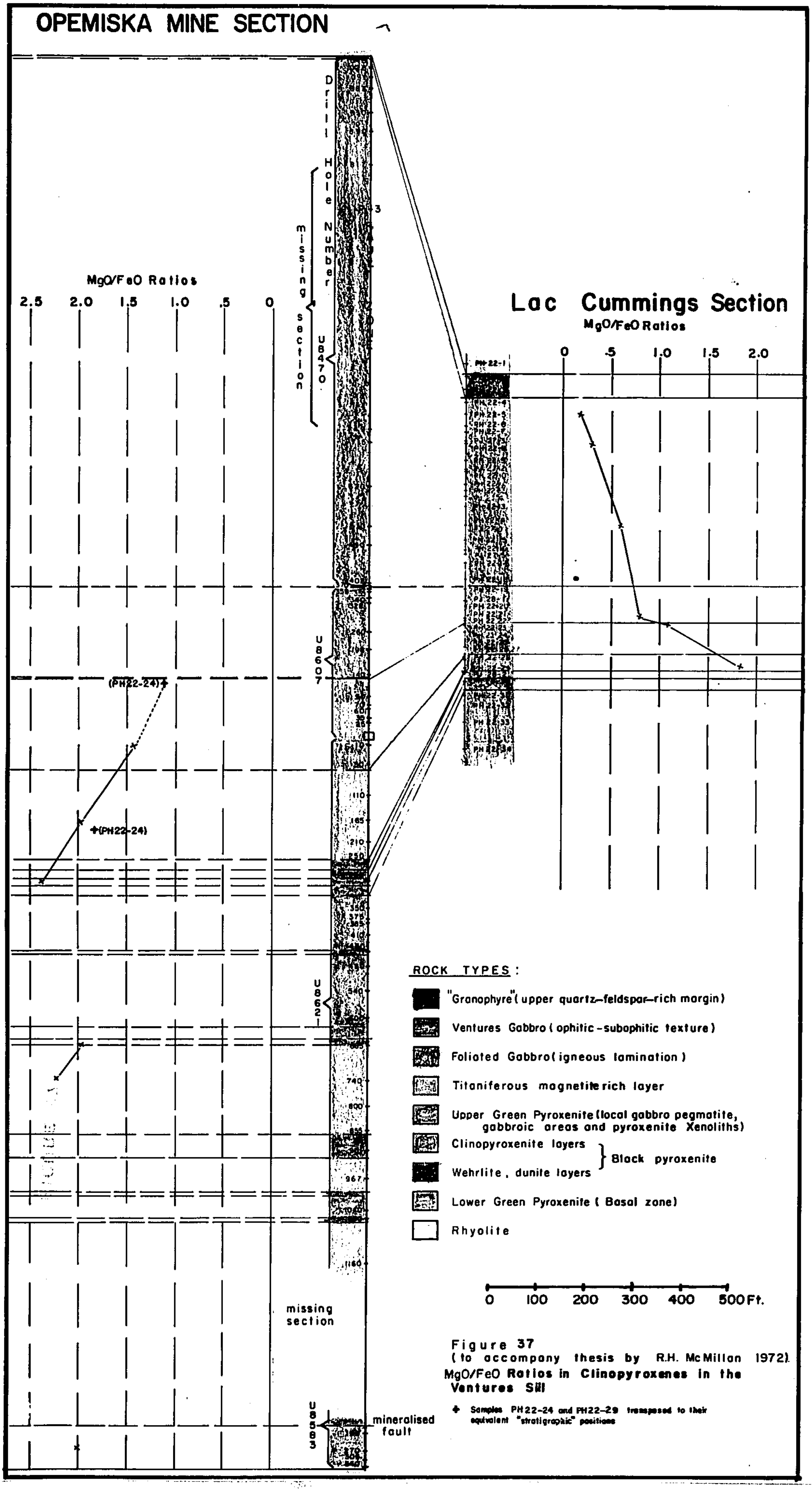


Figure 37
(to accompany thesis by R.H. McMillan 1972).
MgO/FeO Ratios in Clinopyroxenes in the Ventures Sill

✚ Samples PH22-24 and PH22-29 transposed to their equivalent "stratigraphic" positions the upper parts of the Sill (from 8621-290 and 165 upwards) is disrupted by the olivine-rich layers between 8621-290 and 665, and suggests that there was a new injection of magma in that section. The sharp break in slope of the MgO/FeO fractionation curve (Fig. 37) at the Upper Green Pyroxenite-Foliated Gabbro contact probably results from the appearance of magnetite and plagioclase as cumulus phases. This caused the partitioning of iron into a second major phase and also decreased the relative abundance of clinopyroxene, with a consequent decrease in slope. Although not conclusive, the smooth trend of iron enrichment in clinopyroxenes of the Ventures Gabbro suggests, despite the absence of textures unequivocably indicating a cumulus origin, that this rock is a "cumulate".

Figure 38 illustrates the Ventures Sill clinopyroxene trends relative to the Skaergaard and Bushveld trends. The trend in the Ventures Sill is similar to the other two in showing progressive iron enrichment, but there are also two major differences. In the Ventures Sill, the intermediate clinopyroxenes do not show the marked calcium depletions seen in the Skaergaard and Bushveld rocks. Also the iron-rich pyroxenes of the Ventures Sill are richer in calcium than those from the two other intrusions. The similarity in clinopyroxene compositions in the early rocks from all three intrusions suggests that the initial compositions of the magmas were perhaps tholeiitic basalt, but a different crystallization history resulted in the differences in compositions of later crystallized pyroxenes. This explanation is consistent with the textural observations that calcium-poor pyroxene was not a cumulus phase and that the clinopyroxene compositions were therefore not controlled by the intersection of the pyroxene solvus with the solidus curve of pigeonite (Boyd and Schairer, 1964).

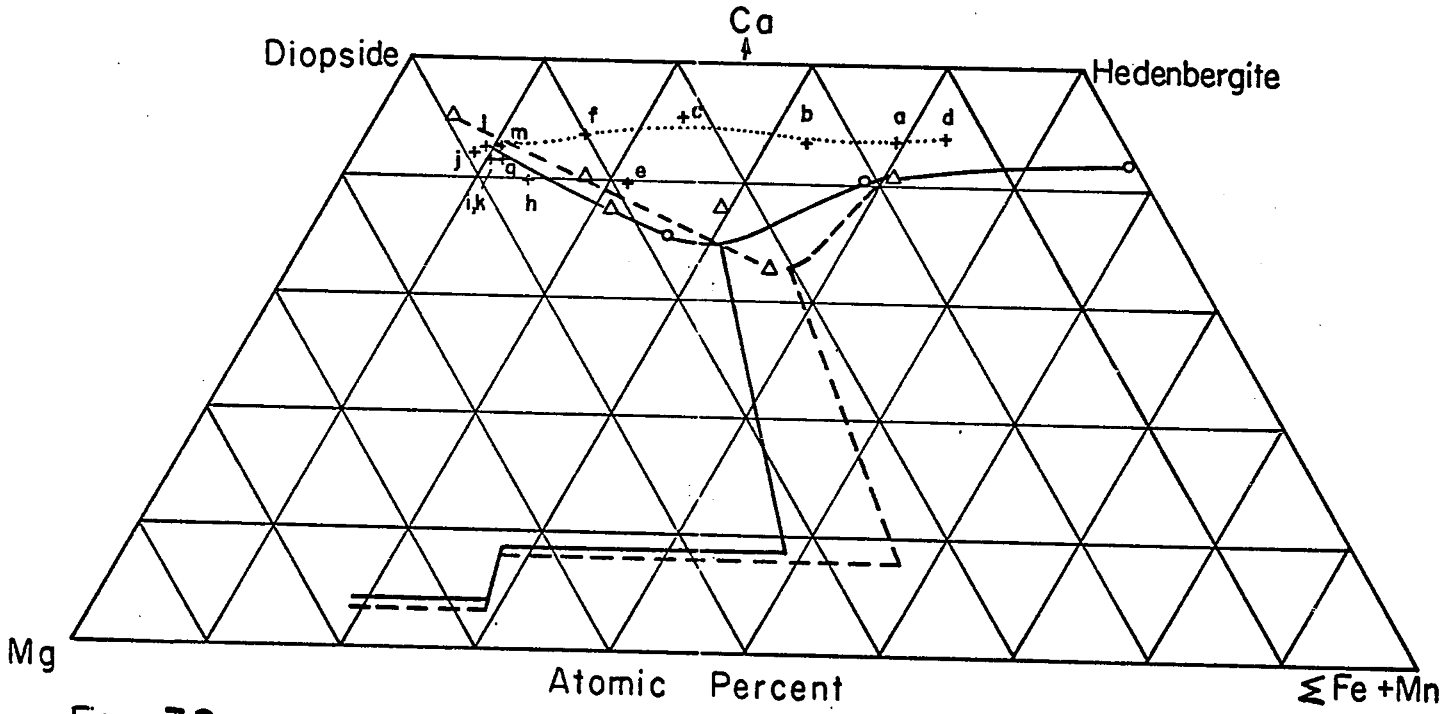


Figure 38

VENTURES SILL CLINOPYROXENE COMPOSITIONS

+a VENTURES SILL ANALYSIS
+·····+ VENTURES SILL TREND
o——o SKAERGAARD TREND (BROWN + VINCENT 1963)
△- - -△ BUSHVELDT TREND (ATKINS 1969)

Clinopyroxene compositions therefore show a simple iron enrichment relative to magnesium at relatively constant calcium composition.

Sample e (PH22-21) (Fig. 38) is anomalous to the above trend, but this is possible because it is located only five feet above the base of the Foliated Gabbro. It is the first specimen analyzed from above the point where the calcium-rich minerals plagioclase and apatite began to crystallize as cumulus phases. The magma probably became temporarily calcium-deficient immediately after these calcium-rich cumulus phases began to form, leaving less CaO available for the clinopyroxenes.

Sample d (PH22-18) is also anomalous in having most iron-rich pyroxenes, yet is low stratigraphically in the Ventures Gabbro. Relative to normal Ventures Gabbro, the sample is slightly finer grained, richer in feldspar and contains only insignificant amounts of titaniferous magnetite. Although not recognized as such during the sampling, this sample is believed to represent a dyke of highly differentiated Ventures Gabbro magma which has intruded its underlying cumulates.

E. Minor Element Abundances in Clinopyroxenes

Cr_2O_3 shows the most definite and useful variation (Fig. 39). The Cr_2O_3 content within two major clinopyroxenite layers shows a consistent decline from bottom to top, for example from sample 8621-740 to 8621-665, and from sample 8621-290 through to 8621-10, and suggests that during crystallization, chromium was partitioned preferentially into cumulus clinopyroxene from the magma. This data together with the fact that Cr_2O_3 content in the whole rock of the intervening olivine-rich layer is higher than that of the clinopyroxenite layers suggest that the magma has been replenished in Cr_2O_3 in the section where olivine was forming

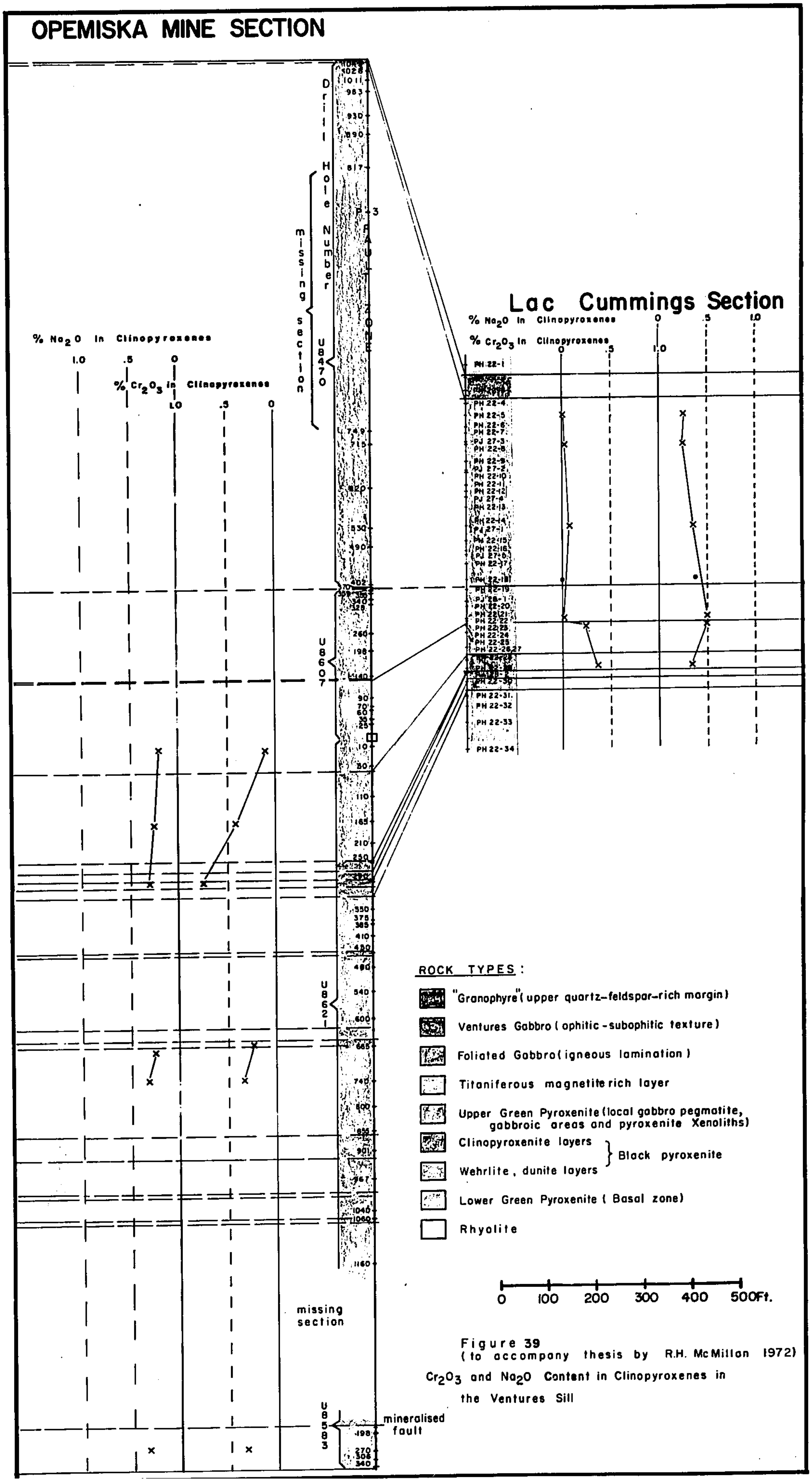


Figure 39
(to accompany thesis by R.H. McMillan 1972)

Cr_2O_3 and Na_2O Content in Clinopyroxenes in the Ventures Sill as the predominant cumulus mineral. This also implies an injection of new magma at the level represented by the olivine cumulates. Fifteen feet above the magnetite-rich cumulate at the base of the Foliated Gabbro, the Cr_2O_3 content of the pyroxenes falls to near zero and suggests that the available Cr_2O_3 was taken up in magnetite, thus depleting the magma at that point.

The titanium content of the pyroxenes increases at higher stratigraphic levels in the ultramafic part of the intrusion (Fig. 40), suggesting that TiO_2 accumulated in the residual magma during crystallization of the ultramafic rocks. The titanium content drops sharply above the titaniferous magnetite-rich layer at the base of the Foliated Gabbro, increasing again to a maximum in the uppermost analysed pyroxene in the Ventures Gabbro.

Manganese content in the clinopyroxenes (Fig. 40) increases from bottom to top of the intrusion, suggesting progressive enrichment of the magma in MnO with progressing fractional crystallization.

Sodium content in the clinopyroxenes (Fig. 39) rises from .3 percent in the ultramafic sections to .5 percent at the base of the Foliated Gabbro, then decreases upward through the Ventures Gabbro. This reflects the preferential partitioning of sodium into cumulus plagioclase after it became a cumulus mineral.

The alumina in the clinopyroxenes (Fig. 41) increases from approximately 1 percent in the lower ultramafic rocks to more than 2 percent at the top of the Upper Green Pyroxenite gradually decreasing upwards through the Ventures Gabbro. This suggests that the alumina content of the magma increased as differentiation proceeded until plagioclase appeared as a

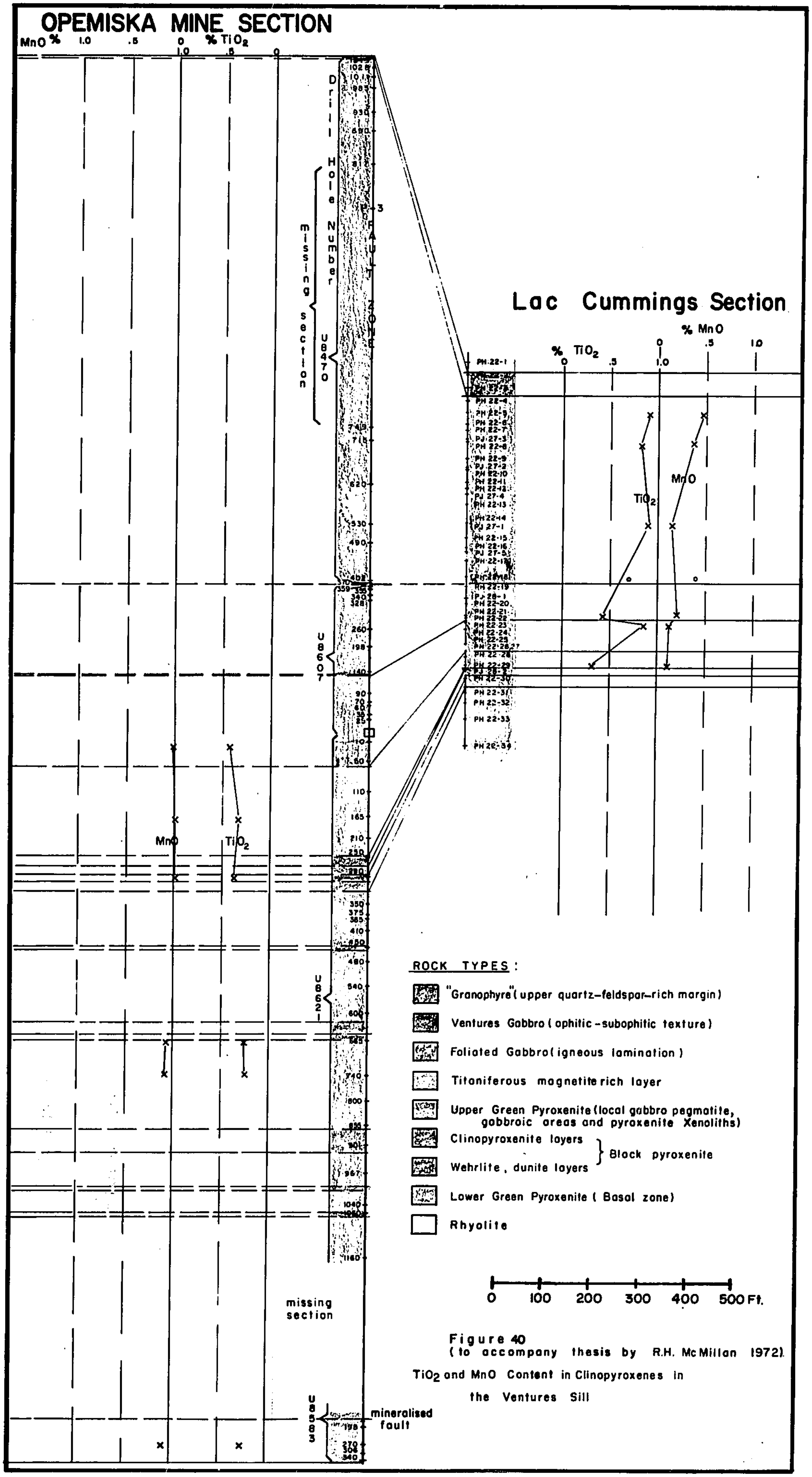


Figure 40
(to accompany thesis by R.H. McMillan 1972).

TiO_2 and MnO Content in Clinopyroxenes in the Ventures Sill

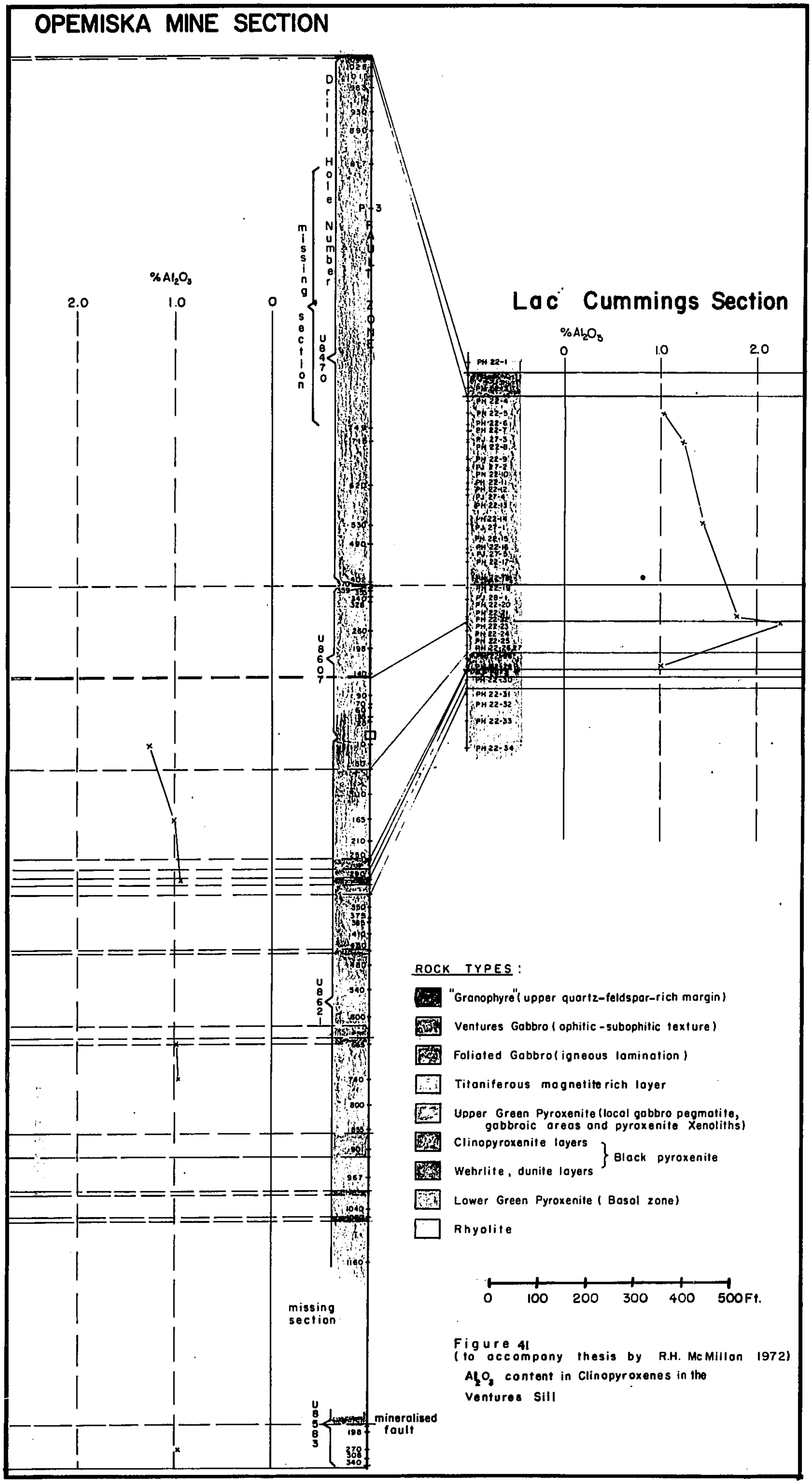


Figure 41
(to accompany thesis by R.H. McMillan 1972)
Al_2O_3 content in Clinopyroxenes in the
Ventures Sill

cumulus phase, and thereafter Al_2O_3 decreased as alumina was partitioned preferentially into plagioclase.

The minor element analyses of the clinopyroxenes in sample d (PH22-18) are all strongly anomalous to the above trends (Figs. 39, 40, 41), and the compositions in most of the variation diagrams suggest that this sample is the most acidic differentiate of all the analysed samples. This adds further substantiation to the textural evidence and major element analyses which suggest that it is from a dyke formed from highly differentiated Ventures Gabbro magma.

CHAPTER V

GEOLOGY OF THE OPEMISKA MINE

A. General Statement

This section is intended to provide detailed data on the lithology and different sulphide occurrences at the Opemiska Mine. In Chapter VII this data is used in interpreting the metallogenic relationships of the different occurrences and the genesis of the Opemiska veins. Most of the specific occurrences mentioned in the text are shown on Figs. 1 and 2, but some features which are too small to be shown, or which occur underground, have their locations specified in Appendix VI.

Some of the data was collected by the author through underground visits and traverses on surface during his tenure at the Mine in the summer of 1970. Discussions with the mine staff also contributed. A few selected polished and thin sections from each of the different mineral deposit types were studied in detail to determine the mineralogy and textural relationships. The latest published geological description of the property is by Derry and Folinsbee (1957). A Ph.D. study by Brown (1970) provides recent but unpublished information. Unpublished company reports by Buchan (1964, 1965), Brown (1963), Winter (1967, 1969) and Walker (1964) cover various aspects of the petrology, structure and mineralization on the property. Norman (1941), Archibald (1960) and Wolhuter (1960, 1962) have mapped the area for the Geological Survey of Canada and the Quebec Department of Mines.

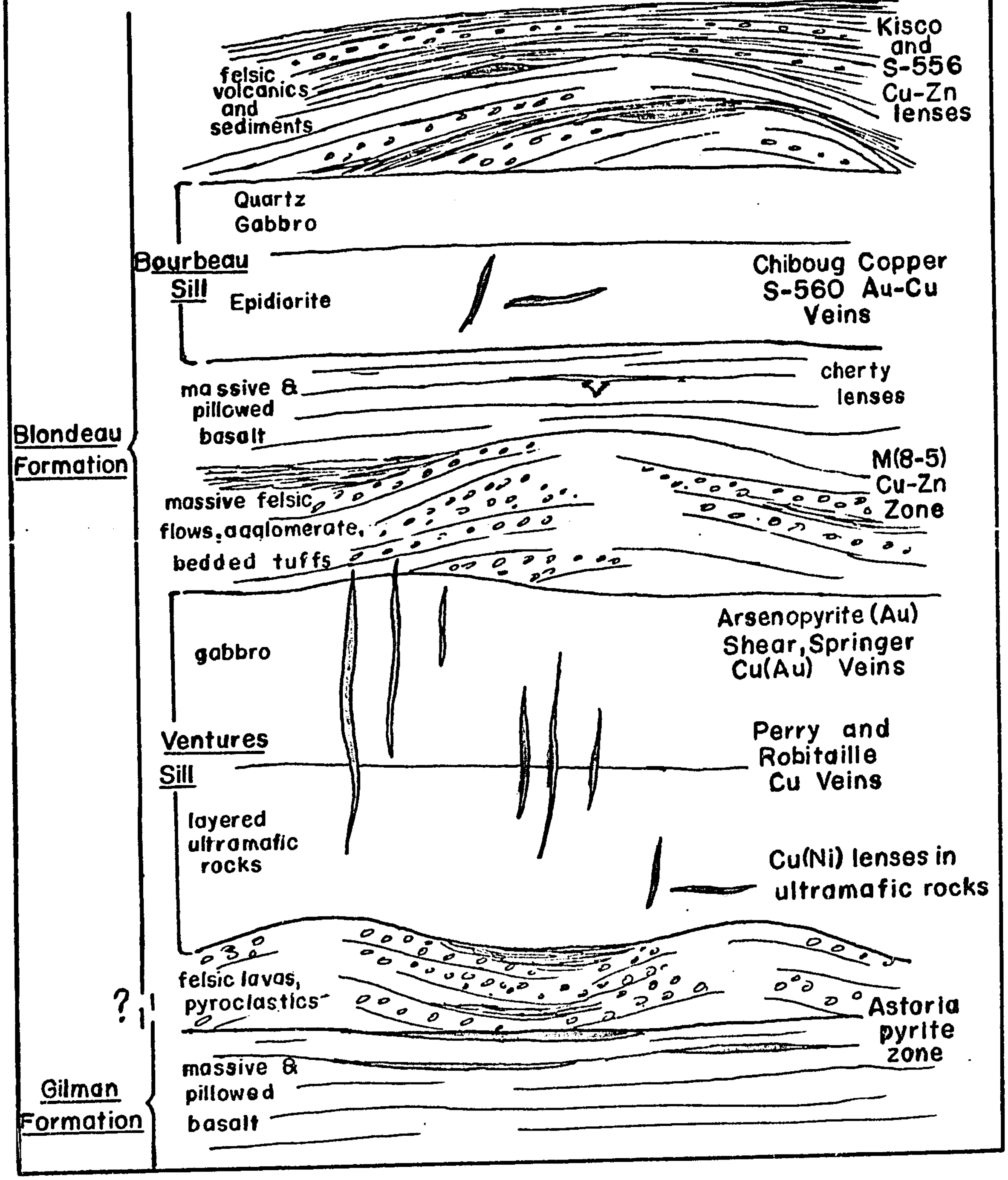
B. Layered Rocks

The property is underlain mainly by volcanic and sedimentary rocks of the Gilman and Blondeau Formations, and the intrusive Bourbeau and Ventures (Roberge) Sills. A diagrammatic stratigraphic section is shown in Fig. 42.

The stratigraphically highest rocks are part of the Blondeau Formation and crop out in the core of the overturned syncline in the western side of the area covered in the map in Fig. 2. These consist of strongly deformed, bedded siltstones, mudstones, felsic volcanic and volcaniclastic rocks, and minor chert. In this area they are host to the Kisco (Ceres) Cu-Zn showing. Similar rocks occur south of the Campbell Lake Fault and west of the Chiboug Copper showing where they are host to the S556 Cu-Zn showing (Fig. 1).

The Bourbeau Sill, which occurs below these rocks, is exposed along the western edge of the area shown in Fig. 1, as well as south of the Campbell Lake fault zone where it is host to S560 and Chiboug Copper gold-quartz veins. In the mine area the Bourbeau Sill is approximately 2,000 feet thick and consists of a basal pyroxenite layer slightly less than 100 feet thick, overlain by approximately 1250 feet of ophitic gabbro (epidiorite) which is in turn overlain by approximately 750 feet of quartz gabbro. The gabbroic rocks are all highly altered and medium grained. However, the quartz gabbro has prominent quartz "eyes", and plagioclase feldspar is much less prominent than in the ophitic gabbro (epidiorite).

Figure 42 GENERALIZED STRATIGRAPHIC SECTION SHOWING LOCATION OF VARIOUS SULPHIDE DEPOSITS AT OPEMISKA



East of and below the Borbeau Sill on the western edge of the property (Fig. 1) is a thick section of locally pillowed basaltic lava flows. Fine grained, thinly laminated felsic "cherty tuffs" occur as small but thick lenses interbedded with these basaltic flows. Brown (1970) suggests that these siliceous lenses may have been deposited from siliceous hot springs because of the presence of partial silicification of the basalts stratigraphically below the "cherty tuffs".

Below these basaltic lavas, there is a sequence of massive felsic flows, agglomerates and bedded tuffs which contain minor sulphide lenses. Similar rocks occur below the Ventures Sill in the area covered by the eastern edge of Fig. 1 and again just north of the Campbell Lake fault. Immediately west of the Chiboug Copper showing, the felsic rocks between the Ventures and Bourbeau Sills are host to the conformable M(8-5) Cu-Zn zone.

The volcanic and sedimentary rocks in the Astoria area, shown in the southwest portion of Fig. 1, are believed lower in the section and part of the Gilman Formation. Stratigraphic correlations remain speculative in this area, however, because exposures and drilling information are scarce. Faulting also contributes to the stratigraphic uncertainties in this area.

In addition to the Ventures and Bourbeau Sills, a number of smaller mafic bodies up to 100 feet in thickness occur intercalated with the volcanic rocks and are thought to be sills, but could also be thick lava flows. One such body occurs west of the Springer Mine (Fig. 1), and another forms the hanging wall of the M(8-5) zone.

C. Dykes

At least four petrographically distinct types of dykes cut both the volcanic and sill rocks in the mine area. These include ultramafic, lamprophyric, syenitic and intermediate to mafic dykes. The intermediate to mafic dykes are the most common, and range in width up to about 15 feet. They are steeply dipping, and usually occupy northeast and west to northwest trending fractures. In hand specimen they are medium to dark green and massive. The narrow mafic dykes are all fine grained, but the centers of some of the thicker ones contain hornblende and saussuritized plagioclase phenocrysts. Some also have a "mottled" appearance with irregular light-coloured feldspar-rich "clots" or irregular greenish epidote rich areas.

In thin section, the fine grained groundmass material is seen to consist predominantly of amphibole and altered plagioclase, but quartz, sericite, chlorite, K-feldspar, leucoxene, zoisite, epidote and calcite are also common. Stilpnomelane and biotite are scarce, considering their abundance in Ventures Gabbro. The thin section examination and the chemical analyses indicate that there are several compositional sub-types. Neither of the two dykes which were analysed for major elements (Fig. 27) appear to be typical of the majority of the intermediate to basic dykes. OG24-9 is medium grained and equigranular with hornblende phenocrysts and abundant quartz. OH25-10 is similar in appearance, but has significantly less quartz, and clear K-feldspar can be seen replacing saussuritized plagioclase, particularly in chloritized areas.

Crosscutting relationships in the intermediate to mafic dykes suggest that there have been various episodes of intrusion, some earlier and some later than vein emplacement. These dykes are commonly faulted and sometimes carry stringers of pyrite-chalcopyrite mineralization and quartz veins, particularly those which are close to ore zones. On the other hand, some of these dykes appear to be post mineral. For example in 11K drift, northeast of the J-zone (Fig. 7), one such dyke displaces a three inch wide weakly mineralized zone carrying pyrite and chalcopyrite in bleached pink (fine hematite, not K-feldspar) Ventures Gabbro.

The syenitic dykes are less common than the intermediate to mafic dykes, and commonly occupy structures which parallel the veins. They are pre-ore and in places in the no. 2 Vein, carry ore-grade disseminated chalcopyrite-pyrite-pyrrhotite mineralization (Fig. 45). The mineralization and dykes have been sheared, and a schistosity is evident. The dykes are porphyritic with albite phenocrysts averaging 2 mm. in size forming about 60-70 percent of the rock. Occasional phenocrysts reach 5 mm. The groundmass is composed of fine grained albite and quartz. Accessory and alteration minerals include sericite, biotite, stilpnomelane, chlorite, calcite, epidote and zircon. The dykes are grey or pink in colour, but cobaltinitrite staining of the rock indicates that the pink in most cases is not a feldspar but fine hematite in albite. K-feldspar was found only as fine interstitial material associated with chlorite and sulphide mineralization. These dykes range from a few to sixty or more feet in thickness. Although these dykes have been regarded as apophyses of the Opemiska Lake Pluton, the low K_2O (Fig. 43 content makes this interpretation unlikely. Wolhuter's (1968) analyses of rocks from the pluton range from 2.52% to 3.44% K_2O and although the rock is a "leucocratic soda granite" with a narrow rim of "soda syenite" it is four to five times as rich in potassium (Fig. 43) as the syenites at the mine. It seems

Figure 43 ...... continued

Sample No.	S%	K_2O%	Co ppm	Cu ppm	Ni ppm	Ag ppm	Zn ppm	Mn ppm	Cr ppm	Type	Location
OG10-4	.36	.53	27	8	20	.6	8	170	16	grey silicified syenite porphyry	8-3 Drift
7294-1190	.07	.35	22	25	19	1.1	16	300	16	grey syenite porphyry	901 Drift Drill hole cross section
9031-510	.08	.43	24	10	16	nd	18	210	14	pink syenite porphyry	901 Drift Drill hole cross section
9031-533	.08	.91	27	6	18	nd	14	140	15	pink syenite porphyry	901 Drift Drill hole cross section

* Analyses by Quebec Department of Natural Resources

x Not analyzed

nd Not detected

See Fig. 28 and Appendix III for statistics on precision and accuracy, and for information on analytical methods.

more likely that the syenitic dykes are hypabyssal equivalents of the rhyolitic volcanic rocks and/or the "Tonalite-Diorite" suite of granitic rocks.

An ultramafic dyke was encountered in specimen OG28-9 (Fig. 5). It is part of a composite mafic-ultramafic dyke which strikes east and dips steeply north, cutting Foliated Gabbro. The contact relationships between the two dykes remain unclear because of poor exposures. In polished thin section, it was seen to be composed of about 45% altered olivine crystals up to 1 cm., which are pseudomorphed by talc and minor secondary magnetite. Amphibole occupies most of the rest of the section, along with lesser quantities of chlorite, stilpnomelane, magnetite, pyrite, chalcopyrite and chromite. The chromite has rims of secondary magnetite. An X-ray diffractometer pattern confirmed the presence of talc, amphibole, chlorite and stilpnomelane and the absence of plagioclase.

A biotite-augite lamprophyre dyke (OH21-15) was identified in the Springer Mine (Fig. 3). This dyke is two feet wide and strikes east, dipping 80° south. It is composed of about 15 percent coarse brown pleochroic biotite phenocrysts together with about 5 percent coarse partially uralitized clinopyroxene in a fine to medium grained groundmass of altered plagioclase and mafic minerals. Apatite is abundant in the groundmass.

The major and minor element geochemistry of the different types of dykes are presented in Figs. 27 and 43 respectively. For the most part the analyses are consistent with the observed petrography. The ultramafic and biotite lamprophyre dykes are high in Cr and Ni. The K_2O content of the intermediate to mafic dykes (excluding OH25-10) averages .63%

compared to .55% (Fig. 43) for the other four syenite porphyry dykes. All of the syenite dykes have copper contents of less than 25 parts per million.

In summary, there are two important dyke types in the area: the syenitic dykes, which occupy fractures in and/or parallel to the veins and are clearly pre-ore, and the more numerous intermediate to mafic dykes, some of which show evidence of being "post-ore", while others are mineralized.

D. Mineralization in the Ventures Sill

i) Structure

The Opemiska ore zones or veins are fracture zones permeated by sulphides and gangue minerals (Fig. 45), with some "massive" areas (Fig. 44). They range from a few to more than one hundred feet in width. Pyrite, less commonly chalcopyrite, and rarely pyrrhotite are disseminated in the wallrocks. Although in general the structure is simple, both Winter (1957) and Brown (1970) have shown that in detail the ore zones consist of a number of different intersecting en echelon and zig-zagging smaller-scale fracture sets which show consistent attitudes throughout most of the Springer and Perry Mines. Many of these smaller-scale fractures transect the overall trend of the ore zones. These ore zones are cut and displaced by southwest dipping, northwest trending faults, the S and P faults, which themselves contain economic sulphides in places. Other smaller faults of different orientations also cut the ore zones in places, and these too are commonly mineralized.

Fig. 44. Massive chalcopyrite and quartz in the No. 2 Vein, Springer Mine. Narrow lenticular bands of pyrrhotite up to 1/2 inch wide are parallel to the walls, and are barely perceptible in the lower left portion of the photograph. The altered wallrocks contain disseminated chalcopyrite. (10-2-60 stope)

Fig. 45. Pink and white syenite dyke cut by quartz, chalcopyrite and stilpnomelane veinlets. Disseminated chalcopyrite is also present. Cobaltinitrite staining indicates the presence of only minor K-feldspar which occurs associated with stilpnomelane and sulphides. The pink colour is albitic plagioclase, probably containing finely divided hematite. (10-2-6E stope, No. 2 Vein, Springer Mine)

ii) Mineralogy

Chalcopyrite is the most important metallic mineral present in the veins, but pyrite is also plentiful. Magnetite, pyrrhotite and molybdenite are less abundant and erratically distributed. Local areas contain visible and relatively abundant sphalerite, and less commonly galena. In polished section, minor sphalerite (Fig. 46) is seen in almost all sections containing abundant sulphides, galena (Fig. 46) was seen in two (Appendix VI) and arsenopyrite in two (Appendix VI) of the 22 polished sections examined from the Springer and Perry Veins. Native gold was seen in three (Appendix VI) of the polished sections under oil immersion (Fig. 47). Pentlandite is present in some of the veins cutting the ultramafic rocks. Ilmenite and rutile are common minor constituents and usually show skeletal outlines (Fig. 48). Magnetite in the veins is usually non-titaniferous and contrasts sharply with the "magmatic" magnetite found intergrown with ilmenite in the gabbro wallrocks. Buchan (1964) reported minor quantities of hematite, linnaeite and gersdorffite, the latter two being confirmed by X-ray diffraction.

Quartz is the most abundant non-metallic mineral, and calcite is also relatively abundant. Biotite and stilpnomelane are common, and although coexisting in some samples (Fig. 49) are more often antipathetic. Chlorite is common and actinolite is minor, locally occurring as subradiating crystals up to one inch in length. Minor K-feldspar is seen in thin section as fine material replacing plagioclase along grain boundaries, and rarely as massive fine grained material up to a few inches in width. Scheelite is erratic but locally abundant. Buchan (1964) identified minor quantities of axinite which he confirmed by X-ray diffraction.

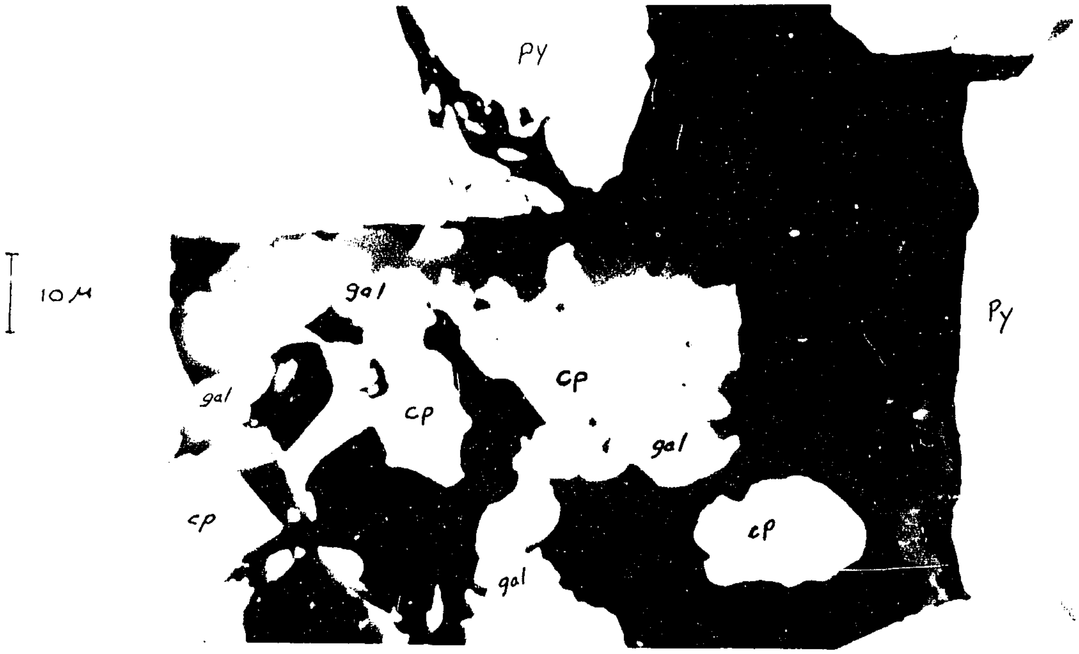


Fig. 46. Chalcopyrite rimmed by galena and sphalerite. Small exsolved chalcopyrite blebs (white) are present in sphalerite. The dark area is non metallic. The mineral on the rim of the photo is fractured pyrite. (Sample P4B5; Perry Mine, B-Zone, 4 level, 7350N; reflected light, oil immersion, 630x)

Fig. 47. Native gold in chalcopyrite between two rounded pyrite grains. (Sample S-2-3-7; No. 3 Vein, Springer Mine, 2 level, 5025E; reflected light, oil immersion, 150x)

Fig. 48. Magnetite portion of "magmatic" magnetite-ilmenite intergrowth replaced by chalcopyrite in "stringer" sulphide zone. (Sample S13-2-4; No. 2 Vein, Springer Mine, 13-2-8 stope, 6965E; reflected light, x96)

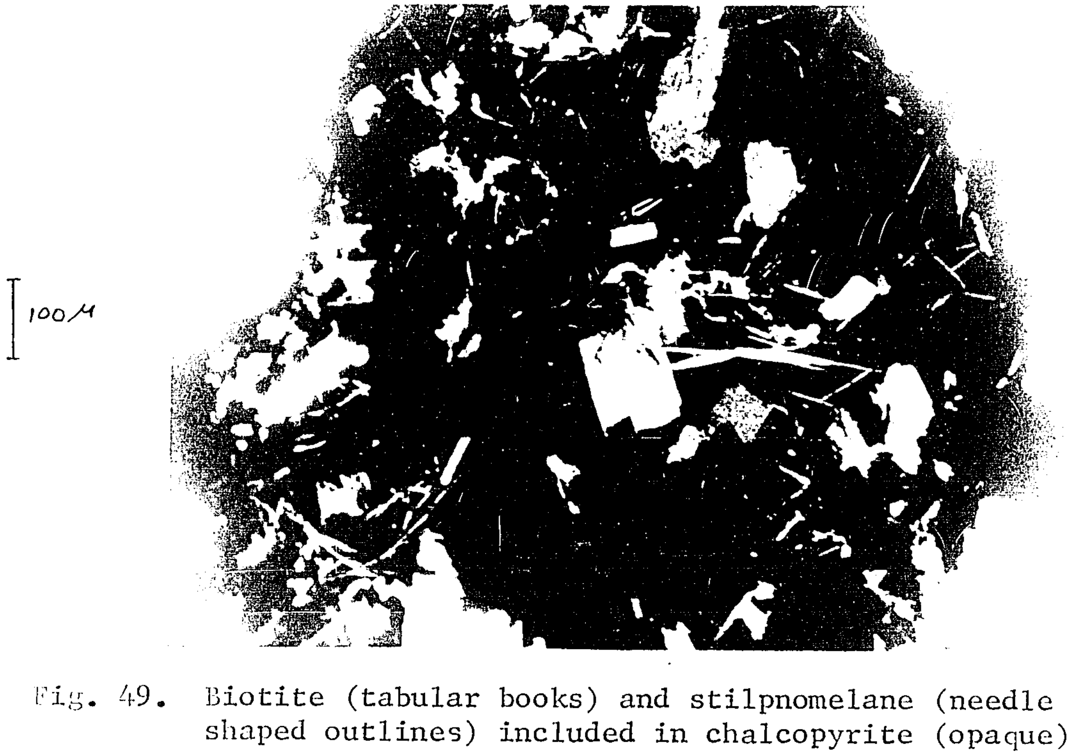


Fig. 49. Biotite (tabular books) and stilpnomelane (needle shaped outlines) included in chalcopyrite (opaque) in Ventures Gabbro 3 ft. into hanging wall of No. 31 Vein. (Sample OH24-10; 3 level Springer Mine; transmitted light, 60x)

iii) Textures

Much of the pyrite is euhedral but some is fractured and rounded (Figs. 46, 47), commonly with chalcopyrite filling the fractures. Arsenopyrite too is euhedral and displays rhomb-shaped outlines, but may be fractured similar to the pyrite. Chalcopyrite, pyrrhotite and sphalerite are anhedral. Native gold occurs along fine fractures in pyrite or included in chalcopyrite. Molybdenite is usually smeared out along late fractures. Most of the magnetite in the veins occurs as fine octahedra, but some occur as massive lenses up to 6 inches in thickness. The presence of ilmenite and leucoxene occurring as skeletal outlines partially invaded by sulphides (Fig. 48) suggests that these are refractory remnants of wallrock: this texture is found even in some massive quartz and chalcopyrite.

The quartz is massive and anhedral. Calcite is similar but usually occurs in smaller later fractures than quartz. Much of the biotite and stilpnomelane is bent and deformed, but some grains form euhedral books and plates in massive chalcopyrite (Fig. 49). They also occur as massive schistose material. Scheelite forms euhedral crystals in massive quartz or chalcopyrite. Most of the ore shows some degree of deformation and commonly chalcopyrite and pyrite form a matrix for brecciated silicate fragments. The softer sulphides, chalcopyrite, pyrrhotite and sphalerite, commonly invade fractures or cleavages in the pyrite or silicates. A few specimens are sulphide mylonite, with granulated, rounded quartz and pyrite fragments in a schistose matrix of phyllosilicates and chalcopyrite.

Cellular ovoidal pyrite nodules, which occupy cavities in massive chalcopyrite, are a curious feature of parts of the mine and are similar to those described by Rose (1965) at Temagami. The nodules are 1/2 to 4 inches in diameter, and are composed of an interlocking network of porous pyrite crystals which penetrate the edges of the enclosing massive chalcopyrite. They are common in the no. 14 Vein but are also found in the no. 2 Vein.

iv) Metal Content

As mentioned earlier, production to the end of 1968 was 7,945,580 tons, averaging 3.12% Cu, 0.030 oz. Au and 0.464 oz. Ag (Duquette, 1970). Detailed studies of minor element distributions have also been made, because some elements almost reach recoverable concentrations, or are possible undesirable contaminants. Mill-head assays for January 1969 showed 0.04% WO_3, 0.022% MoS_2, 0.12% Sn, 0.01% Ni, 0.03% Zn and negligible lead, and represent an average for ore drawn largely from the Springer Mine, with less from the Perry Mine and minor amounts from the Robitaille Mine. Tailings for September, October, November 1967 averaged 0.055% WO_3, and sampling at that time of the old tailings showed a low tungsten portion with 0.087% WO_3 and a high tungsten portion with 0.123% WO_3. Semi-quantitative spectographic analyses of the mill heads confirm these assays, and although Sn was not detected, barium (0.02% to 0.05%), chromium (N.D. to 0.02%), cobalt (0.01% to 0.1%) and lead (N.D. to 0.3%) were reported in various analyses.

Lead is abundant in one area in the no. 2 Vein (Appendix VI) where it occurs as galena in a one foot wide shear with quartz, carbonate, pyrite and chalcopyrite. The shear trends at 100°, dipping 75° north, and is parallel to the no. 2 Vein. The northwest trending, south dipping S-4 fault passes through the same area, and the high lead may in some way be related to its presence. Across forty feet, muck samples average 0.32% Pb.

Assays of up to five percent zinc are found associated with high gold values in the Arsenopyrite Shear. Local high zinc associated with high gold assays are also present in various parts of the no. 3 Vein. South of the Springer vein system but north of the Campbell Lake fault, one drill hole assay (Appendix VI) reached 7.5 percent Co over two feet. Uraninite or pitchlende has been identified in trace quantities by X-ray diffraction by the Geological Survey of Canada from the no. 31 Vein on the fourth level, and one assay across 2.5 feet indicated 0.16% U_3O_8 soluble in HNO_3.

v) Sulphide Deposits

a) Arsenopyrite Shear

The Arsenopyrite Shear (Asp. on Fig. 1) is near the Springer veins, but has a different mineralogy and attitude. It occupies a steeply southwest-dipping shear which trends at 130°, is up to two feet wide and contains quartz, carbonate, arsenopyrite, pyrite, sphalerite and chalcopyrite. Minor galena was identified in polished section. It has been traced from surface down to the third level, and although it contains notably more gold than the Springer veins it is not large enough to be minable. Although the fracture occupied by the "Arsenopyrite Shear" clearly displaces the structures occupied by the no. 1 and no. 2 Veins in a right-hand direction, the age of the mineralization in the former relative to that in the latter is still unclear.

b) Springer Veins

The Springer veins (Fig. 50) consist of a number of different ore

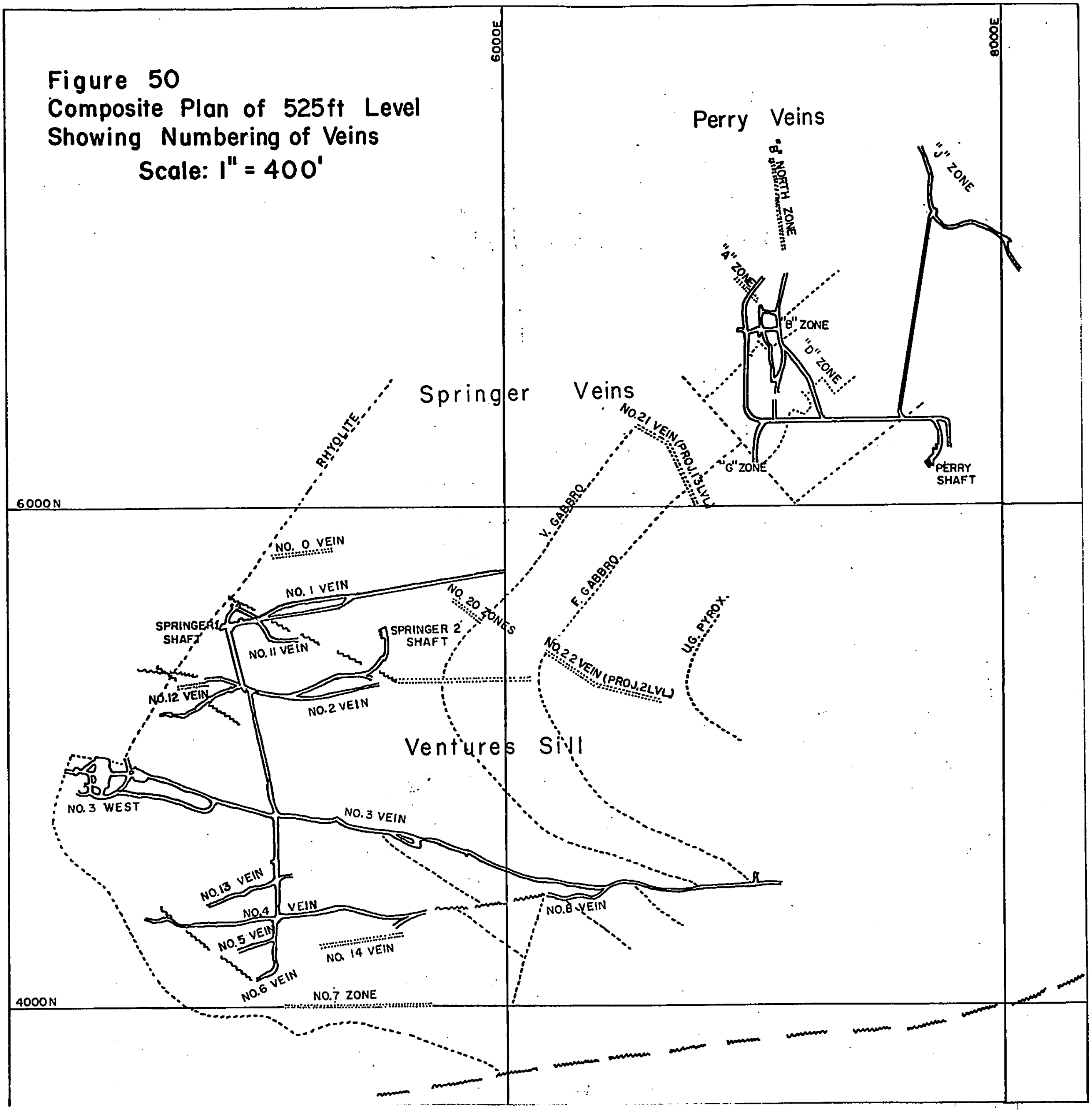


Figure 50
Composite Plan of 525ft Level
Showing Numbering of Veins
Scale: 1" = 400'

"zones" of generally similar attitude and mineralogy. Most of the high-gold ore at Opemiska is found in the Springer Veins, particularly in the upper levels of the no. 3 Vein. Local concentrations of magnetite are also characteristic of the Springer veins, and have been found in the no. 20 Vein (7 level), erratically throughout the no. 3 Vein and in the other veins south of the no. 3 Vein. Scheelite is locally very abundant in the no. 2 Vein and is also common in the no. 3 Vein and no. 20 Vein. Molybdenite is abundant in the no. 22 Vein, pyrrhotite is common in the no. 2, no. 20 and the no. 14 Veins, and quartz is abundant in the no. 3 and no. 20 Veins and erratically in the no. 2 Vein.

Most of the ore is in Ventures Gabbro, with lesser amounts in the Foliated Gabbro and Upper Green Pyroxenite. To the west, minor isolated occurrences of Cu-and Au-bearing sulphides have been intersected by drill holes in the overlying rhyolite along the strike of the Springer veins. In the upper levels of the mine, massive chalcopyrite is common, but on the Vein extremities and at depth, stringer mineralization is more characteristic. Below 13 level, narrow chalcopyrite-bearing stringers with relatively high sphalerite, gold and arsenopyrite contents are common.

The most important ore zone at Opemiska is the no. 3 Vein, which has produced most of the ore mined to date. The fracture zone it occupies has a left-hand displacement of about 300 feet and trends 100°, dipping steeply north. Detailed work by Winter (1967) has shown that the ore-bearing stringers within the zone occur along four different fracture sets. Ore occurs in Ventures Gabbro, Foliated Gabbro and Upper Green Pyroxenite and is continuous from surface to below the 13th level. The Vein rakes east, following the plunge of the synform (overturned anticline) of enclosing Ventures Sill rocks (Fig. 1). The no. 3 Vein contains massive chalcopyrite in the upper levels toward the center of the vein, but changes westward into a series of closely spaced stringers and disseminated mineralization which extends over widths of up to 200 feet. Small erratic structures located near the no. 3 Vein, but not in it, contain pyrrhotite veins, arsenopyrite-pyrite veins, galena veins and sphalerite veins.

The no. 2 Vein is much less regular than the no. 3 Vein and the mineralization within it also occupies four different fracture sets (Winter, 1967). It is similar in attitude to the no. 3 Vein, and like the no. 3 Vein, contains ore down to the 13th level and possibly below. On 12 level, the no. 2 Vein continues as a mineralized structure 300 feet into the rhyolites. The rhyolite walls are pervasively altered over a few inches to massive fine grained pink K-feldspar but the amount of chalcopyrite is insufficient to make ore. The other veins in the Springer system (0 or north, no. 1, no. 11, no. 12, no. 8, no. 13, no. 4, no. 5, no. 6, no. 7, no. 14 Veins) are generally similar in attitude, mineralogy and structure to the no. 2 and no. 3 Veins but are much less continuous, some being merely branches of the larger veins. These small veins are more prevalent on the upper levels and all pinch out above the 11th level. The numbers 20, 22 and 21 Veins are small offshoots of the no. 2 Vein which strike northwest and are similar in attitude to the veins in the Perry system.

c) Perry Ore Zones

The mineralogy of the veins in the Perry System is similar to that in the Springer veins, with some slight differences. Magnetite is scarce in the Perry veins, and the tenor of gold is much lower than in the Springer veins. Scheelite is thought to be less abundant than in the Springer

Mine. Molybdenite and arsenopyrite are erratically distributed. Sphalerite and pyrrhotite tend to be more abundant at depth.

Here the veins are totally confined to rocks of the Ventures Sill, and are stratigraphically lower in the sill than the Springer veins. Compared to the Springer Mine there is more ore in the Foliated Gabbro and Upper Green Pyroxenite, with small amounts in the Black Pyroxenite. Winter (1967) showed that four different fracture sets control the mineralization and that these individual fracture sets are similar in attitude to the fractures in the Springer veins although the gross trend of the ore zones is considerably different. The general rake of the ore zones is northeast.

The B-zone, the largest ore body, continues from surface to the 11th level where it is cut off by the B-2 fault. The zone strikes slightly west of north, dips steeply east and is mineralized with chalcopyrite, pyrite, minor pyrrhotite and traces of scheelite. Minor quartz and calcite are present. Massive chalcopyrite is present as well as disseminations and stringers.

The D-zone (Fig. 50) extends from surface to the 17th level and is composed of a number of parallel zones which continue from the south end of the B-zone in a southeasterly to easterly direction, dipping north. Chalcopyrite, pyrite and pyrrhotite are the important metallic minerals, with pyrrhotite increasing at depth. Calcite and quartz are present, with minor scheelite and molybdenite.

The J-zone is located about 700 feet northeast of the B-zone (Fig. 50) and strikes north-northwest, dipping steeply east. It continues from near surface to the 17th level, becoming weaker on the lower levels. It is essentially a quartz vein carrying chalcopyrite, pyrite and pyrrhotite. Between the 13th and 14th levels, the vein carries abundant sphalerite and pyrrhotite but little chalcopyrite.

The K-zone is a small northwest striking, northeast dipping structure which extends from above the 9th level to below the 13th level. It contains chalcopyrite and abundant pyrrhotite with minor pyrite. Some scheelite occurs in massive chalcopyrite. Quartz and calcite are not abundant. Other small veins which occur in the Perry system are the A, G and K-2 zones. The K-2 zone is one of the few examples of a minable tonnage of ore which occurs in a southwest dipping, northwest trending fault, the P-3, which is part of the northwest-trending set, members of which normally displace the ore zones.

d) Robitaille Vein

The Robitaille mineralization is similar to that in the Perry and Springer Mines, but its structural attitude is considerably different and it is separated from them by the Beaver Lake fault, a major northwest trending fault which dips approximately 45° northeast. The ore zone trends west-northwest, dipping steeply south with a rake to the east. It is cut off by the Beaver Lake fault below the 3rd level.

The vein is confined to the lower part of the Ventures Gabbro and the Foliated Gabbro. Chalcopyrite and pyrite are the main metallic minerals, and pyrrhotite is rare. The mineralization occurs mainly as disseminated sulphides, stringers and minor massive chalcopyrite containing angular fragments of brecciated altered wallrock. Locally (2-3-1 stope), molybdenite is common along shears in calcite, chalcopyrite and phyllosilicate minerals. A few barren quartz veins up to 2 feet in width are present. Calcite occurs as narrow late veinlets which carry minor sulphides. Scheelite is absent and the gold content is low relative to the Springer veins. The best ore occurs on the lower levels above the Beaver Lake fault where disseminated mineralization is up to 4% Cu across 20 feet.

e) Miscellaneous

Two showings occur in Ventures Gabbro south of the Campbell Lake fault. A high-tungsten zone located about 400 ft. east of Tadpole Lake (9200 N, 17,500 E, Fig. 2) contains scheelite mineralization associated with sections of massive pyrrhotite up to a few feet in width. Chalcopyrite and pyrite are also present. One hole contained 37.5 feet grading 0.58% Cu and 0.34% WO_3 (Appendix VI). The zone could not be traced over any significant distance and appears to be an isolated lens. A second small showing, the 5559 zone, strikes slightly north of west, and contains pyrite and chalcopyrite. It also occurs in Ventures Gabbro 1,000 feet south of Tadpole Lake (7,600 N, 16,000 E, Fig. 2).

f) Copper Mineralization in Ultramafic Rocks

These mineral showings are all small and resemble the veins in the gabbro in that they contain chalcopyrite and iron sulphides and occur in sheared zones. However they have some significant differences in metal content and the associated gangue minerals.

The East and North of East zones, located 2000 and 2200 ft. south of Trout Lake (Fig. 2), are both in the Black Pyroxenite and contain chalcopyrite-pyrrhotite occurring as disseminated material, narrow stringers, and small massive pods which commonly contain breccia fragments of altered wallrock. These zones occur 1300 ft. above similar mineralization occurring in Black Pyroxenite south of 901 Drift (Fig. 9) and the mineralization could be semicontinuous between them. No quartz is present in the zones, and the gangue minerals consist of talc, serpentine and carbonate. Pyrite is subordinate to chalcopyrite and pyrrhotite, and minor amounts of molybdenite (Appendix VI) or scheelite (Appendix VI) have been found in all of them. The metal content of these zones is illustrated by hole S-80 from the East zone where 2.1 feet of mineralization grades 15.72% Cu, 0.01 oz. Au, 4.37 oz. Ag and 0.41% Ni, and a second section 4.1 feet wide grades 1.92% Cu, 0.04 oz. Au, 1.08 oz. Ag and 0.22% Ni. In a few samples where Co was analysed, it is in the same range as nickel. The zones are steeply dipping, with strikes subparallel to the lithologic contacts.

The L zone, located 2800 ft. south of Trout Lake (Fig. 2), occurs in Lower Green Pyroxenite in a steep west-northwest trending shear. It contains pyrite, pyrrhotite and chalcopyrite with very minor quartz. Hole no. S-119 contained 2.8 ft. grading 4.05% Cu and 0.16% Ni. The G zone, located 2400 ft. W of Ellis Lake (Fig. 2), occurs in a steep south-dipping, west-northwest trending shear which transects serpentine and pyroxenite layers near the lower contact of the Black Pyroxenite. It reaches a maximum of five feet in width, and is composed of pyrite, chalcopyrite with minor calcite and no quartz. The vein is cut off at its southern end by a small mineralized fault containing pyrite and chalcopyrite which also forms the contact between Black Pyroxenite and Lower Green Pyroxenite. The Royran zone, located 200 ft. NW of Ellis Lake (Fig. 2), occurs near the Lower Green Pyroxenite-rhyolite contact. A number of narrow drill hole intersections cut the zone which occurs mainly in Lower Green Pyroxenite but also in rhyolite.

E. Sulphide Occurrences in Other Rocks

i) Chiboug Copper - S560 Au-Cu Zones

The S560 zone, at the easternmost edge of the Opemiska property, continues across the boundary into the Chiboug Copper Company property (Figs. 1, 2). The zone has been intersected both in surface drilling and underground in the 8-3 drift (1,355 foot level). Mineralization is confined to the Bourbeau Sill and occurs in two and possibly more narrow shear zones which trend west-northwest, dipping steeply north, approximately parallel to the lithologic contacts. The vein consists of discontinuous lenses of massive pyrrhotite-chalcopyrite which contain pyrite and fragments of altered wallrock. Quartz, stringers of calcite-pyrrhotite-chalcopyrite and small pink feldspar veinlets occur in association with the structure. Molybdenite and free gold have been recognized in drill core. Disseminated pyrite and chalcopyrite are present in the walls. One sample on the face of 8-3 drift assayed 4.02% Cu, 0.69 oz. Au and 1.36 oz. Ag across four feet. The epidiorite host rock in the vicinity is extensively invaded by a swarm of feldspar porphyry dykes approximately 1 to 2 feet in width which appear to strike parallel to the vein structures and are distinctly different from the dykes in the Springer and Perry Mines.

ii) Cu-Zn Mineralization in Volcanic Rocks

The M(8-5) zone occurs south of the Campbell Lake fault (Fig. 1), stratigraphically above the rhyolite which overlies the Ventures Sill. It was intersected underground by 8-3 drift which was driven from the Robitaille shaft to intersect the S560 zone. The Cu-Zn mineralization is stratiform and the ore is largely "massive" sulphide, striking east, with a steep dip to the north. The zone occurs stratigraphically below and north of a massive fine to medium grained feldspathic pyroxenite which could be either a sill or a thick lava flow. To the north, the zone is stratigraphically underlain by well banded pyritic cherty "tuffs" which overlie the rhyolite. The massive ore is largely chalcopyrite, but 1/4 to 1/2 inch contorted bands of pyrrhotite and sphalerite are present. A two-inch thick silicate band rich in chlorite is boudinaged with sulphides filling the cracks. In the crests of folds, the ore minerals are coarser grained, with no banding. Chalcopyrite veins, lenses and blebs, calcite veins and quartz veins crosscut sulphide-rich tuffs and massive sulphides. In the drift the sulphide ore zone is about 10 feet wide, with an average content of 3.82% Cu. A few assays for zinc indicate it to be slightly lower than copper. On surface immediately above the M(8-5) zone, discontinuous intersections of chalcopyrite, sphalerite, pyrrhotite and pyrite were encountered in holes drilled from surface into approximately the same stratigraphic horizon.

Drill holes 2400 ft. south of Ellis Lake (Fig. 2) have encountered the S556 zone, a small occurrence in volcanic rocks and tuffs overlying the Bourbeau Sill. The mineralization is pyrrhotite, chalcopyrite, pyrite and sphalerite, and it appears to be conformable from the limited drilling information available. The Ceres (Kisco) Cu-Zn showing, located approximately 8000 feet west of the Springer Mine (Fig. 2), occurs in volcanic rocks, tuffs and sediments a few hundred feet stratigraphically above the Bourbeau Sill.

iii) Astoria Pyrite Zone

On the southern edge of the Opemiska property (Figs. 1, 2) within the Gilman Formation, a large zone of massive conformable pyrite-pyrrhotite has been outlined by drilling along a strike length of approximately 5000 feet. The stratigraphic section in the area appears to be overturned, and the main zone, which dips steeply southwest, occurs at the contact between locally graphitic "tuffs" and felsic "agglomerates" overlain by mafic volcanics. Drilling has indicated that the main zone is up to 150 feet in width. On Opemiska's portion of the Astoria zone, drilling has indicated that in addition to the main zone, a second conformable massive iron sulphide zone occurs roughly 500 feet stratigraphically above the main zone, within the mafic lavas. The southern half of the main zone, owned by Opemiska Explorers Ltd., is well exposed in a 40 ft. wide trench which contains areas of coarse grained calcite with minor pyrite, coarse massive pyrrhotite enclosing pyrite crystals up to 1/2 inch in diameter, well banded fine "massive" pyrite and fine grained chert with disseminated pyrrhotite and pyrite. In polished section, chalcopyrite and sphalerite are present in very minor quantity, and the pyrite is fractured.

CHAPTER VI

ALTERATION OF VEIN WALLS

A. General Statement

Wallrock alteration was studied in detail in samples collected along six profiles (Figs. 3 to 8) across five different veins in both the Springer and Perry Mines. In order to avoid, insofar as possible, differences resulting from igneous differentiation or fractionation, each profile was parallel, or nearly parallel to the lithology of the Sill rocks. Each area was mapped in detail, and representative samples were collected for petrographic and partial chemical analyses. All the profiles except one are from Ventures Gabbro and range from the upper levels to the deep levels of the mine. The single exception (Fig. 5) is from the Foliated Gabbro. The samples were chemically analysed by the Quebec Department of Natural Resources and the results are tabulated together with the details on analytical methods and sample preparation in Appendices I and III. Thin or polished thin sections were examined to determine the alteration minerals and textures. Half of the samples were stained with cobaltinitrite solution to identify K-feldspar. A number of X-ray diffractometer tracings were run both on whole rocks and mineral separates to confirm the optical identifications.

B. Mineralogy of the Wallrocks

Modal estimates were made on each sample in the profiles and the results are summarized in Figs. 3 to 8. Point count modal analyses were conducted on three samples to aid in making the modal estimates, and the results are presented in Fig. 51. These results were based on counting on average of 2000 points in each of the three different thin sections for each sample. Each of the three polished thin sections yielded quite different totals which were averaged in deriving the results presented in Fig. 51. In the alteration profiles, the modal estimate for each mineral in a sample is represented by a blank or dotted, dashed or solid line, with the ranges being approximately as follows in volume percent:

	blank (nil)	dot (minor)	dash (moderate)	solid line (abundant)
quartz	0	0 - 1	1 - 4	3 - 15
K-feldspar	0	0 - 1	1 - 2	1 - 5
biotite	0	0 - 1	1 - 5	3 - 35
stilpnomelane	0	0 - 3	2 - 6	4 - 30
sericite	0	0 - 2	1 - 4	3 - 10
chlorite	0	0 - 3	2 - 6	5 - 30
amphibole	0	0 - 10	10 - 25	25 - 40
augite	0	0 - 1	1 - 3	3 - 15
pyrite	0	0 - 1	1/2 - 2	2 - 10
primary magnetite	0	0 - 1/2	1/4 - 1	1/2 - 4
secondary magnetite	0	0 - 1/2	1/2 - 1	1 - 4
calcite	0	0 - 1	1 - 3	3 - 7
epidote	0	0 - 1/4	1/4 - 1	1 - 4
zoisite	0	0 - 1/4	1/4 - 1	1 - 4

Figure 51. Table Showing Results of Point Count Modal Analyses of Three Specimens of Ventures Gabbro

	OF29-5*	OH18-9+	OH14-8@
chlorite	6.35	5.13	3.70
stilpnomelane	17.45	---	---
biotite	---	2.47	17.20
sericite	1.12	1.90	.18
amphibole	3.92	25.17	24.50
augite	16.76	2.43	---
epidote°	5.67	5.77	.90
plagioclase	41.88	50.43	38.62
sulphides	.75	.40	1.90
ilmenite	.08	1.47	.30
leucoxene	5.96	2.70	6.60
magnetite	---	2.03	---
apatite	.06	.10	.10
calcite	---	---	6.00
	100.00	100.00	100.00

° epidote group minerals

* Lac Cummings section

\+ Opemiska area (relatively fresh, Fig. 4)

@ Opemiska area (highly altered, adjacent to no. 3 Vein, Fig. 4)

Quantitative modal analyses using the X-ray diffractometer were attempted, but were abandoned because of poor reproducibility due to the high iron content in the samples. Other problems included the overlap of critical peaks, as well as compositional variations in the minerals. In addition, there was considerable difficulty in preparing mineral concentrates to use in preparing standards because of the fine intergrown nature of the alteration minerals.

The wallrock alteration is related to a number of different types of minor veins which cut the Ventures Sill in the Opemiska area. These include quartz veins carrying very minor pyrite and chalcopyrite, and ranging in thickness from a few inches to a number of feet. In addition, fine epidote veins are common and the albitized plagioclase in the walls is frequently devoid of the usual cloudy saussurite. Hairline fractures containing stilpnomelane, chlorite and biotite are also common. Calcite-stilpnomelane veinlets cut both the economic veins and the Ventures Gabbro wallrocks. The youngest veins contain lavender axinite, minor calcite and stilpnomelane and traces of chalcopyrite and pyrite. These veins are generally found some distance away from the ore-bearing veins, but Buchan (1964) has identified axinite in ore. The axinite veins range up to 4 inches in thickness, have sharp walls and while most are flat, a few are steeply dipping.

There is a gradation from complete recrystallization of "normal" Ventures Gabbro to the mineralogy prevailing in the ore-bearing veins, through partially altered Ventures Gabbro cut by small veinlets to largely unaffected Ventures Gabbro. The K-silicate type or "facies" (Meyer and Hemley, 1967) is the only clearly definable type present in addition to the middle greenschist facies regional alteration of the Ventures Gabbro. The width of the alteration zones is proportional to the size of the adjoining vein, ranging from only a few feet adjacent to smaller structures such as the K-zone (Fig. 7) to thirty feet on either side of the no. 3 Vein on the third level (Fig. 3).

Biotite, the most characteristic of the alteration minerals, comprises up to 35 percent of the mode in "pervasively" altered specimens near the ore-bearing veins, but usually ranges from 5 to 20 percent in most alteration zones. The biotite is brown, coarse grained, has mottled extinction and forms coarse schistose patches replacing amphibole or irregular patches of randomly-oriented, finer grained material which is interstitial to plagioclase and uralite. In other cases it rims pyrite crystals, or forms euhedral "books" enclosed in chalcopyrite (Fig. 49).

Amphibole (uralite), normally the predominant mafic mineral in Ventures Gabbro, diminishes as biotite increases in the alteration zones. In some specimens it has been completely removed. Curiously, amphibole is a minor constituent in some veins, where euhedral prisms of actinolite have been observed together with euhedral biotite and stilpnomelane in chalcopyrite. Augite, like amphibole, is normally replaced by biotite in the alteration zones.

Epidote, which normally occurs in Ventures Gabbro as medium grained clusters of grains or fine irregular material in altered plagioclase, has been completely removed in the intensely altered specimens, and is antipathetic to biotite. Zoisite, or possibly some other epidote group mineral with low birefringence, which normally occurs as fine secondary material in plagioclase, has been removed in some intensely altered specimens.

but nevertheless appears more refractory than epidote.

Stilpnomelane, although closely associated with ore, is also abundant in some specimens remote from sulphides. It has at least three habits. It is a normal greenschist facies constituent of the Ventures Gabbro, both at the mine and in the Lac Cummings section. In alteration zones near veins, it constitutes up to 30 percent of the rock, and although it coexists with biotite in some specimens (Fig. 49), the two are generally antipathetic. The stilpnomelane forms bladed patches replacing amphibole and lacks any well defined schistosity. It also is present in fine veinlets which cut biotite veinlets.

Calcite often accompanies the late stilpnomelane, the two commonly occurring together in veinlets which cross-cut both ore and earlier alteration minerals. Calcite also occurs as disseminated grains in the alteration zone adjacent to the veins, apparently forming at the expense of epidote and zoisite. The late axinite veins also carry calcite and stilpnomelane at the margins.

Quartz is a minor constituent in some of the alteration zones, and occurs as small veinlets and fine anhedral grains in the sheared altered rocks.

Plagioclase (albite) is one of the more refractory minerals in the gabbro, and is the last silicate mineral to undergo alteration. In the intensely altered zones it is usually cleared of all secondary alteration products (zoisite, epidote and sericite), which it normally contains.

Chlorite usually constitutes a few percent of the rock and increases in abundance to as much as 15% near the veins. Although it occurs with sulphides in some places, it tends to be more abundant on the flanks of the K-metasomatized zones. It occurs as deformed schistose material, irregular patches of fine randomly oriented grains, in fine veinlets and rimming pyrite crystals. In the latter two cases it is associated with biotite and appears to have formed during retrograde metamorphism after biotite, and perhaps also from stilpnomelane, although this relationship is less clear.

Sericite, which normally occurs in minor amount in plagioclase, is commonly removed from the feldspar in the alteration zones. The alteration associated with the J-zone on 13 Level (Fig. 8) provides an exception to this, and sericite locally forms up to ten percent of the rock where it completely replaces some plagioclase crystals, forming fine plates with parallel orientation.

K-feldspar rarely forms narrow massive fine-grained borders up to three inches wide on the walls of some veins, and completely envelops chalcopyrite of the no. 2 Vein extension where it continues into rhyolite on the 12 level. Fine grained K-feldspar replaces plagioclase in the alteration envelopes, where it is usually associated with chlorite rather than biotite. This would suggest that at least some of it may be, like chlorite, a product of retrogression resulting from the breakdown of biotite. Cobaltinitrite staining was required to recognize K-feldspar because it is not always pink in colour, and most of the pink feldspars are albite stained with fine hematite. In thin section the K-feldspar is clear and untwinned - only rarely is cross-hatched twinning evident. Some of the grey and pink syenite dykes contain minor metasomatic K-feldspar where they are heavily mineralized with chalcopyrite; usually they are completely barren of K-feldspar.

In most cases magnetite has been removed in the alteration zones adjacent to the veins, but in some veins of the Springer system where magnetite is present there is little change in the magnetite of the wallrocks. Ilmenite and the secondary titanium minerals rutile, anatase and sphene are very refactory. These minerals persist within the veins themselves, some specimens retaining their skeletal outlines from the primary igneous rock.

C. Element Distribution in the Wallrocks

The results of the partial chemical analyses of samples from the wallrock alteration profiles are presented in Figs. 3 to 8. The average values for the Ventures Gabbro in the Lac Cummings sections (Fig. 29) have also been plotted on each profile to provide a reference for comparison.

i) Potassium

An anomalously high potassium zone of approximately twice background is evident in the walls of all veins, and ranges from a few feet next to the narrow veins up to about 30 feet adjacent to large zones like the no. 3 Vein and J-zone (Figs. 4, 5). There is a good correspondence between specimens with high K_2O and high biotite content. Most of the samples in the mine area are higher than the Lac Cummings average of .3% K_2O.

ii) Sulphur

Sulphur in all diagrams is abnormally high adjacent to the veins. The width of the anomalous areas ranges from about 10 feet near the larger veins (no. 3 Vein, Figs. 3, 4) down to a few feet for the smaller veins. Because there is such a small amount of sulphur in most of the samples it is unclear from this data whether there is a depletion zone relative to the Lac Cummings average.

iii) Copper

Copper is abnormally high adjacent to the veins over widths comparable to sulphur. The profiles (Figs. 3 to 8) do not show any areas of copper "depletion" which could reasonably have been a source of copper for the veins. Inter-vein areas with background copper content comparable to the Lac Cummings average of 34 ppm include J-zone, 13 level (Fig. 8), the area between the no. 2 and no. 3 Veins (Fig. 3), and the area southwest of the J-zone (Fig. 7). Inter-vein areas with background copper content above the Lac Cummings average include the area north of no. 2 Vein (Fig. 3), which has approximately 80 ppm Cu, and the area north of the no. 3 Vein (Fig. 4), with 70 to 100 ppm Cu. Inter-vein areas with background content below the Lac Cumming average include the area east of the J-zone (Fig. 6), with 18 ppm Cu and the area between the J and K-zones (Fig. 7), with 23 ppm Cu, and the two areas south of the no. 3 Vein (Fig. 3), with 10 to 15 ppm Cu. The section through the Foliated Gabbro (Fig. 5 on the J-zone) is approximately 34 ppm, very close to the average for the Lac Cummings Ventures Gabbro, but above comparable Foliated Gabbro in the Lac Cummings area.

iv) Silver, Zinc, Nickel, Cobalt, Manganese, Silica and Iron

Silver follows copper very closely and is anomalously high over a comparable width in the wallrocks.

Zinc shows little detectable change in the walls of some veins relative to the rocks farther away, but in the walls of other veins it is anomalously high and displays a trend similar to that of the copper and sulphur values. This is probably a reflection of the erratic nature of sphalerite distribution in the veins. There is a hint of an increase in zinc on the outer flanks of some of the alteration zones, but this is far from definite.

In profiles through Ventures Gabbro nickel distribution appears little affected by proximity to veins except to become more erratic as the vein is approached. An exception occurs in the section cutting the Foliated Gabbro (Fig. 5) where a five foot wide zone containing ten times background nickel is coincident with the high sulphur and copper zone for that vein. Most of the nickel profiles are reasonably consistent but change abruptly on either side of a vein. This probably reflects the fact that the vein occurs in a fault zone and the change in nickel content on either side is a reflection of differing nickel content of different stratigraphic levels in the differentiated Ventures Gabbro host rocks.

Cobalt distribution is similar to that of nickel but in some profiles from the Perry Mine (Figs. 5, 6, 7) cobalt values reach two to five times background in the vein walls. The anomalously high cobalt samples are also high in sulphur.

Manganese fluctuates near or slightly above the Lac Cummings average. It shows a marked depletion from an average of around 2,000 ppm down to 1000 to 1400 ppm in the walls of the veins coincident with the area of potassium enrichment. The zone of depletion ranges from a few feet in the walls adjacent to small veins (Fig. 7, K-zone) up to 25 feet on either side of the no. 3 Vein (Fig. 3).

Silica and total iron were determined for the profile of Fig. 4 and have been plotted there both as weight percent oxide and weight percent oxide "corrected" for differences in rock density. The density "correction" is based on the assumption that alteration or replacement of rocks occurs at constant volume. For the calculation, a density of 3.08 was assumed for the original rock. The specific gravity of the rock shows a decrease from a background average of about 3.08 down to about 2.98 adjacent to the vein (Fig. 4). In Fig. 4, an arbitrary reference line was drawn for both silica and iron to facilitate comparison. In the alteration zone, silica shows a marked depletion of four percent or more of the amount present despite the presence of free silica in the rock. Iron shows a similar, but less definite trend. Both of these trends are exaggerated by "correcting" for density differences, with silica approximately 6 percent and iron approximately 10 percent lower than unaltered gabbro.

D. Reconciliation of Mineralogy and Element Distribution

The chemical and mineralogical changes in the alteration zones are complementary. The most striking effect of the wallrock alteration is the potassium metasomatism and development of the K-silicate facies metasomatic alteration (Meyer and Hemley, 1967, p. 178), with accompanying hydration and breakdown of the magmatic minerals in the rocks adjacent to the veins. The decrease in density of the rock in the altered zone is a reflection of the metasomatic addition of the volatiles H_2O, CO_2 and S to form phyllosilicate minerals (biotite, stilpnomelane and chlorite), calcite and sulphides at the expense of amphiboles, epidote group minerals, iron oxides and silicates. Silica shows a definite depletion in the wallrock in spite of the presence of free quartz in some specimens, again reflecting the breakdown of the amphiboles to phyllosilicate minerals. Total iron shows a small decrease, suggesting that the sulphides in the alteration zones formed at the expense of magnetite and possibly iron silicates, and that some iron could even have been removed from the vein walls during mineralization and alteration. The depletion of manganese is probably related to the breakdown of amphibole, augite and magnetite.

CHAPTER VII

PETROGENESIS

A. General Statement

This chapter uses all the earlier data in an attempt to reconstruct the genetic history of the Opemiska veins. It starts with an analysis of the nature of the host Ventures Sill and by comparison, emphasizes the differences between Sill in the Mine area and the Lac Cummings area in order to disclose any factors related to vein genesis. Next the genesis of the veins themselves is discussed and later the relationships of the veins to the other sulphide deposits at Opemiska. Finally an attempt is made to reconstruct the geological history of the Opemiska area.

B. Time and Mode of Emplacement of the Ventures Sill

The Ventures Sill is undoubtedly of Archean age because it has been folded and metamorphosed during the Kenoran orogeny with the enclosing Archean volcanic and sedimentary rocks. Naldrett (1972) suggested that comparable rocks elsewhere were "synvolcanic". Duquette (1970) also considers these sills synvolcanic and favours an intrusive origin, suggesting that the Roberge, Ventures and Bourbeau Sills are the product of a complex history beginning with intrusion of basaltic magma into the volcanic pile at the stratigraphic level of the Roberge Sill. After accummulation of a sequence of olivine and pyroxene cumulate rocks which now form the Roberge Sill, the remaining magma was expelled upward to the level of the Ventures Sill, where more crystallization took place, and upward expulsion of remnant magma occurred once again to form the Bourbeau Sill. During the process fresh basaltic magma replenished the residual liquids at various stages. Naldrett's and Duquette's ideas are consistent with the petrology of the Ventures Sill as determined in this study.

In addition to its strong stratigraphic control and the similarity of structural and metamorphic features with the enclosing rocks, there are many chemical similarities between the sills and their host volcanic rocks. The Archean volcanic rocks of the area are potash poor and the alumina content of the basalts averages less than 16 percent (Appendix IV). The Ventures Sill is also abnormally low in K_2O and the fact that plagioclase appears late as a cumulus phase suggests that the magma was lower in alumina than that of some post-Archean layered sills such as Skaergaard and Bushveld. All these features suggest that the volcanic rocks and the Ventures Sill rocks are products of a common parental basalt; possibly a low-alumina tholeiite.

There is little evidence suggesting an extrusive origin for the Ventures and other related sills except for their strong stratigraphic control. No fine grained chill zone is present at the contacts of the Ventures Sill and these features together with the coarse grained nature of the rocks are compatible with the Sill being a sub-volcanic intrusion. If such were the case, the level of intrusion was probably controlled by a delicate balance between the lithostatic pressure developed by the overlying recently extruded volcanic rocks and the density of the intruding magma. This hypothesis not only offers a convenient explanation as to why the Ventures Sill rocks show a marked stratigraphic control, but can also account for the periodic movement of residual magma into successively higher stratigraphic levels as volcanism built up the overlying stratigraphic pile.

C. Petrogeny of the Ventures Sill

i) Crystallization History

Textural evidence indicates that the main cumulus minerals in the Ventures Sill crystallized in the order olivine, clinopyroxene, plagioclase - an order similar to that shown by MacRae (1969) and Naldrett and Mason (1968) for similar sills in the Abitibi region of Ontario. Calcium-poor pyroxene may have been a cumulus mineral in the gabbroic rocks, but here the ophitic texture obscures the textural evidence for cumulus or postcumulus origin. However, the calcium-rich nature of the clinopyroxenes (Fig. 38) relative to their counterparts in the Bushveldt and Skaergaard magmas which crystallized together with calcium-poor pyroxenes suggests that the compositions of the Ventures Sill clinopyroxenes were not controlled by the constraints imposed by the intersection of the pyroxene solvus with the solidus curve of pigeonite (Boyd and Schairer, 1964), and that therefore the calcium-poor pyroxenes are postcumulus. The absence of calcium-poor pyroxene as a cumulus phase also suggests that the sill invaded a low pressure, sub-volcanic environment. The magma was silica rich, as indicated by magmatic quartz in the Ventures Gabbro, in which case calcium-poor pyroxene should have been a stable cumulus phase at higher pressure (Irvine, 1970).

The low alumina content of the Lower Green Pyroxenite (Fig. 27) clearly indicates that this unit is not a marginal chilled portion of basaltic magma. It is also unlikely that this rock formed by early accumulation of clinopyroxenes from fractionating basaltic magma because it is doubtful whether clinopyroxene formed as a cumulus phase earlier than olivine. Irvine (1970, p. 469) recognizes "no intrusions where clinopyroxene is a forerunner of olivine" and "no volcanic series whose chemical trends indicate that clinopyroxene crystallized first". Consequently, he concludes that magmas with compositions which would crystallize clinopyroxene first may not exist. The presence of titaniferous magnetite also suggests that the Lower Green Pyroxenite is not an early cumulate because magmatic magnetite is normally a late magmatic mineral. Duquette's (1970) ideas are consistent with these observations. Perhaps the initial magma which intruded the Ventures Sill horizon was expelled upward from a previous magma chamber where it had already crystallized a sequence of olivine-rich cumulates, and had fractionated to the stage where clinopyroxene was the stable cumulus mineral. After entering the Ventures Sill horizon it continued to crystallize clinopyroxene and accessory magnetite until the first influx of fresh basaltic magma mixed with the partially fractionated magma, reheated it and shifted the composition such that olivine became the "earliest" cumulus phase in the olivine-rich layer above the Lower Green Pyroxenite.

The Black Pyroxenite is clearly of cumulus origin. The MgO/FeO ratios (Fig. 37), the minor elements in clinopyroxenes (Figs. 39, 40, 41) and the minor element content of the whole-rocks (Figs. 30 to 35) suggests that the recurrent layers of dunite and wehrlite within the Black Pyroxenite resulted from periodic influxes of new magma which raised the temperature and replenished the depleted elements (Brown, 1968; Jackson, 1970; Irvine, 1970). The pyroxene analyses from the uppermost olivine-rich layer in the Black Pyroxenite through the Upper Green Pyroxenite and Foliated Gabbro, up to the top of the Ventures Gabbro show a continuous enrichment of FeO relative to MgO (Fig. 37) and suggests fractionation with no new influx of magma. The fact that the clinopyroxenes do not reach hedenbergite in composition as do the Bushveldt and Skaergaard pyroxenes (Fig. 38) lends support to Duquette's hypothesis of expulsion of residual magma prior to complete crystallization. The intermediate composition of the Bourbeau Sill is also consistent with this hypothesis.

The appearance of cumulus plagioclase, as well as cumulus titaniferous magnetite and apatite marks the base of the Foliated Gabbro. The igneous lamination which characterizes the Foliated Gabbro is probably "due to deposition of crystals of tabular habit from a moving magma" (Wager and Brown, 1968, p. 23). The absence of igneous lamination in the Ventures Gabbro possibly reflects a slowing of these magmatic currents, possibly due to a rise in the viscosity of the magma, or to the changing shape of the magma chamber.

The "Granophyre" does not appear to have formed by crystallization of residual liquid produced by extreme fractionation of the Ventures Gabbro magma. Less than half the thin sections that were cut from the rock have granophyric texture and the K_2O content of the rock is lower than normal Ventures Gabbro (Fig. 30). The "Granophyre" possibly formed as an upward-floating cumulate at the top of the magma chamber in a manner similar to that proposed by Wager and Brown (1968, p. 31) for the Upper Border Group of the Skaergaard intrusion, or possibly it formed by partial melting of volcanic or volcaniclastic roof-rocks.

Metamorphism of the Ventures Sill has resulted in greenschist facies assemblages superimposed on the original magmatic mineral suite. Metamorphic grade in the Lac Cummings area is lower greenschist. However the presence of biotite in the Opemiska area suggests middle greenschist conditions there.

There is a sharp contrast in the distribution of magnetite between the two areas. Although secondary non-titaniferous magnetite is associated with the serpentines in both areas, in the gabbroic rocks at Lac Cummings all the magnetite is gone and only skeletal ilmenite remains, except in the titaniferous magnetite-rich layer at the base of the Foliated Gabbro. In contrast, at Opemiska magnetite-ilmenite intergrowths are common in the gabbros and these rocks also contain some secondary magnetite along oriented intergrowths with actinolite in calcium-poor pyroxene pseudomorphs. The data from the Lac Cummings section suggests that under conditions of normal greenschist or late deuteric alteration the magnetite of the gabbroic rocks reacted with primary silicates to form secondary iron-rich silicate minerals such as stilpnomelane. This would suggest that at Opemiska relatively oxidizing conditions developed earlier than or contemporaneous with greenschist facies metamorphism or deuteric alteration and were instrumental in preserving magnetite. These more oxidizing conditions could be related to a relatively high volatile pressure associated with hydrothermal ore deposition.

ii) Sulphide Genesis

The behaviour of sulphur in the Lac Cummings section of the Ventures Sill is quite similar to that described by Wager, Vincent and Smales

(1957) for the Skaergaard intrusion which has a copper-rich sulphide zone consisting mainly of bornite, chalcopyrite, digenite and chalcocite, with an iron-sulphide zone above consisting of pyrrhotite and minor chalcopyrite. Wager et al. (1957) propose that copper and sulphur accumulated in the magma until the solubility of a copper-rich immiscible sulphide liquid was exceeded, when an immiscible sulphide liquid separated which settled with the cumulus silicate minerals. Copper-rich immiscible sulphide liquid continued to separate until the available copper in the magma became depleted, after which the sulphur content of the magma built up until an iron-rich immiscible sulphide liquid separated which is now represented by pyrrhotite and minor chalcopyrite. Although the similarities in distribution of copper and sulphur suggest a similar primary origin for the sulphides in the Skaergaard and Lac Cummings section of the Ventures Sill, the Skaergaard sulphides show features characteristic of magmatic immiscibility such as droplet textures, complex intergrowths and association with non-titaniferous magnetite. In contrast, the Lac Cummings sulphides are found intergrown with secondary silicates and magnetite, and replacing the magnetite portion of magnetite-ilmenite intergrowths. This is not unexpected however, since sulphides are quite reactive, and magmatic sulphides would almost certainly recrystallize under greenschist metamorphic conditions. The mineralogical similarities and the absence of conspicuous veining also suggest that there has been little migration of copper and sulphur during the low grade metamorphism suffered by the Ventures Sill in that area. However it is still unclear whether the copper-rich sulphide assemblage mineralogy now present in the Lac Cummings section is exactly the same as it was under primary magmatic conditions because almost certainly there were changes in oxygen fugacity during greenschist facies metamorphism which would have resulted in changes in the amount of iron in the sulphide system (Ramdohr, 1967; Chamberlain, 1967).

The origin of the nickel-rich sulphide assemblage in the serpentinized ultramafic rocks of the Lac Cummings section is uncertain. The heazlewoodite and millerite assemblage is clearly secondary and is probably related to serpentinization as suggested by Ramdohr (1967) and Chamberlain (1967) for other serpentinized ultramafic rocks. Much of the nickel was probably present in the original magmatic rock as a minor element in olivine and was released during serpentinization of the olivine (Ramdohr, 1967). However some of the nickel might have been present as an immiscible iron-nickel sulphide which reacted with the nickel released during serpentinization to produce the present nickel-rich sulphide assemblage. Some sulphur could have been introduced during the H_2O metasomatism which accompanied serpentinization. Sulphate carried in solution could have been reduced by the strong reducing conditions accompanying serpentinization (Ramdohr, 1967), or possibly some migrating H_2S was available for reaction with the released nickel. Any conclusions regarding the genesis of the nickel-rich sulphides remain speculative because of the lack of information regarding the occurrence of comparable magmatic sulphides in unaltered ultramafic-mafic intrusions.

A comparison of the copper and sulphur content of the Ventures Gabbro in the Lac Cummings and the Opemiska sections indicates that the latter has an average sulphur content 4-6 times and copper content 2-3 times as high as comparable rocks in the Lac Cummings section (Fig. 29).

Together with the prominent hydrothermal alteration, and their association with areas of potash enrichment, this is strong evidence that these two elements have been introduced into the Ventures Gabbro at Opemiska subsequent to its emplacement as a magmatic rock. The contrasting sulphide assemblages between the two areas, and especially the presence of relatively sulphur-rich phases at Opemiska also indicates a relatively high sulphur fugacity in the Opemiska area and adds support to the suggestion of sulphur metasomatism in that area.

D. Genesis of the Opemiska Veins

Various possible hypotheses might explain the genesis of the Opemiska veins. The most important of these are: a) separation of immiscible magmatic sulphides, with subsequent remobilization into the present structural sites, b) lateral secretion of finely dispersed copper present in the Ventures Sill into veins under the influence of hydrothermal activity (Derry and Folinsbee, 1957; Graham and Charteris, 1961; McMillan, 1969), c) epigenetic emplacement related to emplacement of the Opemiska Lake Pluton and presumably related to hydrothermal solutions expelled during the final stages of crystallization of the "granite" (Duquette, 1970), d) a subvolcanic origin related to Archean volcanic and intrusive activity.

The above four hypotheses are not necessarily mutually exclusive, and various features at Opemiska suggest that more than one geological process was involved in vein genesis. However some aspects of these hypotheses are incompatible with the situation at Opemiska. The first hypothesis appears very unlikely in the light of the evidence. Not only is the structure of the Opemiska veins dissimilar to that of "magmatic" deposits, but the mineralogy of the gangue minerals at Opemiska (ie., quartz, phyllosilicates and carbonate) is the same as that found in hydrothermal deposits and provides stark contrast to the silicates typical of "magmatic" deposits. The geochemistry of the ore is also strikingly different from that of "magmatic" deposits. The presence of molybdenite and scheelite in moderate amounts is not typical of "magmatic" deposits and the paucity of nickel in the veins cutting Ventures Gabbro suggest hydrothermal rather than "magmatic" affiliations. What cannot be discounted is the possibility that copper and perhaps sulphur were remobilized by hydrothermal solutions from magmatic segregations in the ultramafic rocks and re-emplaced into the veins.

Lateral secretion from the immediate wallrocks, the second possibility, is highly unlikely in the case of copper and sulphur although it does provide a reasonable explanation for silica and possibly iron. A comparison of the Opemiska and Lac Cummings gabbro sections (Fig. 29) suggests that Cu, S and K_2O have been metasomatically introduced into the Opemiska section. In addition, the alteration diagrams (Figs. 3 to 8; Chapter VIc) indicate Cu, S and K_2O metasomatism into the walls of the veins. There is clearly no depletion of Cu or K_2O in the areas between the veins although silica shows a definite depletion in the wallrocks (Fig. 4) and could have migrated into the structures and been deposited as quartz. Possibly SiO_2 was more soluble in the relatively alkaline wallrocks undergoing alteration and was precipitated in more acidic mineralizing channelways which are now veins. Although it is less conclusive, iron also appears to be depleted in the walls (Fig. 4) and some of it could have migrated and contributed to the formation of iron-rich minerals in the veins. Nickel and cobalt were probably derived locally, as they are significant only in veins close to olivine-bearing ultramafic rocks (Chapter VIc) which would provide a logical source. Of the two, cobalt would appear to be the more mobile under the hydrothermal conditions accompanying vein formation, because it occurs in anomalous amounts in the vein wallrocks further up into the gabbroic rocks.

The possibility of vein emplacement related to late-stage expulsion of hydrothermal solutions from the Opemiska Lake Pluton appears unlikely in the light of evidence on the geochemistry and the timing of the intrusion relative to the wallrock alteration in the veins. Wolhuter's (1968) data indicate that the pluton itself is low in Cu and S. In addition, an average of five samples of metabasalt from near the contact aureole of the Opemiska Lake pluton is 25 ppm Cu (Gunn, 1969, Appendix IV), which is 1/3 the average of 77 ppm calculated for nine metabasalts from the Gilman and Blondeau Formations (Appendix IV). These data would suggest that the pluton was not a source of copper but could have been instrumental in mobilizing copper in the country rocks. Most important, the Opemiska Lake Pluton is post-kinematic, and the presence of "magmatic" magnetite in the gabbro wallrocks at Opemiska (viz. none in Lac Cummings) suggest that relatively oxidizing conditions possibly related to epigenetic hydrothermal activity prevailed prior to greenschist facies metamorphism. This would suggest that the veins were already emplaced prior to intrusion of the Opemiska Lake Pluton.

The fourth possibility, that of a subvolcanic origin related to late-stage Archean felsic volcanic and intrusive activity, appears to be the most plausible in the light of evidence. The timing of the alteration relative to known igneous activity is reasonably accounted for. The deformed nature of some of the ore is also accounted for. The mineralogy, structure and general environment at Opemiska show similarities to some of the Japanese vein deposits of Neogene age, particularly the Akenobe and Ashio Mines (Nakamura and Hunahashi, 1970; Nakamura, 1970). These deposits occur in silicified zones in rocks of the late Tertiary Green Tuff region, and are believed to have formed from hydrothermal solutions related to volcanic and intrusive activity. The Akenobe Mine is zoned, with a central tin-tungsten zone which grades upward and outward through copper-tin, copper-zinc, zinc-lead and gold-silver zones. The Opemiska deposits display a crude stratigraphic zoning which is not incompatible with this pattern. The highest gold values in the mine occur with higher zinc values in the Arsenopyrite Shear and at depth in the Springer veins toward the stratigraphic top of the Ventures Gabbro. In the Perry veins, the higher zinc values also occur on the deeper levels, again stratigraphically higher in the Ventures Sill.

Another parallel between the Japanese and Opemiska vein deposits is the occurrence of "massive sulphide" mineralization in correlative rocks. The Japanese veins occur in rocks correlative with the well known Kuroko deposits (Matsukuma and Horikoshi, 1970) which occur in pyroclastic rocks of a submarine environment. At Opemiska, the copper-zinc mineralization in the felsic volcanic rocks of the Blondeau Formation overlying the Bourbeau Sill suggests that submarine hot springs and fumaroles were active during the latter stages of Archaean volcanism. Contemporaneous endogenous hydrothermal activity could also be responsible for deposition of the Opemiska veins.

Brown (1970) indicated that the structures which carry the veins are related to the latest, right-hand movement on the Campbell Lake fault. This view is in the writer's opinion overly simplistic, and it seems more probable that movement along the fractures began much earlier than this and was repetitive, occurring in different directions as the stress fields changed in response to successive tectonic events. Much of the ore in the veins appears to be sheared and brecciated and lacks textures characteristic of undeformed vein deposits such as botryoidal, cockade, crustification and druse textures, suggesting that the ore was there prior to this latest movement on the Campbell Lake fault.

The lead isotope data (II, G) can be explained by a two or multi-stage model with primary emplacement during Archean times and later modification during subsequent tectonic episodes. Perhaps some addition of lead occurred during the late-stage movement on the Campbell Lake fault as well as in earlier tectonic events.

The reason for the restriction of ore to the Ventures Sill is still not satisfactorily answered, but would seem to be a result of some favourable characteristic of the gabbroic rocks in the Ventures Sill. One such factor might be favourable wallrock competence and the ability of the gabbroic rocks to maintain widespread blocky fractures which form veins rather than deform by plastic flow or penetrative shearing. A second reason might be the reactivity of the wallrocks, and the preference of copper mineralization for a mafic host as has been noted at Ray, Arizona (Metz and Rose, 1966). It is clear that some of the vein components particularly Cu, S and K_2O and probably WO_3 and Mo are external in origin and have been mobilized into their present environment by hydrothermal activity. Other components such as SiO_2, Co, Ni and possibly Fe were probably derived from the Sill rocks.

E. Metallogenesis of the Opemiska Property

The major sulphide occurrences at Opemiska can be subdivided into three major types, with subtypes in each as follows:

1. Conformable "massive" sulphides
    - (i) Barren Fe sulphide type
    - (ii) Cu-Zn type
2. Cu(Ni) sulphides in ultramafic rocks of the Ventures Sill
3. Vein deposits
    - (i) Cu and Cu-Au in Ventures Sill
    - (ii) Au and Au-Cu in the Bourbeau Sill

The conformable barren iron sulphides and Cu-Zn sulphides appear to be related to Archean volcanism. The conformable disposition, deformed nature, mineralogy and textures of these deposits suggest that they are synvolcanic, and probably formed by volcanic exhalations as indicated for similar deposits in other areas (Hutchinson, 1965; Roscoe, 1965; and Anderson, 1969). The presence of the Cu-Zn type apparently higher in the stratigraphic section than the iron sulphide type might indicate the thickening and possible petrochemical evolution of the orogenic volcanic suite as suggested by Hutchinson (1971).

The nickel in the Cu(Ni) sulphides in the ultramafic rocks appears to have been locally derived. However the tenor of nickel, except in rare cases, is only slightly enriched above background values for nickel in dunites and suggests that the nickel sulphides possibly formed by postmagmatic sulphidization of silicates. The association of scheelite and molybdenite also suggests that these deposits are epigenetic. The source of the copper and sulphur is still uncertain; they could have formed as primary immiscible sulphides, but it seems more likely that these components too were epigenetic and related to the "Opemiska type" veins.

The deposition of the "Opemiska type" Cu (Au) veins and the Au (Cu) veins found in the Chiboug copper-S560 zone are believed related to late stage felsic igneous activity in Archean times. These were apparently emplaced as endogenous veins and could be temporally related to the conformable Cu-Zn deposits in the upper parts of the Blondeau Formation. The relationship may be analogous to the Japanese vein deposits and Kuroko deposits which are associated with Miocene volcanic activity in the Green Tuff region. The gold mineralization in the Bourbeau Sill is perhaps related to a slightly younger and slightly more evolved stage of crustal evolution than the copper veins, and consequently favours stratigraphically higher and more siliceous host rocks.

F. Sequence of Geological Events in the Opemiska Area

1) Extrusion of submarine basaltic rocks of the Gilman Formation. Minor associated sill intrusion and sedimentation. Some associated hydrothermal activity resulted in deposition of the Astoria conformable massive iron sulphide deposits.

2) Evolution to felsic igneous activity and deposition of the lower part of the Blondeau Formation. Felsic submarine pyroclastic volcanism as well as clastic and chemical sedimentation. Minor intrusive activity. Associated hydrothermal activity resulted in deposition of the M(8-5) zone and other Cu-Zn showings near the base of the Blondeau Formation.

3) Renewed mafic igneous activity. Extrusion of submarine basalts as part of the Blondeau Formation, and intrusion of the Roberge, Ventures

and Bourbeau Sills into the upper portions of the Gilman and lower portions of the Blondeau Formations. Minor clastic and chemical sedimentation.

4) Evolution of another felsic igneous episode. Formation of the "Tonalite-Diorite" intrusive suite, with hypabyssal equivalents. More felsic volcanism with clastic and chemical sedimentation to form the upper portions of the Blondeau Formation. Associated hydrothermal activity formed stratiform Cu-Zn deposits (Ceres and S556 zones) as well as the Cu and Au bearing veins.

5) Folding and metamorphism towards the end or after episode 4.

6) Intrusion of the Opemiska Lake Pluton near or after the close of episode 5.

7) Intrusion of diabase dykes

8) Faulting and minor folding associated with the Grenville orogeny. Late stage movement on the Campbell Lake fault resulted in further deformation of the Opemiska veins and left them in more or less their present disposition.

9) Uplift and erosion.

CHAPTER VIII

CONCLUSIONS

1. The Ventures Sill is a layered igneous intrusion which formed by fractional crystallization and "igneous sedimentation" from primary tholeiitic basaltic magma.

2. The pyroxene analyses and the minor element differentiation trends indicate that the olivine-rich layers in the lower ultramafic portions of the intrusion were caused by periodic influxes of new basaltic magma.

3. No major new influxes of magma occurred after crystallization of the uppermost dunitic layer in the Black Pyroxenite. The Upper Green Pyroxenite, Foliated Gabbro and Ventures Gabbro formed in ascending sequence as magmatic cumulates from the residual magma.

4. Plagioclase occurs late as a cumulus mineral in the Ventures Sill because of the low Al_2O_3 content of the parental basaltic magma.

5. The Lower Green Pyroxenite is not a chilled contact phase representative of parental basaltic magma.

6. Data from these investigations substantiate Duquette's suggestion that the Ventures Sill magma was expelled upward from a previous magma chamber, and after formation of the Ventures Sill cumulates, crystallization was disrupted with the residual magma moving upward, probably to the

level of the Bourbeau Sill.

7. K_2O, S, Cu, H_2O and CO_2 were metasomatically introduced into the Ventures Sill at Opemiska during vein formation.

8. SiO_2 and possibly Fe were "laterally secreted" into the veins to form quartz and iron-rich minerals.

9. The opaque minerals in the Ventures Sill reflect a relatively high volatile fugacity in the Opemiska area compared to more reducing conditions in the Lac Cummings section.

10. This high volatile fugacity is thought to have been present in the Opemiska rocks prior to greenschist facies metamorphism because "magmatic" magnetite is preserved in the gabbroic rocks in that area.

11. The Opemiska veins were emplaced in late Archaean times contemporaneous with the closing stages of felsic volcanism and the "Tonalite-Diorite" intrusive suite. They are possibly temporally related to stratiform Cu-Zn deposits in stratigraphically higher felsic volcanic rocks.

CHAPTER IX

RECOMMENDATIONS FOR FURTHER WORK

1. A detailed study should be made of the geochronology of the alteration and ore minerals, metamorphism and igneous intrusions, using the appropriate radiometric dating methods. It would probably be useful to include the different dykes at Chiboug Copper, as well as some of the plutonic rocks in the area. This study might clarify the absolute timing of the different tectonic, magmatic and metamorphic events, but the interpretation might prove difficult if the time span separating the various episodes is small.

2. A comprehensive study of the mineral zoning in the veins should be undertaken. Assuming the veins were originally emplaced in a manner similar to the Japanese vein deposits, they have subsequently undergone deformation and folding, and reconstruction of the Sill (and veins) to a relatively undeformed position might indicate further similarities. Because of the considerable size of the mine the study would be best conducted by someone working there. Quantitative documentation could be obtained by making up composite samples representative of different blocks of ore from the face and muck samples which are collected daily at the mine.

3. The amount of copper in the Lac Cummings section of the

Ventures Sill is quite low in comparison to the Skaergaard intrusion. This might suggest that the Ventures Sill magma was originally lower in copper than the Skaergaard, or alternatively it might mean that there are lenses of early immiscible sulphides in the ultramafic sequence in the Sill. A study of the mineralogy and geochemistry in the ultramafic rocks in the Lac Cummings area could clarify this. There are diamond drill holes through these rocks which would provide suitable sample material.

4. More information is necessary on the nature of early immiscible sulphides in layered igneous rocks. The Skaergaard intrusion (Wager, Vincent and Smales, 1957) has provided good information on the copper and iron-rich immiscible sulphide liquids which form late in the crystallization sequence, but as yet there is little documentation on the nature of the earlier sulphides from unaltered layered intrusions.

5. Additional analyses of the volcanic and intrusive rocks in the Chibougamau region might clarify the behaviour of copper during the different metamorphic and igneous events which affected the area. This could be a particularly fruitful approach considering the apparent depletion of copper from the metabasalts in the contact aureole of the Opemiska Lake pluton (Appendix IV).

6. More data on the nature of the mineralizing fluid could be obtained by studying the distribution of major elements in the walls of the Opemiska Veins. Analyses of the halogen content in biotites of the alteration zones might also provide useful information on the mineralizing fluids. A comparison of the Fe^{++}/Fe^{+++} ratios in stilpnomelane might provide information regarding the oxidation state of comparable material in the veins, vein walls, Opemiska Section and Lac Cummings

section.

7. Isotopic analyses of oxygen in co-existing magnetite and quartz and of sulphur might clarify the source of these anions.

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APPENDIX I

Preparation of Samples for Analysis

All of the analysed samples, except those from the Lac Cummings Section, were either hand specimens collected underground or diamond drill core. These samples were cut with a diamond saw into slices across the grain of the rock. All metal and foreign material was then cleaned away using a carborundum wheel, soap and hot water. After a thorough rinse in tap water, the specimen was dried in a stream of compressed air. No veinlets were included in the samples, and approximately 1/2 to 1 pound of sample was selected for crushing. The samples were crushed in a Bico jaw crusher with ordinary carbon steel plates, then reduced to about 100 mesh using a Bico-Braun pulverizer with ceramic plates. The crushing apparatus was cleaned between each sample preparation by running quartz sand through the pulverizer and then thoroughly sweeping out the crushing and pulverizing apparatus and the adjoining work area using compressed air, a vacuum cleaner, disposable paper dusters and a stiff brush. The sample was then prepared for shipment to the Quebec Department of Natural Resources by coning the sample, and cutting two pie-shaped slices, large enough to fill a four dram plastic vial from the cone. The Lac Cummings section samples were prepared in the same manner except that special care was taken to remove any weathered or oxidized material near joints or fractures. Any samples which have small oxidized areas have been indicated on figures with a circle rather than with a cross.

APPENDIX II

Analytical Procedure for Major Element Analyses

X-ray fluorescence analyses for SiO_2, Al_2O_3, total Fe as Fe_2O_3, CaO and K_2O were conducted on fused lithium tetraborate pellets using two AGV-1 pellets as standards. Analyses for these elements were conducted both by the author and J. Olatunde on the same pellet. Although the data presented here are the author's, J. Olatunde's data agreed within 10%. X-ray fluorescence analyses for MnO, P_2O_5, TiO_2 and MgO are by J. Olatunde, using the same standards. The X-ray fluorescence analyses were corrected for absorption using the computer program published by Gunn (1967), as modified and improved by Donald Hattie of this Department (1972). Na_2O and samples with less than six percent MgO were analysed by flame emission and atomic absorption spectroscopy respectively, by J. Olatunde. The samples were dissolved in a perchloric-hydrofluoric acid solution. J. Olatunde also conducted the loss on ignition determinations. The results presented in Fig. 27 are shown with two analysed standards and a duplicate analysis for comparison. The X-ray fluorescence results have been normalized to total 100% to compensate for variations in flux/sample ratio in the analysed pellets.

APPENDIX III

Analytical Methods with their Precision and Limits of Detection; Results of Minor Element Analyses by the Quebec Department of Natural Resources Analytical Laboratories.

MAJOR ELEMENTS

	METHOD	PRECISION
SiO_2, Al_2O_3, TiO_2	Shapiro colorimetric method	± (1 - 1.5%)
MgO, CaO	Edta titration and/or atomic absorption	± 1%
Total Fe	Dichromate titration and/or atomic absorption	± 1%
FeO	HF-HCl attack, dichromate titration	± 1%
Fe_2O_3	Difference between total Fe and FeO	- - -
Na_2O, K_2O	Flame spectrophotometry	± 0.5%
S	Leco furnace. Absorption of SO_3 in KI + KIO_3, titration of I_2 produced	± 1.5%
CO_2	Liberation of CO_2 with HCl absorption in ascarite	± (1.5 - 2%)
H_2O^+	Leco furnace at 1400°C absorption in anhydrone	± 1%
H_2O^-	105°C	± 1%
Total	- - -	99.5 - 100.5%

MINOR ELEMENTS

	METHOD	LIMITS OF DETECTION	PRECISION
Co, Cu, Ni	Atomic Absorption	1 ppm.	± 10%
Ag, Mn	" "	.05 ppm.	± 10%
Zn, Cr	" "	.01 ppm.	± 10%
Mo	Spectrography	50-100 ppm.	± (5 - 10%)
W	Spectrography	100 ppm.	± 10%

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Department of Natural Resources
Laboratories

Annex E - Parliament Buildings

Certificat
Certificate No- 70h-9022/9031 P.

Quebec, December 4th, 1970.

10 Échantillon soumis par
Sample submitted by

The University of Western Ontario
c/o Mr. H.R. McMillan
Department of Geology
Biological & Geological Building
London, Ontario.

Désignation Description	Numéro Number	Ag	Cu	Zn	W	S	x x x	x x x
#1 CH14-8	70h-9022	6.8ppm	1.05%	150ppm	0.00%	0.61%		
#2 CH14-10	70h-9023	1.2ppm	93ppm	130ppm	0.00%	0.43%		
#3 CH14-12	70h-9024	1.2ppm	300ppm	121ppm	0.00%	1.81%		
#4 CH14-14	70h-9025	0.8ppm	80ppm	120ppm	0.00%	0.25%		
#5 CH14-15	70h-9026	1.0ppm	110ppm	200ppm	0.00%	0.21%		
#6 CH14-17	70h-9027	1.0ppm	190ppm	120ppm	0.00%	0.02%		
#7 OH16-3	70h-9028	0.7ppm	42ppm	94ppm	0.00%	(x)		
#8 OH16-9	70h-9029	0.7ppm	92ppm	84ppm	0.00%	(x)		
#9 W-1	70h-9030	0.6ppm	88ppm	76ppm	0.00%	(x)		
#10 OH16-3	70h-9031	1.0ppm	47ppm	98ppm	0.00%	0.15%		

(x) Insufficient sample

The Director:..
Joseph Gagnon

Province de Québec
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Department of Natural Resources
Laboratories

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Certificat
Certificate No- 701-12846/12878 B.

Québec, le 28 juin 1971.

33 Échantillons soumis par
Sample submitted by

Monsieur R.H. McMillan
University of Western Ontario
London 72
Ontario.

Désignation Description	Numéro Number	S %	K_2O %	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.
<u>OF-29</u> - 3	701-12846	0.19	0.33	73	68	44	0.7	97
4	701-12847	0.68	0.20	76	100	26	0.5	120
5	701-12848	0.21	0.20	72	240	70	2.8	84
11	701-12849	0.008	0.14	32	15	33	0.3	43
12	701-12850	0.50	0.75	64	72	29	n.d.	120
<u>OG-5-</u> 1	701-12851	0.59	0.38	110	130	23	1.0	130
2	701-12852	0.007	0.15	44	18	21	0.6	66
3	701-12853	0.023	0.02	63	270	480	0.5	40
4	701-12854	0.021	0.04	91	51	255	1.1	72
5	701-12855	0.008	0.05	120	20	84	1.2	130
6	701-12856	0.006	0.04	79	71	472	0.6	67
7	701-12857	0.009	0.02	54	43	460	n.d.	37
8	701-12858	0.005	0.02	53	30	470	n.d.	39
9a	701-12859	0.12	0.04	140	35	1840	0.8	83
9b	701-12860	0.004	0.02	57	14	570	n.d.	46
10	701-12861	0.021	0.03	140	21	2370	0.9	78
11	701-12862	0.008	0.30	53	120	77	0.5	86
12	701-12863	0.14	0.04	59	66	30	0.6	57
<u>OG-14-</u> 1	701-12864	0.36	0.39	64	267	29	2.0	170
2	701-12865	0.13	0.41	65	170	24	0.7	120
<u>OG-16-</u> 1	701-12866	2.34	0.58	120	18080	46	10	590
2	701-12867	0.11	0.45	54	710	24	1.2	140
3	701-12868	0.050	0.35	52	85	23	0.6	84
4	701-12869	1.79	0.33	75	4190	24	12	95
5	701-12870	0.22	0.35	53	570	21	0.5	86
6	701-12871	0.034	-.77-	36	19	23	0.5	35
7	701-12872	0.013	-.35-	49	14	22	0.3	69
8	701-12873	0.019	-.30-	47	17	21	0.4	78
9	701-12874	2.47	1.26-	85	39	20	0.9	62
10	701-12875	0.018	-.33-	50	20	20	n.d.	54
11	701-12876	0.090	-.25-	45	21	22	0.7	91
12	701-12877	0.050	1.44	68	63	290	(x)	140
13	701-12878	0.30	-.77	62	70	29	0.9	120

(x) signifie: échantillon épuisé.

Le Directeur:..............................

pour Joseph Gagnon

Province de Québec
Ministère des Richesses Naturelles
Laboratoires

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Department of Natural Resources
Laboratories

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Certificat
Certificate No- 701-12846/12878 B.

Québec, le 28 juin 1971.

33 s
Échantillon soumis par
Sample submitted by

Monsieur R.H. McMillan
University of Western Ontario
London 72
Ontario.

Désignation Description	Numéro Number	Mn p.p.m.	Cr p.p.m.	Mo p.p.m.	W p.p.m.	x x x	x x x	x x x
OF-29 - 3	701-12846	1730	26	n.d.	n.d.			
4	701-12847	2075	20	n.d.	n.d.			
5	701-12848	1880	24	n.d.	n.d.			
11	701-12849	605	40	n.d.	n.d.			
12	701-12850	2676	23	n.d.	n.d.			
OG-5 - 1	701-12851	3210	22	n.d.	n.d.			
2	701-12852	1518	21	n.d.	n.d.			
3	701-12853	1247	590	n.d.	n.d.			
4	701-12854	1740	230	n.d.	n.d.			
5	701-12855	1734	28	n.d.	n.d.			
6	701-12856	1663	270	n.d.	n.d.			
7	701-12857	1278	1330	n.d.	n.d.			
8	701-12858	1161	1390	n.d.	n.d.			
9a	701-12859	1420	320	n.d.	n.d.			
9b	701-12860	1174	1035	n.d.	n.d.			
10	701-12861	1478	670	n.d.	n.d.			
11	701-12862	1224	31	n.d.	n.d.			
12	701-12863	1638	22	n.d.	n.d.			
OG-14- 1	701-12864	1113	21	n.d.	n.d.			
2	701-12865	1253	24	n.d.	n.d.			
OG-16- 1	701-12866	872	21	n.d.	n.d.			
2	701-12867	1298	23	n.d.	n.d.			
3	701-12868	1352	27	n.d.	n.d.			
4	701-12869	1120	21	n.d.	n.d.			
5	701-12870	1620	19	n.d.	n.d.			
6	701-12871	853	19	60	n.d.			
7	701-12872	1480	19	n.d.	n.d.			
8	701-12873	1422	18	n.d.	n.d.			
9	701-12874	3488	20	n.d.	n.d.			
10	701-12875	1730	180	n.d.	n.d.			
11	701-12876	1426	22	n.d.	n.d.			
12	701-12877	1510	180	n.d.	n.d.			
13	701-12878	1980	23	n.d.	n.d.			

Le Directeur: Jean Planeur Rex
Joseph Gagnon

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Certificat
Certificate No- 701-12879/12911 B. Québec, le 28 juin 1971.

33 Échantillons soumis par
Sample submitted by

Monsieur R.H. McMillan
University of Western Ontario
London 72
Ontario.

Désignation Description	Numéro Number	S %	K_2O %	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.
OG-20- 1	701-12879	0.11	.34	40	21	23	0.3	180
2	701-12880	0.008	.31	50	21	23	n.d.	86
3	701-12881	0.10	.30	48	56	21	n.d.	52
5	701-12882	0.16	.58	44	12	77	n.d.	77
OG-21- 1	701-12883	0.09	.28	24	91	20	n.d.	42
2	701-12884	0.19	.74	59	18	50	n.d.	52
3	701-12885	0.14	.85	42	320	23	0.8	35
4	701-12886	0.04	.96	37	18	42	0.8	37
5	701-12887	4.65	.58	47	89	18	17	80
6	701-12888	0.24	.62	38	40	18	0.4	46
7	701-12889	0.28	.64	32	46	19	0.9	37
8	701-12890	0.33	.67	39	68	20	0.4	34
9	701-12891	0.36	.30	39	560	19	1.5	79
10	701-12892	1.52	.54	44	1960	17	1.2	32
11	701-12893	2.38	.76	44	12860	15	4.1	56
13	701-12894	3.28	.74	115	14900	23	8.0	450
14	701-12895	2.06	.74	95	6050	19	4.0	100
15	701-12896	0.070	1.47	53	280	13	0.8	49
16	701-12897	0.040	1.17	45	36	14	0.4	62
18	701-12898	0.18	.76	51	66	15	0.6	55
19	701-12899	0.15	.24	56	19	40	1.3	88
20	701-12900	0.020	.21	48	43	17	n.d.	67
21	701-12901	0.008	.38	55	32	16	n.d.	75
23	701-12902	0.016	.49	54	26	15	n.d.	65
24	701-12903	0.024	.20	57	28	16	n.d.	84
27	701-12904	0.057	.32	52	89	22	0.4	85
28	701-12905	0.32	.75	67	85	22	0.4	120
OG-23- 2	701-12906	2.36	.24	57	11275	18	6.3	87
3	701-12907	3.23	1.41	140	6540	20	4.7	81
4	701-12908	4.74	1.23	230	3950	31	3.2	84
5	.01-12909	0.41	.25	48	3825	21	2.9	78
6	701-12910	0.21	1.44	59	44	19	0.9	54
7	701-12911	0.028	.47	46	39	17	0.7	94

OG8

Le Directeur: Jean Gagnon
Joseph Gagnon

Province de Québec
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Laboratoires

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Department of Natural Resources
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Certificat
Certificate No- 701-12879/12911 B.

Québec, le 28 juin 1971

33 Échantillons soumis par
Sample submitted by

Monsieur R.H. McMillan
University of Western Ontario
London 72
Ontario.

Désignation Description		Numéro Number	Mn p.p.m.9	Cr p.p.m.	Mo p.p.m.	W p.p.m.	x x x	x x x	x x x
OG-20-	1	701-12879	1331	23	50	n.d.			
	2	701-12880	2356	23	n.d.	n.d.			
	3	701-12881	1280	23	n.d.	n.d.			
	5	701-12882	1190	280	n.d.	n.d.			
OG-21-	1	701-12883	855	18	n.d.	n.d.			
	2	701-12884	936	93	n.d.	n.d.			
	3	701-12885	1644	25	n.d.	n.d.			
	4	701-12886	525	79	n.d.	n.d.			
	5	701-12887	1294	22	n.d.	n.d.			
	6	701-12888	950	19	n.d.	n.d.			
	7	701-12889	1016	19	n.d.	n.d.			
	8	701-12890	876	23	n.d.	n.d.			
	9	701-12891	920	22	n.d.	n.d.			
	10	701-12892	404	15	8	n.d.			
	11	701-12893	664	8.7	n.d.	n.d.			
	13	701-12894	492	9.3	n.d.	n.d.			
	14	701-12895	1280	9	n.d.	n.d.			
	15	701-12896	2752	8.3	n.d.	n.d.			
	16	701-12897	1020	7	n.d.	n.d.			
	18	701-12898	1575	9.4	n.d.	n.d.			
	19	701-12899	1130	27	n.d.	n.d.			
	20	701-12900	1500	9.3	n.d.	n.d.			
	21	701-12901	1575	10	n.d.	n.d.			
	23	701-12902	1540	8.8	n.d.	n.d.			
	24	701-12903	1900	8.4	n.d.	n.d.			
	27	701-12904	2360	8	n.d.	n.d.			
	28	701-12905	2010	10	n.d.	n.d.			
OG-23-	2	701-12906	1055	11	n.d.	n.d.			
	3	701-12907	884	7.5	n.d.	n.d.			
	4	701-12908	868	9.4	n.d.	n.d.			
	5	701-12909	1778	7.8	n.d.	n.d.			
	6	701-12910	1123	7.8	n.d.	n.d.			
	7	701-12911	1375	9.4	n.d.	n.d.			

Le Directeur:..........................
Joseph Gagnon

Province de Québec
Ministère des Richesses Naturelles
Laboratoires

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Province of Québec
Department of Natural Resources
Laboratories

Annex E - Parliament Buildings

Certificat
Certificate No- 701-12912/12915 B.

Québec, le 28 juin 1971.

4 Échantillons soumis par
Sample submitted by

Monsieur R.H. McMillan
University of Western Ontario
London 72
Ontario.

Désignation Description	Numéro Number	S %	K_2O %	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.
OG-23- 8	701-12912	0.031	-.54-	47	43	20	0.6	150
9	701-12913	0.040	-.64-	62	32	20	0.5	150
10	701-12914	1.63	-.67-	67	170	20	0.4	84
11	701-12915	2.88	-.62-	84	270	20	0.7	120

Le Directeur: ....
pour Joseph Gagnon

Province de Québec
Ministère des Richesses Naturelles
Laboratoires

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Department of Natural Resources
Laboratories

Annex E - Parliament Buildings

Certificat
Certificate No- 701-12912/12915 B.

Québec, le 28 juin 1971.

4 Échantillons soumis par
Sample submitted by

Monsieur R.H. McMillan
University of Western
London 72
Ontario.

Désignation Description	Numéro Number	Mn p.p.m.	Cr p.p.m.	Mo p.p.m.	W p.p.m.	x x x	x x x	x x x
OG-23- 8	701-12912	1684	9.8	n.d.	n.d.			
9	701-12913	1856	9.3	n.d.	n.d.			
10	701-12914	1900	9	n.d.	n.d.			
11	701-12915	1800	8.5	n.d.	n.d.			

Bons: 601621/625 - 601631/660 - 601681/750 - 601865
601626/627 - 601581/620 - 601751/800 -
602221/ 273 - 601628/630 - 601801/861- 601866
602274/350

Le Directeur: ....
pour Joseph Gagnon

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21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 701-12871/12915 B. Québec, le 6 juillet 1971.

45 Echantillons soumis par
Sample submitted by M. R.H. McMillan,
The University of Western,
London 72, Ontario,
Canada.

		K_2O %			K_2O %
701-12871,	OG-16-6.	0.79	701-12894,	OG-21-13	1.71
701-12872,	OG-16-7	0.25	701-12895,	OG-21-14	0.74
701-12873,	OG-16-8	0.30	701-12896,	OG-21-15	1.17
701-12874,	OG-16-9	1.26	701-12897,	OG-21-16	1.17
701-12875,	OG-16-10	0.33	701-12898,	OG-21-18	0.96
701-12876,	OG-16-11	0.25	701-12899,	OG-21-19	0.24
701-12877,	OG-16-12	1.44	701-12900,	OG-21-20	0.21
701-12878,	OG-16-13	0.77	701-12901,	OG-21-21	0.38
701-12879,	OG-20-1	0.34	701-12902,	OG-21-23	0.49
701-12880,	OG-20-2	0.31	701-12903,	OG-21-24	0.20
701-12881,	OG-20-3	0.30	701-12904,	OG-21-27	0.22
701-12882,	OG-20-5	0.58	701-12905,	OG-21-28	0.75
701-12883,	OG-21-1	0.18	701-12906,	OG-23-2	0.84
701-12884,	OG-21-2	0.74	701-12907,	OG-23-3	1.47
701-12885,	OG-21-3	0.85	701-12908,	OG-23-4	1.53
701-12886,	OG-21-4	0.96	701-12909,	OG-23-5	0.85
701-12887,	OG-21-5	0.58	701-12910,	OG-23-6	1.44
701-12888,	OG-21-6	0.62	701-12911,	OG-23-7	0.47
701-12889,	OG-21-7	0.64	701-12912,	OG-23-8	0.54
701-12890,	OG-21-8	0.67	701-12913,	OG-23-9	0.64
701-12891,	OG-21-9	0.30	701-12914,	OG-23-10	0.67
701-12892,	OG-21-10	0.54	701-12915,	OG-23-11	0.62
701-12893,	OG-21-11	0.76			

Le Directeur:..........................
pour Joseph Gagnon

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71e-6591/6620 B.

Québec, le 19 novembre 1971.

30 Echantillons soumis par
Sample submitted by

Monsieur R.H. McMillan
Dept. of Geology
University of Western Ontario
London 72 - Ontario.

	OG-23	K %	Mn %	Cu ppm	Ni ppm	Zn ppm	Cr ppm	Co ppm	Ag ppm
71e-6591,	12	0.67	0.48	21	17	110	7.3	51	0.6
71e-6592,	13	0.68	0.46	39	21	160	6	54	0.5
71e-6593;	14	0.66	0.43	76	21	120	6.3	60	0.8
71e-6594,	15	0.50	0.43	50	17	130	6.3	48	0.8
71e-6595,	16	0.37	0.39	136	19	85	5.5	57	0.5
71e-6596,	17	0.43	0.38	155	18	69	8	49	0.4
71e-6597,	18	0.55	0.30	800	21	140	6.5	80	1.6
71e-6598,	19	0.61	0.28	2000	20	150	6	48	2.7
71e-6599,	20	0.83	0.38	220	24	94	6.3	47	0.8
71e-6600,	21	0.66	0.29	760	20	82	6.8	56	1.5
71e-6601,	22	0.25	0.36	520	16	171	6	71	1.6
71e-6602,	23	0.56	0.39	400	21	270	6.5	67	1.2
71e-6603,	24	0.65	0.49	86	23	1500	6.3	45	0.7
71e-6604,	25	0.71	0.40	180	20	100	6	60	0.5
71e-6605,	26	0.63	0.40	300	22	57	5.8	67	0.7
71e-6606,	27	0.72	0.36	170	20	52	4.3	54	0.3
71e-6607,	28	0.76	0.39	53	18	63	5	43	0.8
71e-6608,	29	0.48	0.39	47	17	65	4.8	41	0.7
71e-6609,	30	0.41	0.41	49	23	69	6	56	0.4
71e-6610,	31	0.57	0.42	31	21	74	4.5	57	0.5
71e-6611,	32	0.69	0.42	20	19	67	7	61	0.4
71e-6612,	33	1.06	0.94	67	19	150	15	26	0.7
71e-6613,	34	0.67	0.42	82	21	110	4.5	54	0.8
71e-6614,	24- 1	0.66	0.44	27	22	79	5.3	61	0.8
71e-6615,	2	0.44	0.48	170	21	97	7.5	75	0.4
71e-6616,	3	0.37	0.23	200	16	55	1.5	50	1.5
71e-6617,	4	0.39	0.21	550	14	47	3.3	51	1.4
71e-6618,	5	0.80	0.38	53	13	118	2.5	38	0.8
71e-6619,	6	0.61	0.19	28	46	55	120	37	n.d.
71e-6620,	7	0.96	0.16	47	33	45	71	35	0.3

Le Directeur: Gagnon
Joseph Gagnon

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71e-6621/6650 B.

Québec, le 19 novembre 1971.

30 Echantillons soumis par
Sample submitted by
Monsieur R.H. McMillan
Dept. of Geology
University of Western Ontario
London 72 - Ontario.

	OG-24	K %	Mn %	Cu ppm	Ni ppm	Zn ppm	Cr ppm	Co ppm	Ag ppm
71e-6621,	8	0.84	0.14	77	33	46	64	34	n.d.
71e-6622,	9	0.63	0.20	77	54	58	140	41	0.5
71e-6623,	10	0.44	0.45	35	13	68	5.5	57	0.7
71e-6624,	11	0.28	0.36	42	14	63	7.5	56	n.d.
71e-6625,	12	0.29	0.25	29	11	43	3	31	0.3
71e-6626,	13	0.40	0.33	1100	13	110	5	63	1.2
71e-6627,	14	0.35	0.30	42	12	63	5.3	49	0.3
71e-6628,	15	0.20	0.31	85	15	87	4.5	45	n.d.
71e-6629,	16	0.50	0.45	105	19	92	2.8	56	0.3
71e-6630,	17	0.76	0.40	25	17	68	3	50	n.d.
71e-6631,	18	0.52	0.43	42	31	110	98	80	0.7
71e-6632,	19	0.89	0.32	67	20	93	4.3	64	1.2
71e-6633,	20	0.46	0.41	130	17	95	4.3	58	0.4
71e-6634,	21	0.45	0.40	76	13	98	5.5	53	0.5
71e-6635,	22	0.18	0.29	51	34	56	18	40	0.6
71e-6636,	23	0.31	0.30	26	13	64	15	46	n.d.
71e-6637,	24	0.18	0.24	49	13	56	2.5	33	n.d.
71e-6638,	25	0.65	0.42	100	23	120	4.8	59	n.d.
71e-6639,	28-1	1.15	0.14	14000	80	170	3.5	98	7.5
71e-6640,	2	1.54	0.16	38000	310	560	5	200	26
71e-6641,	3	0.25	0.22	16000	180	1200	2.8	140	14
71e-6642,	4	0.90	0.23	620	20	130	5	51	1.3
71e-6643,	5	0.58	0.46	170	18	120	5	77	0.7
71e-6644,	6	0.85	0.41	110	15	88	6.3	99	0.7
71e-6645,	7	0.58	0.39	54	14	90	7.3	70	1.2
71e-6646,	8	0.54	0.20	93	62	59	220	51	0.6
71e-6647,	9	0.51	0.24	36	625	70	710	84	0.8
71e-6648,	10	0.44	0.32	100	21	64	6.2	87	n.d.
71e-6649,	11	0.40	0.30	27	18	78	4.8	60	0.5
71e-6650,	12	0.27	0.36	18	14	75	5.8	58	0.5

Le Directeur: ....
Joseph Gagnon

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71e-6651/6662 B. Québec, le 19 novembre 1971.

12 Echantillons soumis par
Sample submitted by

Monsieur R.H. McMillan
Dept. of Geology
University of Western Ontario
London 72 - Ontario.

	OG-28	K %	Mn %	Cu ppm	Ni ppm	Zn ppm	Cr ppm	Co ppm	Ag ppm
71e-6651,	13	0.35	0.46	43	14	85	6.8	71	0.9
71e-6652,	14	0.63	0.42	82	21	120	4.8	64	0.4
71e-6653,	15	1.08	0.17	51	20	160	180	35	0.6
71e-6654,	30- 1	0.35	0.35	50	18	65	6.5	69	n.d.
71e-6655,	OH-4-1	1.00	0.47	13	320	120	510	58	0.7
71e-6656,	2	1.10	0.39	290	210	100	510	77	0.5
71e-6657,	3	0.62	0.45	67	180	110	350	60	0.6
71e-6658,	4	1.69	0.50	1500	210	150	380	60	2.5
71e-6659,	5	2.62	0.32	560	68	120	330	33	2.2
71e-6660,	6	1.31	0.21	7200	13	130	4.8	180	5.0
71e-6661,	7	1.08	0.17	640	13	70	4.5	96	0.9
71e-6662,	8	0.54	0.11	2000	15	56	6.6	510	1.7

Bons: 602051/120 - 602192/195 - 602197/200
601951/020 - 602022/025 - 602027/030
601870/876 - 601880/890 - 601931/950
602201/220 - 602031/050 - 601901/930
601891/900 - 601877/879 - 602191 -
602196 - 602021 - 602026

Les résultats pour le soufre vous seront envoyés le plus tôt possible.

Le Directeur:..
Joseph Gagnon

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-6591/6662 B. Québec, le 21 décembre 1971

72 Echantillon soumis par
Sample submitted by Monsieur R.H. McMillan
Dept. of Geology
University of Western Ontario
London, Ont.

		S %			S %			S %
71-6591,	OG-23-12	0.01	71-6615,	OG-24-2	0.95	71-6639,	OG-28-1	5.28
71-6592,	OG-23-13	0.18	71-6616,	OG-24-3	1.05	71-6640,	OG-28-2	9.55
71-6593,	OG-23-14	0.35	71-6617,	OG-24-4	3.04	71-6641,	OG-28-3	8.58
71-6594,	OG-23-15	0.15	71-6618,	OG-24-5	0.12	71-6642,	OG-28-4	0.16
71-6595,	OG-23-16	0.60	71-6619,	OG-24-6	0.02	71-6643,	OG-28-5	0.16
71-6596,	OG-23-17	0.38	71-6620,	OG-24-7	0.02	71-6644,	OG-28-6	0.68
71-6597,	OG-23-18	6.31	71-6621,	OG-24-8	0.08	71-6645,	OG-28-7	0.17
71-6598,	OG-23-19	3.26	71-6622,	OG-24-9	0.01	71-6646,	OG-28-8	0.13
71-6599,	OG-23-20	1.20	71-6623,	OG-24-10	0.01	71-6647,	OG-28-9	0.19
71-6600,	OG-23-21	2.83	71-6624,	OG-24-11	0.06	71-6648,	OG-28-10	0.45
71-6601,	OG-23-22	2.23	71-6625,	OG-24-12	0.01	71-6649,	OG-28-11	0.02
71-6602,	OG-23-23	1.13	71-6626,	OG-24-13	3.66	71-6650,	OG-28-12	0.06
71-6603,	OG-23-24	0.15	71-6627,	OG-24-14	0.08	71-6651,	OG-28-13	0.06
71-6604,	OG-23-25	1.04	71-6628,	OG-24-15	0.06	71-6652,	OG-28-14	0.35
71-6605,	OG-23-26	1.62	71-6629,	OG-24-16	0.05	71-6653,	OG-28-15	0.01
71-6606,	OG-23-27	0.93	71-6630,	OG-24-17	0.07	71-6654,	OG-30-1	0.28
71-6607,	OG-23-28	0.20	71-6631,	OG-24-18	0.08	71-6655,	OH-4-1	0.01
71-6608,	OG-23-29	0.16	71-6632,	OG-24-19	0.03	71-6656,	OH-4-2	0.66
71-6609,	OG-23-30	0.23	71-6633,	OG-24-20	0.10	71-6657,	OH-4-3	0.48
71-6610,	OG-23-31	0.09	71-6634,	OG-24-21	0.01	71-6658,	OH-4-4	0.28
71-6611,	OG-23-32	0.03	71-6635,	OG-24-22	0.01	71-6659,	OH-4-5	0.23
71-6612,	OG-23-33	0.02	71-6636,	OG-24-23	0.01	71-6660,	OH-4-6	4.08
71-6613,	OG-23-34	0.33	71-6637,	OG-24-24	0.02	71-6661,	OH-4-7	1.67
71-6614,	OG-24-1	0.04	71-6638,	OG-24-25	0.41	71-6662,	OH-4-8	12.14

Bons: No 601870/602120 - 602191/602220

Le Directeur: Gagnon
Joseph Gagnon

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8545/8564 B.

Québec, le 23 février 1972

20

Echantillons soumis par / *Sample submitted by* The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	S %	SiO₂ %	K₂O %	Fe t. %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8545, OH-14-8	0.74	45.78	2.12	11.94	1100	81	7100	46	5.3	150	2.8
71-8546, 9	2.32	44.42	2.32	13.84	800	80	23500	34	8.3	130	8.5
71-8547, 10	0.70	45.18	0.73	12.32	1450	80	130	80	1.3	140	11
71-8548, 11	0.46	43.48	0.43	12.02	2000	80	120	70	1.6	170	11
71-8549, 12	0.90	47.90	0.63	11.16	1950	60	120	56	0.8	120	9.3
71-8550, 13	0.26	38.16	1.22	6.86	1450	42	130	40	0.8	80	7.0
71-8551, 14	0.24	44.48	0.49	13.10	2050	78	150	78	2.8	120	12
71-8552, 15	0.50	44.48	0.92	13.04	2100	80	170	92	1.2	210	11
71-8553, 16	0.38	47.70	1.03	11.76	2050	71	150	44	1.3	390	8.5
71-8554, 17	0.13	48.50	0.20	11.84	2200	70	110	36	1.1	120	6.8
71-8555, 18	0.36	47.94	0.78	11.58	1950	63	65	22	0.8	120	9.5
71-8556, OH-18-3	0.10	46.08	0.28	12.56	1950	75	40	38	0.6	100	8.4
71-8557, 4	0.15	42.28	0.38	15.08	2250	85	30	34	0.9	110	8.0
71-8558, 5	3.21	36.94	4.58	19.68	750	149	230	26	1.0	74	8.3
71-8559, 6	0.05	49.54	0.26	9.90	1550	61	50	28	2.0	62	6.3
71-8560, 7	0.36	44.40	0.34	15.30	2100	95	120	46	1.0	110	7.8
71-8561, 8	0.09	45.40	0.96	13.12	2000	74	130	36	0.8	110	9.0
71-8562, 9	0.22	46.80	0.70	12.64	1800	71	70	38	1.0	90	7.0
71-8563, OH-25-11	0.07	49.72	0.24	11.36	1850	62	90	24	0.5	82	8.0
71-8564, 12	0.02	46.40	0.45	13.30	2150	64	8	28	0.7	74	8.3

Bons: Nos 601867 - 602121/602190 - 613091/613110 - 613061/613090

Le Directeur: Joseph Gagnon
Joseph Gagnon

[illegible]
[illegible]

NOUS CONSERVONS
LES [illegible] 1 AN
LES [illegible]

[illegible]
THE SAMPLES [illegible] 1 YEAR
THE CERTIFICATES [illegible] YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8565/8584 B. Québec, le 23 février 1972

20 Echantillon Soumis par / *Sample submitted by* The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	K_2O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8565, OH-14-1	1.29	0.13	1750	69	40	16	1.1	76	5.8
71-8566, 2	0.44	2.38	2350	91	340	20	2.2	90	7.3
71-8567, 3	1.30	1.35	2850	86	80	22	2.0	100	8.0
71-8568, 4	0.74	0.12	2700	60	20	20	1.0	82	8.5
71-8569, 5	0.81	0.68	1850	79	180	18	0.8	68	8.8
71-8570, 6	0.86	0.74	2350	95	200	20	1.1	390	8.3
71-8571, 7	0.78	0.44	2000	69	120	20	0.9	68	9.8
71-8572, OH-21-23	0.84	1.16	1650	46	5100	26	3.1	220	5.3
71-8573, 24	1.68	0.62	950	50	4500	22	2.3	130	6.0
71-8574, 25	0.87	0.06	800	40	380	18	n.d.	84	7.0
71-8575, 26	1.74	0.08	850	48	30	14	1.2	54	10
71-8576, 27	0.39	0.07	550	44	150	16	0.8	44	5.5
71-8577, 28	0.61	0.01	1550	54	8	16	0.5	48	7.5
71-8578, 29	0.80	0.35	2050	65	60	22	0.7	110	8.8
71-8579, OH-24-1	0.37	0.01	1650	55	12	14	0.7	70	9.5
71-8580, 2	0.60	0.03	1650	53	12	16	0.8	56	9.8
71-8581, 3	0.61	0.03	1750	53	8	14	1.0	52	10
71-8582, 4	0.74	0.03	1850	52	14	16	1.2	56	4.3
71-8583, 5	0.86	0.01	950	45	12	20	0.7	50	4.5
71-8584, 6	1.10	0.51	1750	73	95	28	0.9	72	5.0

Bons: Nos 601862 - 613111/613190

Le Directeur: ....
Joseph Gagnon

NOUS CONSERVONS
LES ÉCHANTILLONS 1 AN
LES CERTIFICATS 5 ANS

WE CONSERVE
THE SAMPLES FOR 1 YEAR
THE CERTIFICATES 5 YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8585/8604 B.

Québec, le 24 février 1972

20 Echantillons soumis par / *Sample submitted by* The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	K$_2$O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8585, OH-24-7	0.86	0.02	1500	48	20	14	n.d.	50	7.5
71-8586, 8	1.18	0.32	1850	58	160	18	0.9	94	8.0
71-8587, 9	0.53	0.27	800	49	530	14	1.9	34	7.3
71-8588, 10	0.92	0.53	750	51	930	20	2.0	64	7.5
71-8589, 11	1.47	0.02	750	36	50	20	0.8	84	7.3
71-8590, OH-25-1	0.20	0.02	1750	55	10	18	0.5	70	7.5
71-8591, 2	0.21	0.01	2100	57	10	16	n.d.	74	8.5
71-8592, 3	0.32	2.84	1800	101	220	16	1.1	52	10
71-8593, 4	0.24	0.08	1950	51	0	18	0.7	72	9.3
71-8594, 5	0.75	0.25	2350	86	60	16	1.0	110	6.5
71-8595, 6	0.23	0.01	2050	50	25	16	0.5	62	7.8
71-8596, 7	0.32	0.01	1700	54	10	20	n.d.	66	8.0
71-8597, 8	0.30	0.01	1900	53	12	18	0.5	92	8.0
71-8598, 9	0.19	0.06	900	49	30	16	n.d.	68	5.0
71-8599, 10	3.00	0.02	950	52	45	84	n.d.	88	340
71-8600, 13	0.37	0.12	1850	48	40	18	n.d.	66	5.5
71-8601, 14	0.51	0.16	2300	60	40	22	n.d.	110	8.3
71-8602, 15	0.80	0.35	2100	67	70	28	n.d.	120	10
71-8603, 8621-10	0.13	0.14	1550	78	100	360	n.d.	50	140
71-8604, 165	0.04	0.17	1450	74	90	580	n.d.	46	1890

Bons: Nos 613191/613200 - 613206 - 613211/613280

Le Directeur: Joseph Gagnon

[illegible] CONSERVONS
[illegible]
[illegible]

[illegible] YEAR
[illegible] YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8605/8624 B. Québec, le 24 février 1972

20 Echantillon soumis par
Sample submitted by The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	K_2O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8605, 8621-290	0.04	0.07	1600	94	20	1200	n.d.	62	2050
71-8606, 350	0.03	0.37	1550	136	40	1900	n.d.	2320	4200
71-8607, 480	0.03	0.13	2000	141	10	1500	0.7	150	4670
71-8608, 740	0.03	0.05	1350	68	20	510	n.d.	52	2324
71-8609, 901	0.04	0.12	2200	158	6	2100	0.7	200	4320
71-8610, 8607- 25	1.04	0.01	900	57	6	92	0.9	64	310
71-8611, 140	0.84	0.11	1650	108	450	160	1.0	220	7.5
71-8612, 328	0.53	0.06	2200	86	20	16	0.6	92	6.8
71-8613, 359	0.85	0.04	2300	114	10	16	0.5	120	6.3
71-8614, 370	0.26	0.20	1550	41	190	14	n.d.	98	5.5
71-8615, 400	0.76	0.36	2000	66	80	24	0.5	120	7.8
71-8616, 8470-620	0.62	0.03	2350	46	30	18	0.6	200	8.8
71-8617, 715	0.78	0.14	2300	61	25	12	1.2	130	7.3
71-8618, 890	0.70	0.58	2100	72	50	56	1.0	120	7.3
71-8619, 930	1.11	0.11	2000	81	160	72	n.d.	130	12
71-8620, 983	0.75	0.10	2200	80	90	68	1.0	120	8.3
71-8621, 1028	1.90	4.03	3000	68	260	50	1.7	290	9.3
71-8622, 8583-270	0.06	0.03	1500	62	45	440	n.d.	72	1856
71-8623, 340	0.12	0.04	2000	73	120	440	0.5	120	1668
71-8624, 9031-510	0.43	0.08	210	24	10	16	n.d.	18	14

Bons: Nos 613207 - 613281/613360

Le Directeur: ....
Joseph Gagnon

NOUS CONSERVONS
LES ÉCHANTILLONS 1 AN
LES CERTIFICATS 2 ANS.

WE HOLD
THE SAMPLES FOR 1 YEAR
THE CERTIFICATES FOR 2 YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8625/8644 B. Québec, le 24 février 1972

20 Echantillons soumis par
Sample submitted by The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	K_2O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8625, 2031-533	0.91	0.08	140	27	6	18	n.d.	14	15
71-8626, 7294-1190	0.35	0.07	300	22	25	19	1.1	16	16
71-8627, OG-10-4	0.53	0.36	170	27	8	20	0.6	8	16
71-8628, 8621- 50	0.33	0.12	1500	75	45	440	n.d.	54	380
71-8629, 110	0.26	0.22	1400	70	240	520	n.d.	48	1600
71-8630, 210	0.04	0.05	1300	60	35	520	n.d.	44	3500
71-8631, 250	0.03	0.25	1500	81	600	1820	0.9	40	1200
71-8632, 375	0.07	0.12	1900	160	8	1840	0.7	74	3100
71-8633, 385	0.05	0.44	1500	69	18	650	0.5	78	4000
71-8634, 410	0.06	0.10	2000	137	4	2560	0.7	120	5300
71-8635, 450	0.08	0.02	1300	51	100	530	1.2	44	2400
71-8636, 540	0.06	0.23	2000	149	10	2160	1.1	96	4400
71-8637, 600	0.04	0.23	2400	163	10	2120	0.8	130	6200
71-8638, 665	0.18	0.04	1800	59	190	410	1.1	64	3000
71-8639, 800	0.03	0.06	1300	65	60	580	n.d.	40	2300
71-8640, 855	0.05	0.07	1200	70	50	630	n.d.	44	3700
71-8641, 967	0.03	0.03	1300	61	30	540	n.d.	40	3200
71-8642, 1040	0.04	0.03	1300	63	10	550	n.d.	44	3400
71-8643, 1060	0.03	0.14	1400	142	6	2120	0.9	34	290
71-8644, 1160	0.03	0.04	1400	73	14	750	0.6	64	3700

Bons: Nos 613208 - 613361/613440

Le Directeur: Joseph Gagnon
Joseph Gagnon

NOUS CONSERVONS
LES ÉCHANTILLONS 1 AN
LES CERTIFICATS 2 ANS

WE KEEP THE
THE SAMPLES FOR 1 YEAR
THE CERTIFICATE FOR 2 YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES

ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES

ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8645/8664 B.

Québec, le 24 février 1972

20 Echantillons soumis par / *Sample submitted by* The University of Western Ontario
a/s M. R.K. McMillan
London
Ontario, Canada

		K_2O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8645,	8621-1200	0.78	0.34	2000	64	70	27	0.6	110	13
71-8646,	8602- 35	0.54	0.21	1050	50	14	73	0.8	52	250
71-8647,	60	0.41	0.13	1900	83	570	290	n.d.	74	41
71-8648,	70	0.81	0.17	1600	62	50	115	0.7	76	31
71-8649,	90	0.21	0.29	1650	116	210	410	0.8	72	31
71-8650,	198	0.83	0.14	1500	97	380	120	0.8	110	17
71-8651,	260	0.61	0.07	1700	102	12	38	n.d.	100	17
71-8652,	340	0.90	0.41	3700	141	70	14	1.0	120	17
71-8653,	355	0.56	0.03	2200	71	6	16	n.d.	80	16
71-8654,	8470- 402	0.46	0.02	1800	51	8	18	n.d.	76	17
71-8655,	490	0.26	0.04	1300	34	6	14	n.d.	48	14
71-8656,	530	0.26	0.02	1600	40	8	18	n.d.	56	13
71-8657,	749	0.92	0.39	1800	48	60	17	1.2	120	14
71-8658,	817	1.30	0.26	3200	41	40	36	1.8	110	18
71-8659,	1011	1.40	2.30	2100	106	210	52	1.3	160	20
71-8660,	1049	0.39	0.36	1500	44	8	24	1.4	230	18
71-8661,	1105	0.78	0.34	2100	63	60	29	0.5	120	19
71-8662,	8583- 130	0.05	0.13	1700	95	0	2000	0.6	160	4100
71-8663,	151	0.04	0.63	1500	97	40	1240	0.9	92	2500
71-8664,	168	0.06	0.16	1900	64	100	470	1.1	130	1800

Bons: Nos 613210 - 613441/613520

Le Directeur: ....

Joseph Gagnon

NOUS CONSERVONS
LES ÉCHANTILLONS 1 AN
LES CERTIFICATS 2 ANS

WE [illegible] THE
THE SAMPLES FOR 1 YEAR
THE CERTIFICATES FOR 2 YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8665/8684 3. Québec, le 24 février 1972

20 **Echantillon soumis par** / *Sample submitted by* The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	K$_2$O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8665, 8583-198	0.07	0.02	1800	60	6	450	1.3	120	1900
71-8666, 306	0.06	0.31	1400	70	20	1040	n.d.	150	2200
71-8667, 506	0.80	0.35	2100	69	65	24	n.d.	120	69
71-8668, PH-22- 2	0.08	0.02	800	33	0	17	0.6	42	17
71-8669, 3	0.02	0.01	1000	35	0	16	1.1	64	18
71-8670, 4	0.18	0.45	2100	79	60	31	1.0	140	30
71-8671, 5	0.08	0.01	1500	50	4	22	0.9	66	51
71-8672, 6	0.40	0.01	1800	50	6	18	0.8	110	23
71-8673, 7	0.25	0.20	2400	79	50	24	1.3	130	15
71-8674, 8	0.39	0.06	2400	73	20	20	1.1	130	11
71-8675, 9	0.24	0.09	1900	69	60	26	0.8	86	9
71-8676, 10	0.47	0.02	2300	65	20	20	1.0	130	12
71-8677, 11	0.38	0.01	2900	63	50	20	0.6	150	9
71-8678, 12	0.12	0.01	1700	54	40	24	1.0	54	16
71-8679, 13	0.36	0.11	2700	81	50	22	0.8	120	11
71-8680, 14	0.27	0.02	2200	73	10	19	1.2	110	9
71-8681, 15	0.34	0.22	2400	80	80	17	1.0	120	9
71-8682, 16	0.29	0.03	2500	88	16	28	1.1	160	12
71-8683, 17	0.12	0.03	2100	83	12	19	1.2	120	11
71-8684, 18	0.04	0.02	1100	36	4	19	0.5	34	9

Bons: Nos 613209 - 613521/613600

Le Directeur: Joseph Gagnon
Joseph Gagnon

[illegible]
[illegible] 1 YEAR
[illegible] 2 YEARS

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE *No.* 71-8685/8704 B. Québec, le 24 février 1972

20 **Echantillon soumis par** / ***Sample submitted by*** The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	K$_2$O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8685, FH-22-19	0.04	0.02	1200	66	10	43	0.7	58	20
71-8686, 20	0.04	0.06	1400	86	6	114	1.3	80	110
71-8687, 21	0.04	0.01	1600	87	18	160	0.8	82	200
71-8688, 22	0.04	0.02	1400	99	6	150	0.7	88	17
71-8689, 23	0.03	0.11	2100	145	350	290	1.1	96	39
71-8690, 24	0.06	0.02	1800	90	30	390	n.d.	68	1200
71-8691, 25	0.08	0.01	2000	79	4	300	n.d.	54	290
71-8692, 26	0.04	0.01	1500	64	18	400	0.7	50	640
71-8693, 27	0.03	0.01	1600	66	10	350	n.d.	54	110
71-8694, 28	0.02	0.01	1300	61	70	470	n.d.	42	1700
71-8695, 29	0.02	0.01	1300	60	210	530	n.d.	42	1800
71-8696, 30	0.04	0.05	1600	96	25	2120	0.5	92	2600
71-8697, 31	0.03	0.03	1600	127	6	2720	0.5	56	950
71-8698, 32	0.02	0.01	1600	125	4	2520	0.6	80	1100
71-8699, 32A	(X)	0.01	(X)	39	40	n.d.	n.d.	159	(X)
71-8700, 33	0.03	0.03	1800	132	8	2680	0.7	84	2100
71-8701, 34	0.02	0.01	1500	132	8	2760	1.1	66	2300
71-8702, 35	0.80	-0.39	2300	71	85	27	0.7	130	59
71-8703, FH-24- 1	0.97	1.52	1800	116	1300	240	1.3	96	38
71-8704, 2	0.48	0.14	2200	94	540	300	n.d.	86	30

(X) signifie échantillon épuisé

Bons:Nos 613060 - 613601/613680

Le Directeur: Joseph Gagnon
Joseph Gagnon

NOUS CONSERVONS
LES ECHANTILLONS 1 AN
LES CERTIFICATS 2 ANS

[illegible]
THE SAMPLES FOR 1 YEAR
THE CERTIFICATES FOR 2 YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No 71-8705/8724 B. Québec, le 24 février 1972

20 Echantillons soumis par / *Sample submitted by* The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

		K$_2$O %	S %	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Sn p.p.m.	Cr p.p.m.
71-8705,	PH-24-3	0.53	0.09	1700	88	510	280	n.d.	120	32
71-8706,	4	0.47	0.10	2100	87	440	340	0.5	130	51
71-8707,	6	0.09	0.04	1700	85	320	190	0.6	110	31
71-8708,	7	0.12	0.06	1700	86	210	270	n.d.	96	59
71-8709,	PJ-27-1	0.53	0.42	2300	90	54	22	0.5	160	11
71-8710,	2	0.30	0.04	2000	95	52	28	1.2	140	13
71-8711,	3	0.30	0.05	1600	56	14	24	0.9	210	11
71-8712,	4	0.36	0.05	2000	67	26	22	1.1	230	11
71-8713,	5	0.40	0.11	2100	60	34	20	0.8	130	11
71-8714,	PJ-28-1	0.04	0.04	1500	81	38	130	1.2	83	83
71-8715,	2A	0.02	0.09	2000	130	68	1600	n.d.	74	880
71-8716,	2B	0.02	0.04	1800	69	190	640	0.8	76	1800
71-8717,	3	0.82	0.34	2200	73	70	26	0.6	120	13
71-8718,	OH-5-1	- - -	- - -	960	98	370	18	0.8	96	20
71-8719,	2	- - -	- - -	990	52	10	16	0.5	86	8.8
71-8720,	3	- - -	- - -	2110	58	15	15	1.0	110	9.3
71-8721,	4	- - -	- - -	1200	57	30	16	0.5	78	7.3
71-8722,	5	- - -	- - -	1620	53	10	16	0.5	96	9.5
71-8723,	6	- - -	- - -	1320	48	14	16	n.d.	82	11
71-8724,	7	- - -	- - -	1560	56	18	15	n.d.	83	12

Bons: Nos 613681/613740

Le Directeur: Joseph Gagnon
Joseph Gagnon

NOUS CONSERVONS
LES ÉCHANTILLONS 1 AN
[illegible]
[illegible]
THE SAMPLES FOR 1 YEAR
THE CERTIFICATES FOR 2 YEARS.

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

Québec, le 24 février 1972

CERTIFICAT
CERTIFICATE *No.* 71-8725/8744 B.

20 Echantillons soumis par
Sample submitted by

The University of Western Ontario
a/s M. R.A. McMillan
London
Ontario, Canada

		Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8725,	OH-5- 8	1260	.51	8	18	n.d.	86	11
71-8726,	9	1290	66	30	18	n.d.	100	11
71-8727,	10	1410	.58	14	18	n.d.	110	10
71-8728,	11	2420	100	10	16	0.7	150	11
71-8729,	12	1820	95	130	20	0.6	150	9.5
71-8730,	13	1680	60	16	16	0.5	120	9.0
71-8731,	14	1500	70	68	24	0.6	140	12
71-8732,	OH-20-1	2470	72	98	46	0.9	140	16
71-8733,	2	2210	120	200	44	0.7	240	12
71-8734,	3	1210	77	100	22	0.5	120	11
71-8735,	4	1450	70	68	32	0.6	160	11
71-8736,	5a	1550	74	74	24	0.7	230	12
71-8737,	5b	2330	43	180	20	18	180	7.5
71-8738,	6	1800	88	100	36	0.6	160	12
71-8739,	7	1950	93	94	34	1.0	170	17
71-8740,	8	2280	85	48	44	0.8	170	14
71-8741,	9	1210	43	54	16	n.d.	220	8.8
71-8742,	10	1040	65	9000	24	3.0	450	9.3
71-8743,	12	965	56	320	20	0.7	210	9.5
71-8744,	13	1460	65	72	18	n.d.	160	12

Bons: Nos 613059 - 613741/613760

Le Directeur: Joseph Gagnon
Joseph Gagnon

[illegible]

À ÊTRE CONSERVÉS
[illegible] 1 AN
[illegible] 2 ANS
TO BE KEPT [illegible] 1 YEAR
[illegible] 2 YEARS

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE No. 71-8745/8764 B. Québec, le 24 février 1972

20 Echantillon soumis par
Sample submitted by The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

		Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8745,	OH-21-1	1490	62	20	18	0.9	130	10
71-8746,	2	2080	82	74	26	0.6	100	11
71-8747,	3	1540	64	20	18	0.9	110	9.0
71-8748,	4	2250	73	28	20	0.9	200	8.5
71-8749,	5	2390	64	62	16	0.5	100	8.8
71-8750,	6	1800	62	20	18	0.7	200	9.0
71-8751,	7	1440	65	32	22	1.2	140	9.5
71-8752,	8	1740	66	78	24	1.0	160	7.8
71-8753,	9	1750	83	150	24	1.1	170	10
-8754,	10	1690	75	30	25	1.2	88	11
71-8755,	11	2190	74	12	22	1.4	170	10
71-8756,	12	1225	81	650	18	1.7	170	9.5
71-8757,	13	850	68	9100	18	4.7	100	8.3
71-8758,	14	1430	59	66	20	1.2	96	10
71-8759,	15	1380	68	110	170	2.5	290	530
71-8760,	16	1880	91	380	58	2.3	280	12
71-8761,	17	1630	76	22	50	1.8	96	9.5
71-8762,	18	1300	70	12	32	2.2	80	9.0
71-8763,	19	720	190	1300	36	3.3	86	8.3
71-8764,	20	1420	68	14	40	2.2	92	11

Bons: Nos 613058 - 613761/613730

Le Directeur: Joseph Gagnon
Joseph Gagnon

[illegible]
[illegible] 1 YEAR
[illegible] 2 YEARS

21-1-8

PROVINCE DE QUÉBEC
MINISTÈRE
DES RICHESSES NATURELLES
LABORATOIRES
ANNEXE E.—HÔTEL DU GOUVERNEMENT

QUÉBEC

PROVINCE OF QUEBEC
DEPARTMENT
OF NATURAL RESOURCES
LABORATORIES
ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE *No.* 71-8765/8784 B. Québec, le 24 février 1972

20 Echantillons soumis par / *Sample submitted by* The University of Western Ontario
a/s M. R.H. McMillan
London
Ontario, Canada

	Mn p.p.m.	Co p.p.m.	Cu p.p.m.	Ni p.p.m.	Ag p.p.m.	Zn p.p.m.	Cr p.p.m.
71-8765, OH-21-21	655	40	4600	33	5.5	160	7.1
71-8766, 22	550	60	440	56	3.2	86	11
71-8767, OH-24-12	160	130	12000	120	8.3	94	5.3
71-8768, 13	680	80	14000	26	11	230	9.5
71-8769, 14	610	60	1100	18	2.0	76	8.5
71-8770, 15	740	62	3600	22	3.0	190	9.0
71-8771, 16	1000	52	2000	18	1.8	66	9.3
71-8772, 17	1480	53	13	20	0.9	150	11
71-8773, 18	1250	56	30	18	1.2	110	8.0
71-8774, 19	1330	52	10	18	n.d.	72	9.0
71-8775, 20	1820	70	13	20	1.7	230	15
71-8776, 21	1540	72	70	28	1.0	170	10
71-8777, VI- 9A	1440	67	120	22	1.0	180	14
71-8778, 30A	1380	87	140	42	1.1	210	13
71-8779, 85C	1770	55	40	20	0.9	190	11
71-8780, 103A	1380	59	68	23	0.6	95	9.9
71-8781, 115	1410	98	1000	28	1.4	200	13
71-8782, 198	1360	92	220	80	1.2	170	12
71-8783, 200	1500	96	540	180	2.5	110	18
71-8784, L-2	1810	83	42	22	1.4	160	11

Bons: Nos 613056 - 613781/613800

Le Directeur: Joseph Gagnon
Joseph Gagnon

[illegible]
[illegible] FOR 1 YEAR
[illegible] FOR 2 YEARS

APPENDIX IV

X-ray Fluorescence Analyses of Chibougamau District Metabasalts by Gunn (1969)

(a)	Average Cu content of nine metabasalts from the Blondeau and Gilman Formations (Samples CH505, CH506, CH512, CH513, CH515, CH522, CH525, CH527, CH530).	77 ppm.
(b)	Average Cu contact of five metabastalts from the contact aureole of the Opemiska Lake Pluton (CHO580, CHO581, CHO585, CHO583, CHO584).	25 ppm.

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                         CHIBOUGAMAU GROUP METABASALTS.      GUNN AND DUQUETTE(1969,UNPUB).

NUMBER     CH505    CH506    CH508    CH509    CH510    CH511    CH512    CH513    CH515    CH522     NUMBER

SIO2       43.32    49.42    48.30    48.03    40.85    53.58    51.60    49.19    50.50    49.11     SIO2
AL203      14.18    15.70    15.13    14.86    16.62    17.45    14.97    14.53    15.05    14.25     AL203
TIO2       1.999    1.875     .956     .869    1.124     .910    1.029     .747    1.058    1.904     TIO2
FE203     20.834   17.581   13.947   13.716   18.679   11.795   12.295   13.515   13.363   17.667     FE203
MNO         .225     .212     .231     .164     .244     .209     .221     .207     .202     .260     MNO
MGO         2.30     5.44     8.67     8.68     7.43     5.10     5.01     9.77     7.28     5.50     MGO
CAO       12.718    8.261   10.152    9.796   11.364    7.949   12.828    9.856   10.726    8.740     CAO
NA2O       4.153    1.306    1.700    2.681    2.689    1.852    1.874    1.809    1.357    2.070     NA2O
K2O         .026     .022     .821     .223     .918     .906     .062     .298     .261     .287     K2O
P205        .241     .182     .097     .980     .083     .249     .102     .080     .206     .207     P205
          ------   ------   ------   ------   ------   ------   ------   ------   ------   ------
TOTAL    100.000  100.000  100.002   99.999  100.001  100.000   99.999  100.000  100.000  100.000     TOTAL

CR          70.8    151.9    268.4    267.4    476.7    229.6    102.2    245.3     97.0     97.5     CR
NI          66.9     79.0    127.7    114.4    148.1     95.3     85.9     97.5     80.3     58.8     NI
CU         110.6     86.8     55.4      5.6    149.0      7.9     79.6     49.6    109.2    108.0     CU
ZN         125.1    175.3    118.4     48.6    137.5    153.4     96.8    113.9    115.0    143.7     ZN
RB           0.0      0.0     25.0      3.2     49.9     17.7       .8     12.7      7.1      9.1     RB
SR         101.8    324.7    133.8     92.7    185.4    933.3    123.2    137.7    118.0    181.3     SR
BA          48.7     48.7    393.2     66.5    268.6    323.2     59.8    123.7     53.3     79.0     BA
TH           0.0       .2       .3       .9      1.9       .8       .7       .2      1.6       .1     TH

                                        C.T.P.W. NORMS

QZ          0.00     7.29     0.00     0.00     0.00     9.52     6.01     0.00     4.97     2.63     QZ
OR           .15      .13     4.85     1.32     3.56     5.35      .37     1.76     1.54     1.70     OR
PLAG       31.47    47.98    45.61    50.55    30.58    52.30    48.12    45.95    45.68    46.25     PLAG
NE         12.82     0.00     0.00     0.00    12.33     0.00     0.00     0.00     0.00     0.00     NE
LEU         0.00     0.00     0.00     0.00     1.46     0.00     0.00     0.00     0.00     0.00     LEU
DI         36.14     2.51    15.24    12.28    21.14     1.12    25.57    14.53    14.66    11.26     DI
HY          0.00    33.68    20.32    16.58     0.00    25.57    13.83    27.70    26.65    29.62     HY
OL         10.31     0.00     7.85    11.40    24.04     0.00     0.00     4.41     0.00     0.00     OL
MT          2.90     2.90     2.90     2.90     2.90     2.90     2.90     2.90     2.90     2.90     MT
IL          3.80     3.56     1.82     1.65     2.13     1.73     1.95     1.42     2.01     3.62     IL
AP           .53      .40      .21     2.14      .18      .54      .22      .17      .45      .45     AP
          ------   ------   ------   ------   ------   ------   ------   ------   ------   ------
TOTAL      98.11    98.44    98.81    98.82    98.33    99.02    98.97    98.85    98.86    98.43     TOTAL

AN PERCENT  62.1     75.9     67.2     53.7    100.0     58.8     65.7     65.4     73.7     60.7     AN PERCENT

                     CH505   METABASALT. BASE OF GILMAN FM, BETWEEN WACONICHI LAKE AND GATE, ROY TSP.
                     CH506   METABASALT. GILMAN FM. NEAR GATE. ALBANEL RD, ROY TSP.
                     CH508   METABASALT. WITH STELLATE ACTINOLITE. WACONICHI FM. ALBANEL RD. BIGNELL.
                     CH509   METABASALT. WACONICHI FM, 16.8 MLS NE OF PARK GATE. BIGNELL TSP.
                     CH510   METABASALT. WACONICHI FM. NEAR GRENVILLE FRONT, ALBANEL RD. BIGNELL TSP.
                     CH511   METABASALT. WACONICHI FM. GRENVILLE FRONT. MIGMATISED, BIGNELL TSP.
                     CH512   METABASALT.. GILMAN FM. 100FT SW OF PARK GATE. ALBANEL RD.
                     CH513   METABASALT. GILMAN FM, ALBANEL RD. 1600FT SW OF PARK GATE.
                     CH515   METAPYROXENITE OR COARSE GR. LAVA. GILMAN FM.. ALBANEL RD.
                     CH522   METABASALT.  GILMAN FM. ALBANEL ROAD.
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CHIBOUGAMAU GROUP METABASALTS. GUNN AND DUQUETTE(1969,UNPUB).

NUMBER	CH525	CH527	CH529	CH530	CH0571	CH0573	CH0580	CH0581	CH0582	CH0583	NUMBER
SIO2	45.57	54.87	52.26	51.45	49.03	46.78	50.74	52.37	50.35	49.83	SIO2
AL2O3	12.51	14.79	16.03	16.23	14.14	14.84	13.95	13.66	12.75	10.80	AL2O3
TIO2	.740	1.114	1.133	1.141	1.272	1.373	1.767	1.034	1.351	.875	TIO2
FE2O3	12.613	10.547	13.135	13.411	14.875	16.556	16.008	10.987	14.708	12.575	FE2O3
MNO	.195	.193	.184	.189	.217	.232	.200	.161	.165	.181	MNO
MGO	13.13	5.18	6.00	6.07	7.12	7.94	5.28	7.55	7.55	11.69	MGO
CAO	9.483	8.881	8.372	8.662	9.931	9.040	9.212	9.627	8.719	11.276	CAO
NA2O	5.614	4.190	2.673	2.688	3.078	2.865	2.446	3.671	3.578	2.195	NA2O
K2O	.012	.043	.032	.033	.221	.259	.213	.814	.653	.489	K2O
P2O5	.141	.188	.175	.133	.114	.116	.190	.128	.172	.096	P2O5
TOTAL	100.000	100.000	100.001	100.001	99.999	100.000	100.000	100.000	99.998	100.000	TOTAL
CR	916.8	242.1	314.3	352.3	0.0	0.0	0.0	0.0	0.0	0.0	CR
NI	255.3	87.4	116.3	122.9	99.5	117.8	56.8	93.5	89.2	202.7	NI
CU	2.1	70.7	63.7	78.7	76.0	21.5	22.1	20.7	37.9	20.4	CU
ZN	136.5	130.5	176.8	138.1	0.0	0.0	0.0	0.0	0.0	0.0	ZN
RB	0.0	.4	.2	0.0	5.5	5.1	2.2	25.3	13.1	12.0	RB
SR	263.6	69.5	101.5	188.4	103.9	154.8	271.0	200.0	275.9	282.8	SR
BA	35.6	49.7	52.9	73.3	439.4	82.8	75.1	172.0	119.5	94.0	BA
TH	.5	0.0	1.7	2.6	0.0	0.0	0.0	0.0	0.0	0.0	TH

C.I.P.W. NORMS

	CH525	CH527	CH529	CH530	CH0571	CH0573	CH0580	CH0581	CH0582	CH0583	
QZ	0.00	3.70	5.12	3.46	0.00	0.00	3.85	0.00	0.00	0.00	QZ
OR	.07	.25	.19	.20	1.31	1.53	1.26	4.81	3.86	2.89	OR
PLAG	20.89	56.88	54.28	54.86	50.15	51.11	47.14	49.46	47.07	36.74	PLAG
NE	19.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NE
DI	30.15	17.72	7.32	8.35	20.27	14.33	15.20	23.32	21.00	30.14	DI
HY	0.00	15.17	26.54	26.64	9.65	5.01	24.47	8.73	7.34	11.72	HY
OL	23.98	0.00	0.00	0.00	11.76	20.79	0.00	7.63	13.61	12.68	OL
MT	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	MT
IL	1.41	2.12	2.15	2.17	2.42	2.61	3.36	1.96	2.57	1.66	IL
AP	.31	.41	.38	.29	.25	.25	.41	.28	.38	.21	AP
TOTAL	98.94	99.15	98.89	98.86	98.71	98.54	98.60	99.10	98.73	98.94	TOTAL
AN PERCENT	41.1	36.3	56.9	57.1	46.6	51.1	54.6	35.8	34.3	48.0	AN PERCENT

CH525	METABASALT. BLONDEAU FM. 16600FT SW OF PARK GATE, ALBANEL RD.	
CH527	METABASALT. DRILL CORE. CENTER OF 4FT PILLOW. GILMAN FM, JOURDAIN AV.	
CH529	BASALTIC INTERFLOW MATERIAL, 1FT THICK. CNR JOURDAIN AV AND 4TH ST, CHIB	
CH530	METABASALT. MASSIVE BASE OF 60FT-THICK FLOW WITH PILLOWS. JOURDAIN AV.	
CH0571	METABASALT. WACONICHI FM., 1/2 MILE S. OF ISLAND AND DIORITE CONTACT.	
CH0573	METABASALT. WACONICHI FM, OPP MIDDLE OF MUSSET ISLAND, L WACONICHI.	
CH0580	METABASALT. BANDED AMPHIBOLITE, NEAR S CONTACT WITH OPEMISCA GRANITE.	AMPHIBOLITE
CH0581	METABASALT. 6 IN. FROM CONTACT WITH N. SIDE OF OPEMISCA GRANITE.	
CH0582	METABASALT. AMPHIBOLITE, 40FT N OF CONTACT WITH OPEMISCA GRANITE.	
CH0583	METABASALT. 90FT FROM N CONTACT OF OPEMISCA GRANITE, OPEMISCA LAKE.	

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                    CHIBOUGAMAU GROUP METABASALTS.     GUNN AND DUQUETTE(1969,UNPUB).

 NUMBER     CH0584   CH0590   CH0591   CH0602   CH0603   CH1604   CH0605   CH0589                        NUMBER

 SIO2       51.34    48.88    48.30    55.44    48.69    46.95    49.99    49.77     0.00      0.00      SIO2
 AL2O3      12.88    13.32    18.44    16.39    15.22    14.83    14.08    10.86     0.00      0.00      AL2O3
 TIO2       1.941    1.637    1.642     .838     .869     .916     .944     .894     0.000     0.000     TIO2
 FE2O3     15.736   17.368   12.846   10.296   13.129   14.828   14.127   12.690     0.000     0.000     FE2O3
 MNO         .199     .221     .162     .164     .186    1.067    1.131     .182     0.000     0.000     MNO
 MGO        5.14     6.27     4.68     4.35     7.96     7.01     5.31    11.49      0.00      0.00      MGO
 CAO        8.776    9.770    9.554    8.852   11.481   12.469   12.433   11.191    0.000     0.000     CAO
 NA2O       3.557    1.834    2.775    3.219    2.170    1.491    1.698    2.269    0.000     0.000     NA2O
 K2O         .229     .504    1.544     .384     .215     .338     .205     .545    0.000     0.000     K2O
 P2O5        .206     .196     .059     .066     .081     .094     .090     .112    0.000     0.000     P2O5
           ------   ------   ------   ------   ------   ------   ------   ------    ------    ------
 TOTAL    100.001  100.001   99.999   99.999  100.000   99.999  100.001  100.000    0.000     0.000     TOTAL

 CR          0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0       0.0      CR
 NI         34.9     66.9     24.4    151.2    150.2    141.6    100.8    210.4      0.0       0.0      NI
 CU         22.4    110.7    136.9    111.1     92.6     10.9    143.6      0.0      0.0       0.0      CU
 RB          3.7     11.4     38.5     12.0      5.2      5.5      4.1     13.4      0.0       0.0      RB
 SR        201.7    175.1    327.3     84.0    116.3     72.5    173.2    285.6      0.0       0.0      SR
 BA         94.9    108.1    282.0    158.7     70.9     82.0     81.0     94.1      0.0       0.0      BA

                                   C.I.P.W. NORMS

 QZ          .68     1.20     0.00     8.07     0.00     0.00     3.07     0.00     0.00      0.00      QZ
 OR         1.35     2.98     9.13     2.27     1.27     2.00     1.21     3.22     0.00      0.00      OR
 PLAG      48.60    42.14    56.79    56.37    49.51    45.40    44.55    37.03     0.00      0.00      PLAG
 DI        19.95    17.31    11.44    11.91    20.80    23.72    25.94    30.01     0.00      0.00      DI
 HY        21.01    28.39     2.92    15.90    15.27    14.57    19.14    10.30     0.00      0.00      HY
 OL         0.00     0.00    12.49     0.00     7.31     8.20     0.00    13.52     0.00      0.00      OL
 MT         2.90     2.90     2.90     2.90     2.90     2.90     2.90     2.90     0.00      0.00      MT
 IL         3.69     3.11     3.12     1.59     1.65      .74     1.79     1.70     0.00      0.00      IL
 AP          .45      .43      .13      .14      .18      .21      .20      .24     0.00      0.00      AP
           ------   ------   ------   ------   ------   ------   ------   ------    ------    ------
 TOTAL     98.63    98.46    98.91    99.17    98.89    98.73    98.80    98.93     0.00      0.00      TOTAL

AN PERCENT  36.7     61.8     57.2     50.2     61.5     71.0     66.4     45.7      0.0       0.0      AN PERCENT


                  CH0584  METABASALT, ON ISLAND, NEAR N CONTACT WITH OPEMISCA GRANITE.
                  CH0590  METABASALT, BIOTITE AMPHIBOLITE, SW CHIBOUGAMAU LAKE,
                  CH0591  METABASALT OR METAGABBRO, [redacted], SW SHORE OF CHIBOUGAMAU L.
                  CH0602  METABASALT, BIOTITE-BEARING, 5/8 MI FROM DAUVERSIERE PLUTON, L ST JEANRD
                  CH0603  METABASALT, AMPHIBOLITE, 100YD SE OF DAUVERSIERE BIOTITE DIORITE PLUTON.
                  CH0604  METABASALT, NEAR OBATAGAMAU LAKE TURNOFF.
                  CH0605  METABASALT,
                  CH0589  METABASALT,
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APPENDIX V

Lead Isotope Data from Samples Collected by Franklin from the Chibougamau and Opemiska Veins

	Lead Isotope Sample Number	204	206	207	208	206/204	207/204	208/204	207/206	208/206	206N	207N	208N
OPEMISKA copper mine (Perry Shaft)													
49°47'23" 74°07'24" 32G15 Levy Twp. 24 miles WSW of Chibougamau, Quebec.		63RF 0622 PYRT L-lead acid-leached from pyrite in branch vein NE off B zone, 975 level.											
	1	1.739	22.41	23.24	52.61	12.89	13.37	30.26	1.04	2.35	22.81	23.65	53.54
Chalcopyrite, pyrite and quartz occur in veins in gabbro phase of a ultrabasic-basic complex; intrusive into Archaean strata.				R									
	2	1.549	22.56	23.08	52.81	14.56	14.90	34.08	1.02	2.34	22.92	23.44	53.64
		63RF 0614 PYRT-lead in pyrite, north end of B zone, 672 drift, 825 level.											
	3	1.425	25.20	22.11	51.25	17.68	15.51	35.96	0.88	2.03	25.57	22.43	52.00
		66RF 0579 GALN-coarse, sparse grains with chalcopyrite and sphalerite; a rare specimen.											
	4	1.502	23.62	22.86	52.01	15.73	15.22	34.63	0.97	2.20	23.98	23.21	52.81
COPPER RAND CHIBOUGAMAU copper mine													
49°53'00" 74°16'50" 32G16 McKenzie Twp. 3 miles E of Chibougamau, Quebec		63RF 0602 PYRT R-lead in pyrite after leaching; lead in leached liquid insufficient for analysis.											
	5	1.548	22.23	23.02	53.20	14.37	14.88	34.37	1.04	2.39	22.58	23.38	54.04
Vein-like body of chalcopyrite-pyrite-siderite ore in sheared, altered gabbro-anorthosite.													
CAMPBELL CHIBOUGAMAU copper mine		63RF 0602 PYRT L-west end, A zone, 1000 level; residue and insufficient lead for analysis.											
	6	1.536	22.72	22.90	52.84	14.80	14.91	34.41	1.01	2.33	23.08	23.26	53.67
48°51'50" 74°20'12" 32G16 Obalski Twp. 3 miles SSE of Chibougamau, Quebec.		66RF 0573 GALN-rare occurrence, specimen donated by mine.											
	7	1.512	22.80	22.83	52.85	15.08	15.10	34.96	1.00	2.32	23.15	23.18	53.67
Veins in highly altered anorthosite-gabbro contain chalcopyrite, pyrrhotite, pyrite and quartz.													
PORTAGE copper mine													
49°54'30" 74°11'00" 32G16 Roy Twp. 7 miles E of Chibougamau, Quebec		63RF 0630 CHLP R-residual lead in pyrite after leaching; sample mylonitized ore.											
Vein-like bodies of chalcopyrite-pyrite-pyrrhotite-quartz siderite in meta-anorthosite.	8	1.478	23.57	22.39	52.56	15.95	15.15	35.56	0.95	2.23	23.93	22.73	53.34
				L-lead leached from pyrite.									
	9	1.473	23.30	22.55	52.67	15.82	15.31	35.76	0.97	2.26	23.65	22.89	53.46
		63 RF 0631 PYRT L-lead leached from pyrite; chalcopyrite-quartz-chlorite ore.											
	10	1.411	25.28	21.27	52.03	17.91	15.07	36.87	0.84	2.06	25.64	21.58	52.78
				R-residual lead in pyrite after leaching.									
	11	1.375	24.81	21.36	52.45	18.05	15.54	38.16	0.86	2.11	25.16	21.66	53.18
				PYRT-unleached									
	12	1.334	25.33	21.06	52.27	18.99	15.79	39.19	0.83	2.06	25.67	21.35	52.98

Legend:			
	N = normalized	GLN = galena	L = leached lead
	PYRT = pyrite	CHLP = chalcopyrite	R = analyzed residue

APPENDIX VI

Specific Locations of Assay Data or Mineral Occurrences

i) Pb: 9-2-6 stope, no. 2 Vein, 9 level

ii) Co: Hole no. S-57,802.6-804.6 ft.

iii) Hole S-346, 37.5 ft. from 691.5 to 729.0 assayed 0.58% Cu and 0.34% WO_3

iv) Scheelite occurrences with chalcopyrite mineralization in Black Pyroxenite

South of B-3 Drift	Hole U-8583 at 157 ft.
North of East Zone	Hole S-443 at 323 ft.

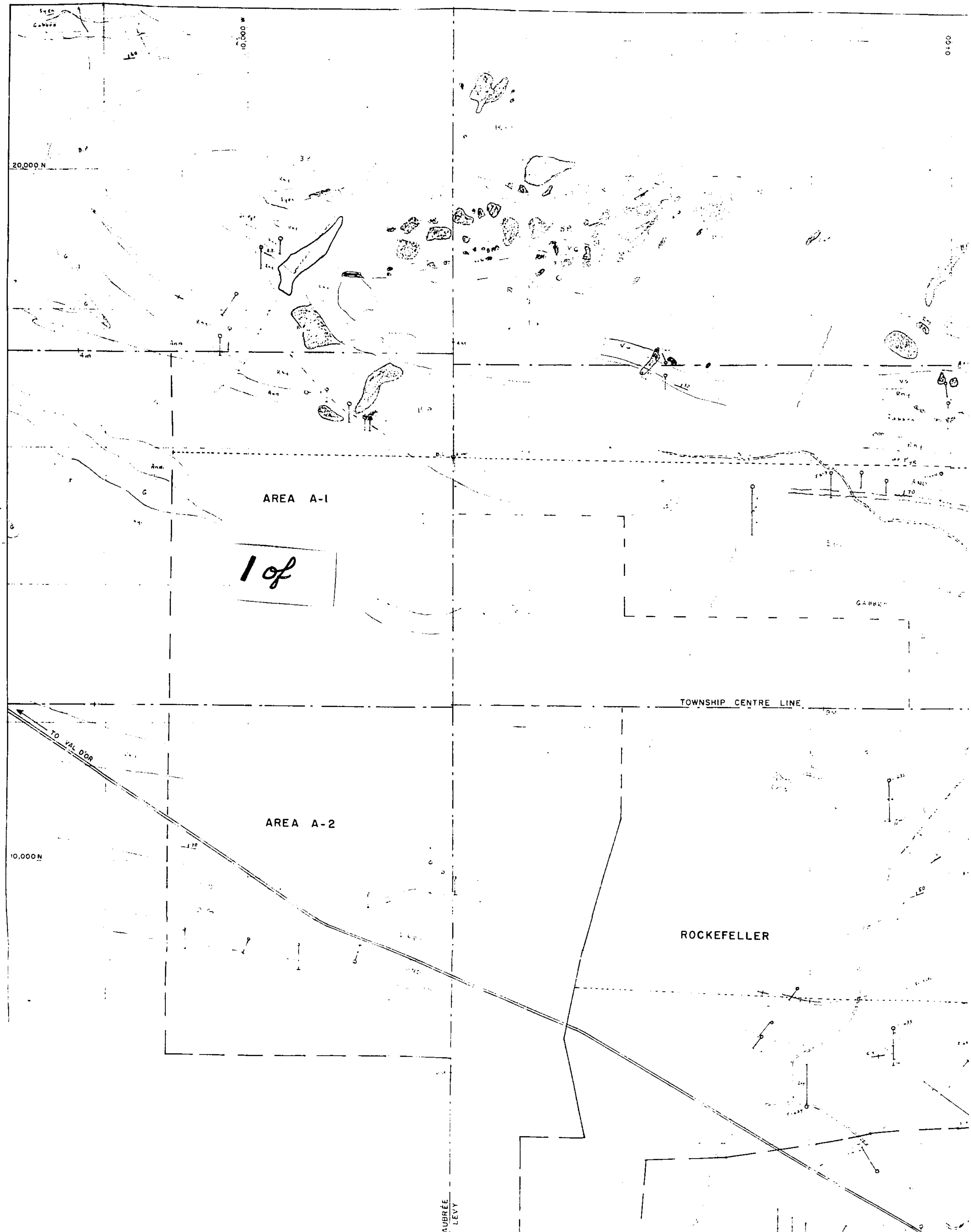
v) Molybdenite occurrences with chalcopyrite mineralization in Black Pyroxenite

East Zone	Hole S-76 at 102 ft.
South of 901 Drift	Hole U-8873 at 734.5 ft.

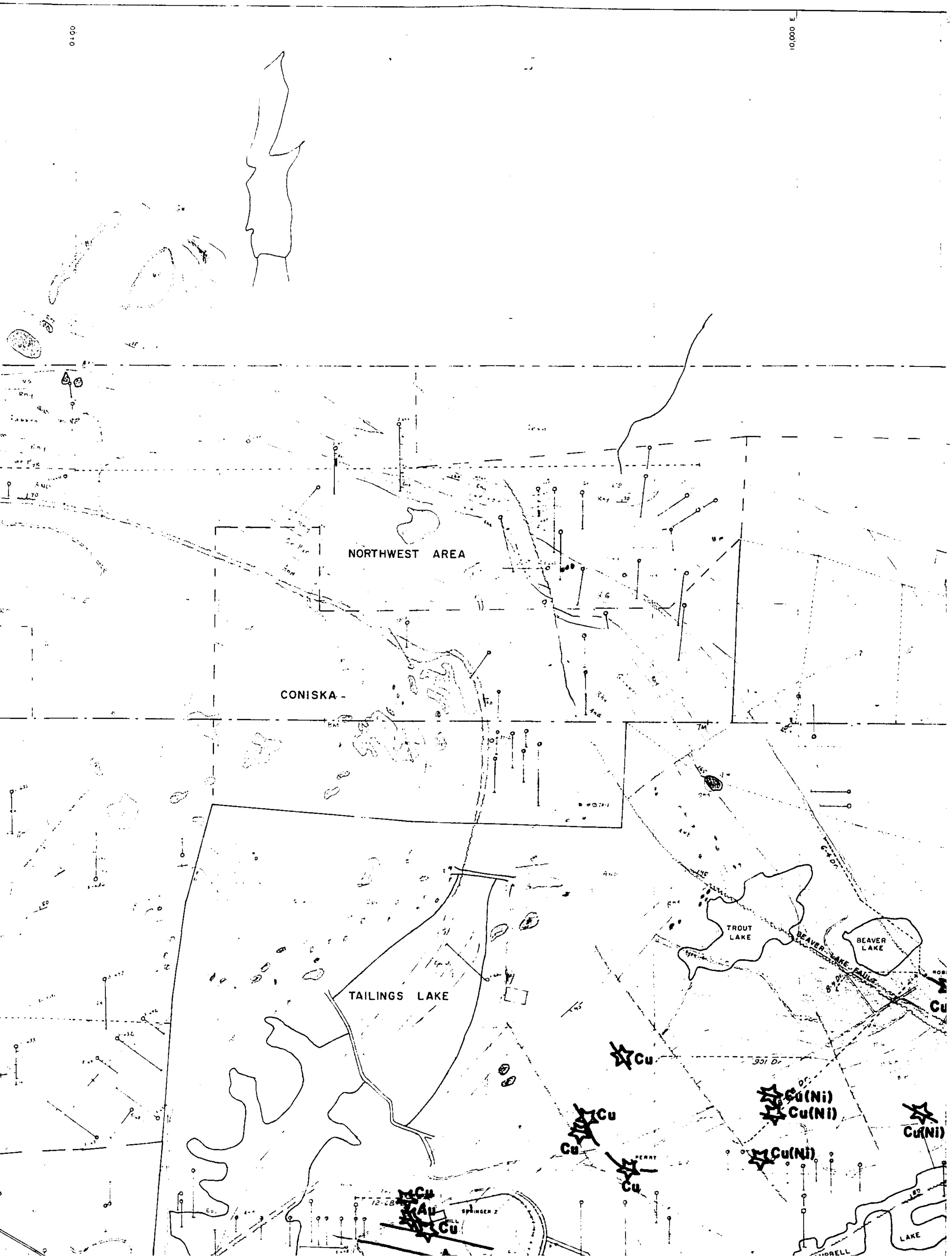
vi) Galena in polished sections from Springer and Perry Veins: P4B5, S13-2-2

vii) Arsenopyrite in polished sections from Springer and Perry Veins: P4B5, S6-4-8

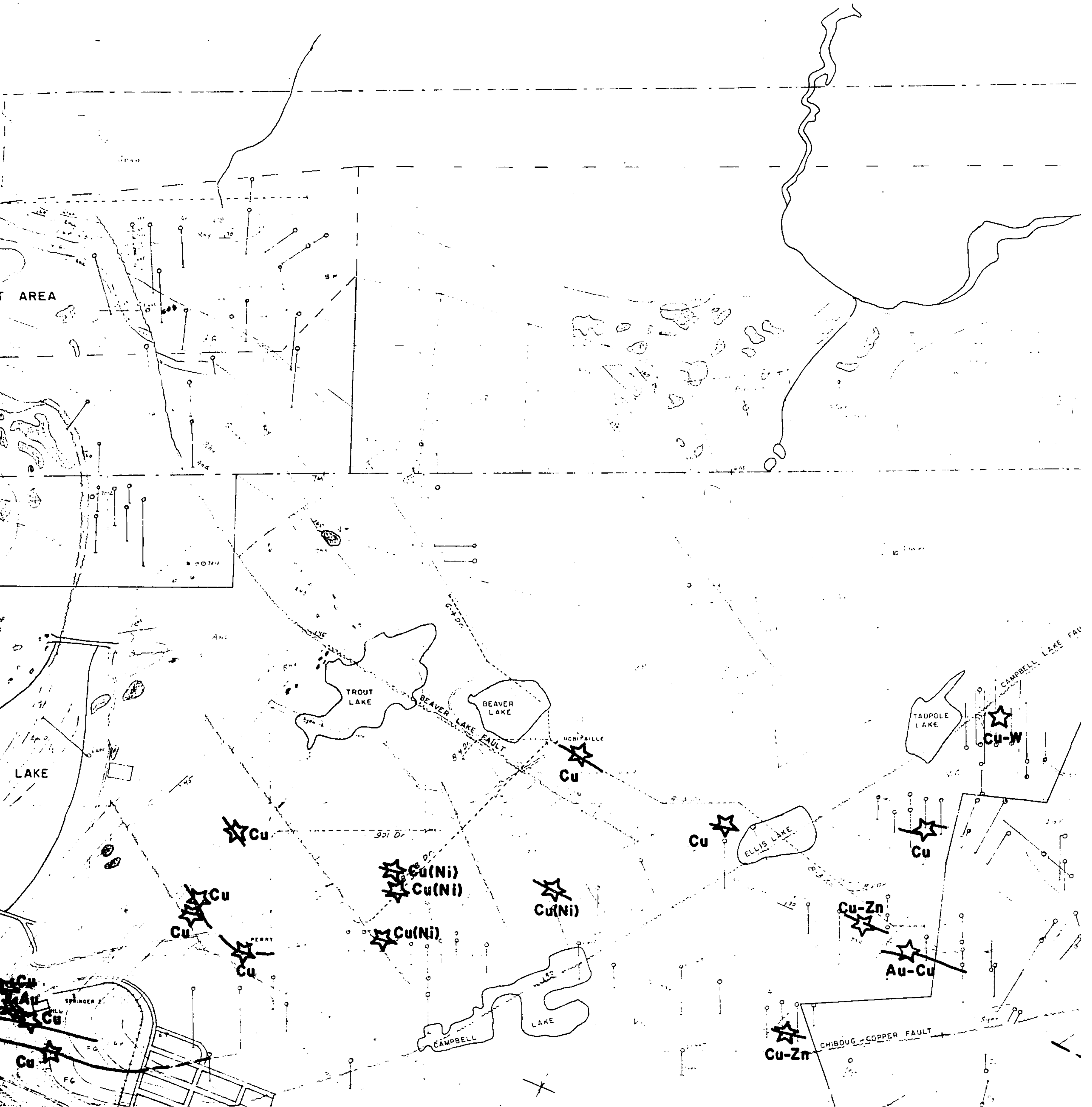
viii) Native gold in polished sections from Springer and Perry Veins: P4B5, S2-3-7, S6-4-8

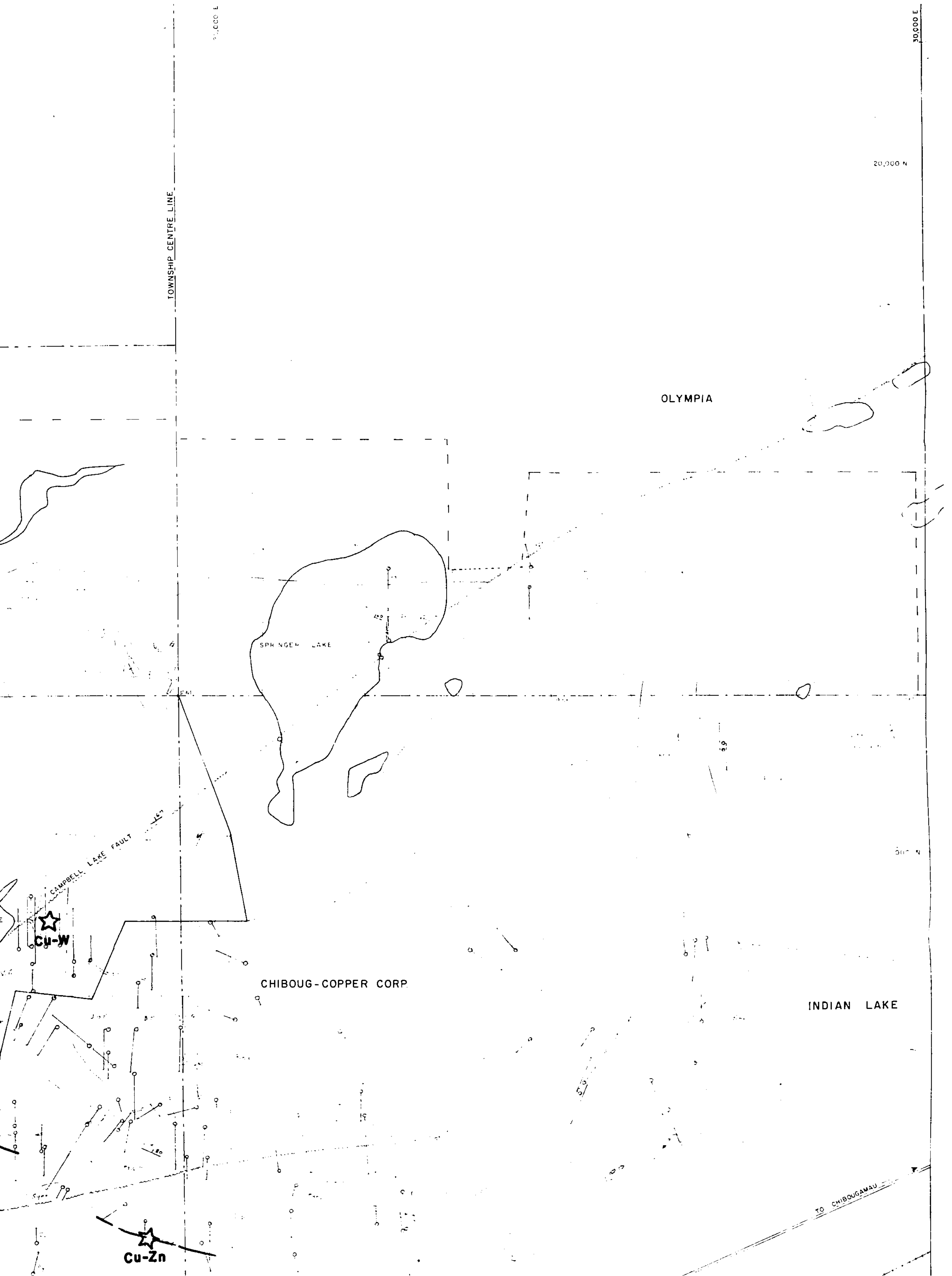


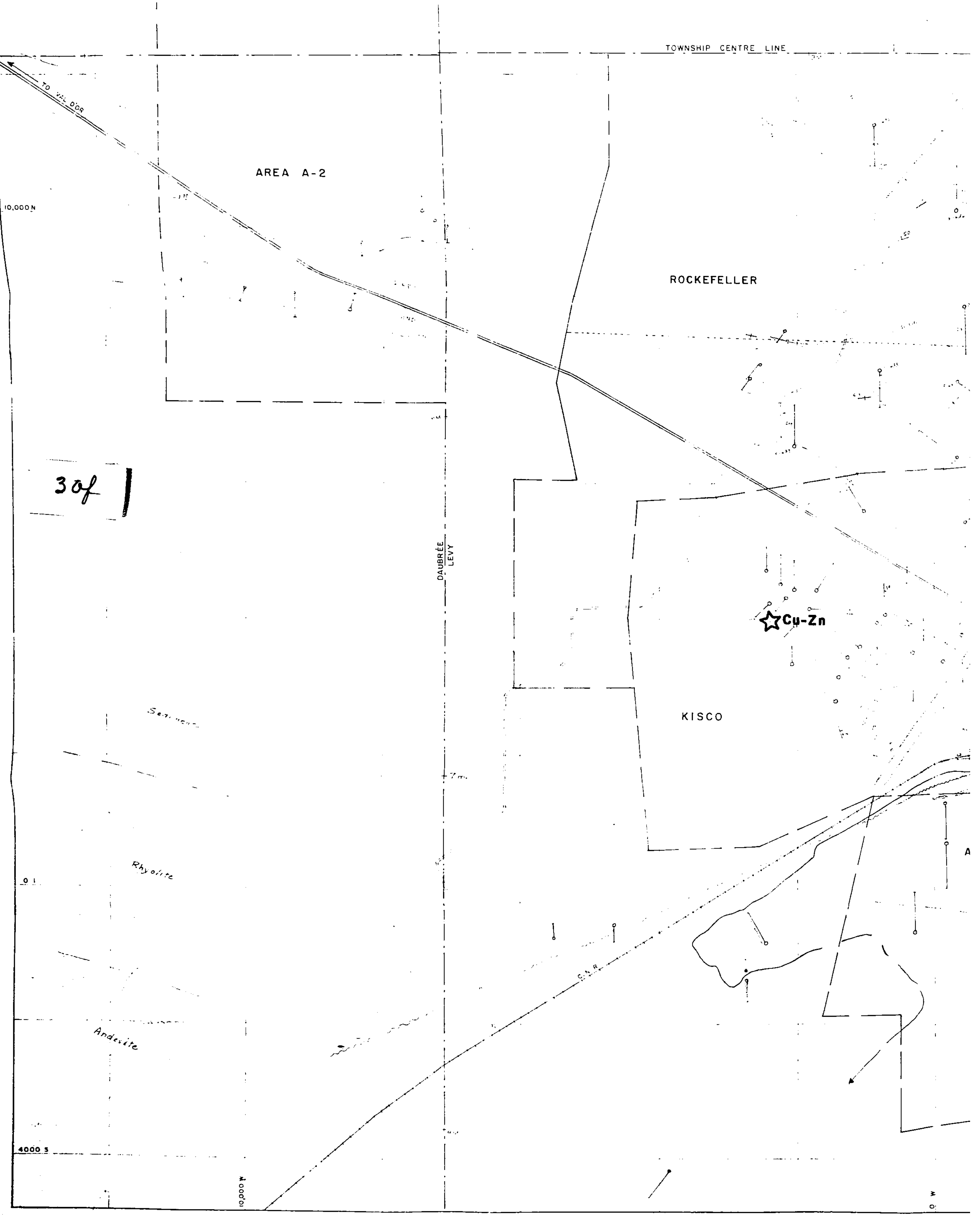
10,000 W
20,000 N
10,000 N
AREA A-1
1 of
AREA A-2
TO VAL D'OR
TOWNSHIP CENTRE LINE
ROCKEFELLER
GABBRO
Gabbro
Syen
Anm
Rhy
AUBRÉE
LEVY


0010
10,000 E
NORTHWEST AREA
CONISKA
TAILINGS LAKE
TROUT LAKE
BEAVER LAKE
BEAVER LAKE FAULT
Cu
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu
Cu
Cu
Cu
Cu
Au
Cu
301 Dr
SPRINGER Z
LAKE

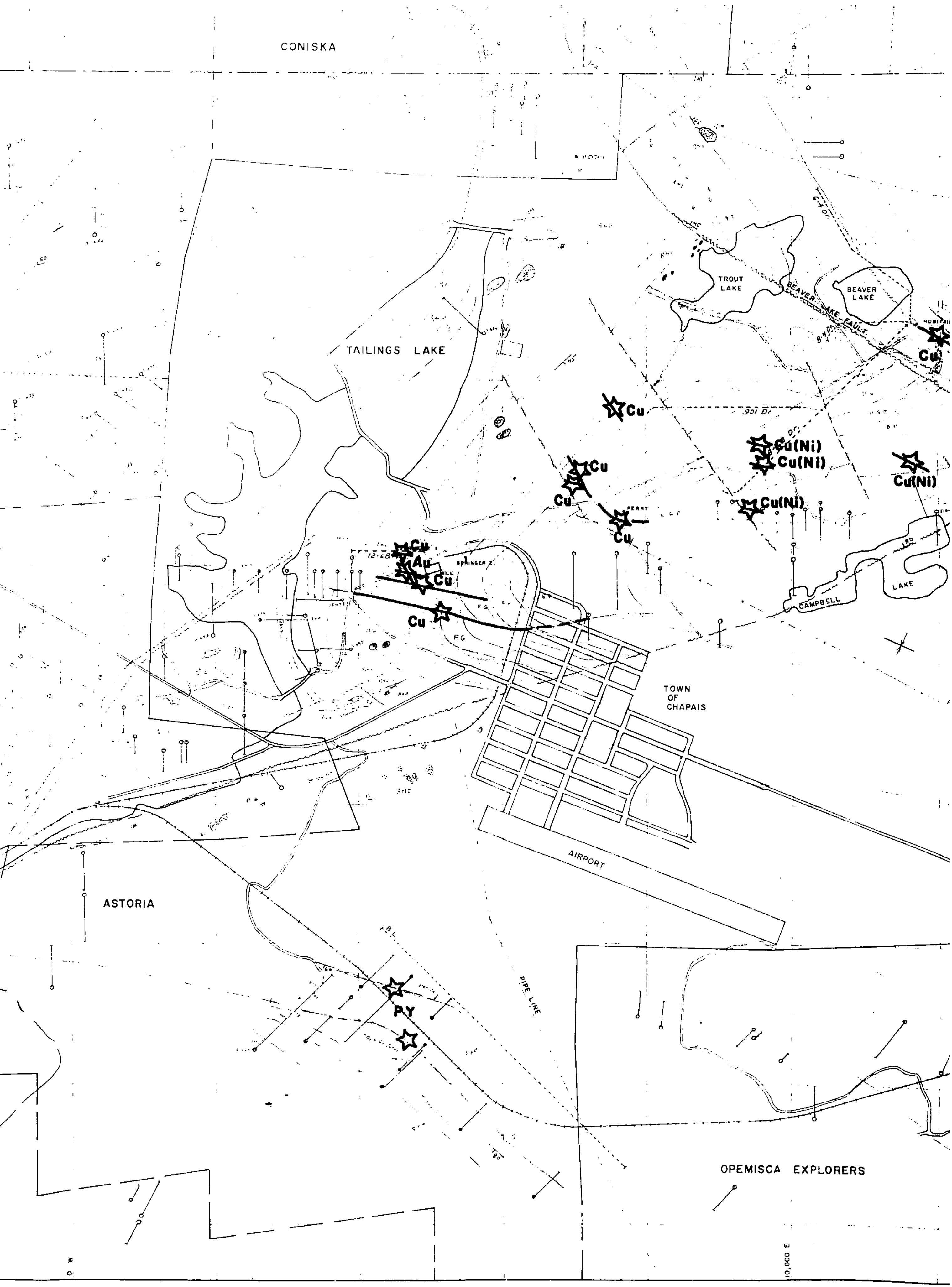
2 of


AREA
LAKE
TROUT LAKE
BEAVER LAKE
BEAVER LAKE FAULT
ROBITAILLE
CAMPBELL LAKE FAU
TADPOLE LAKE
Cu-W
Cu
ELLIS LAKE
901 Dr
Cu
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu
Cu
Cu
Cu
PERRY
Cu-Zn
Au-Cu
Cu-Zn
CHIBOUG - COPPER FAULT
CAMPBELL LAKE
Cu
Au
Cu
Cu
SPRINGER 2
FG

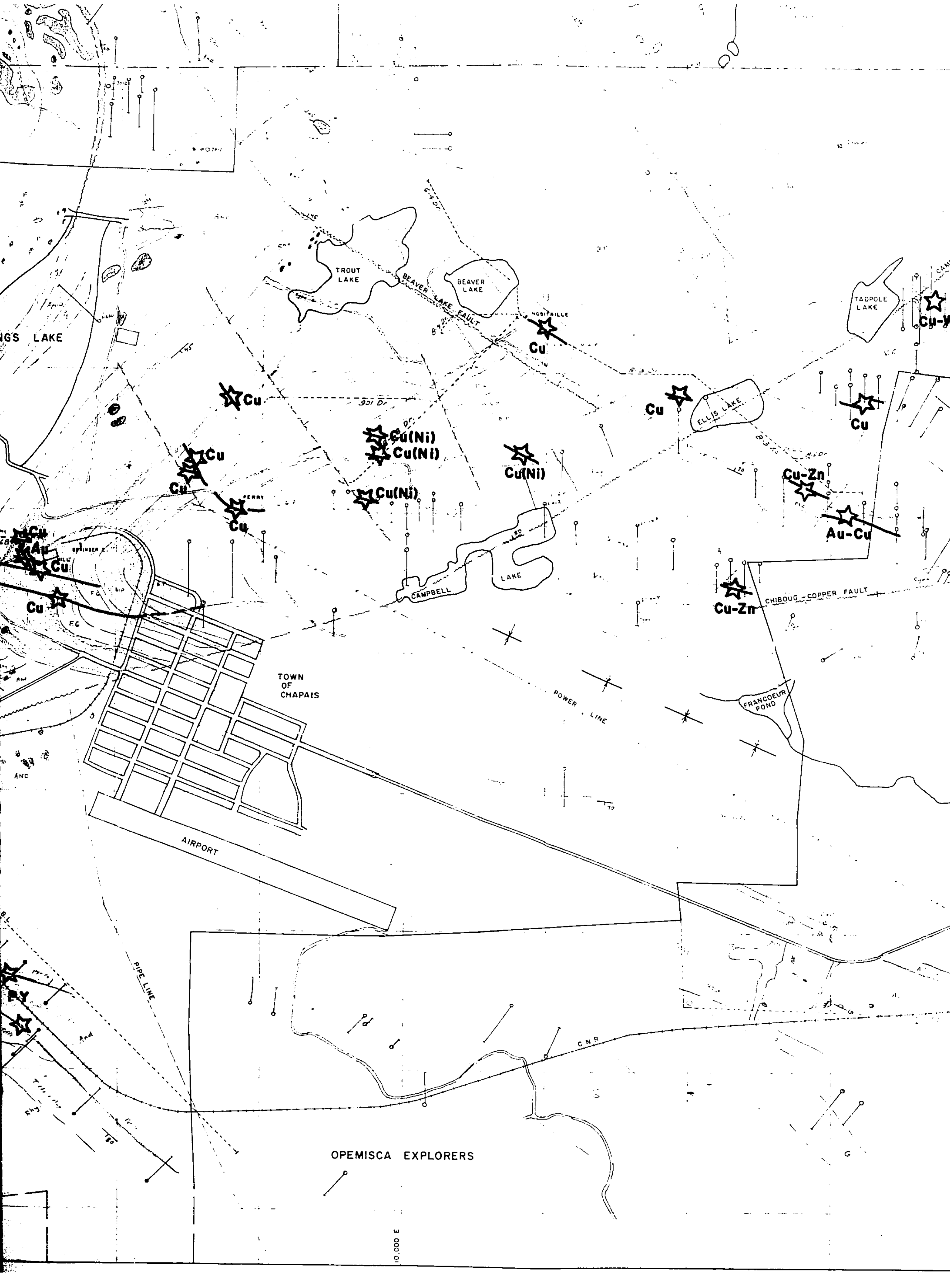

30,000 E
20,000 N
TOWNSHIP CENTRE LINE
OLYMPIA
SPRINGER LAKE
CAMPBELL LAKE FAULT
Cu-W
Cu-Zn
CHIBOUG-COPPER CORP.
INDIAN LAKE
TO CHIBOUGAMAU


TOWNSHIP CENTRE LINE
TO VAL D'OR
AREA A-2
10,000 N
ROCKEFELLER
DAUBRÉE
LEVY
Cu-Zn
KISCO
Sediments
Rhyolite
Andesite
C.N.R.
4000 S
10,000 W
A

3of



CONISKA
TROUT LAKE
BEAVER LAKE
BEAVER LAKE FAULT
TAILINGS LAKE
Cu
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu
Cu
PERRY
Cu
Cu
Au
Cu
SPRINGER 2
Cu
CAMPBELL
LAKE
TOWN OF CHAPAIS
AIRPORT
ASTORIA
PY
PIPE LINE
OPEMISCA EXPLORERS
10,000 E
0 W



NGS LAKE
TROUT LAKE
BEAVER LAKE
BEAVER LAKE FAULT
HOBITAILLE
TADPOLE LAKE
ELLIS LAKE
CAMPBELL
LAKE
PERRY
SPRINGER Z.
Cu
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu(Ni)
Cu-Zn
Au-Cu
Cu-Zn
Cu-Y
Au
CHIBOUG - COPPER FAULT
TOWN OF CHAPAIS
POWER LINE
FRANCOEUR POND
AIRPORT
PIPE LINE
CNR
OPEMISCA EXPLORERS
10,000 E
And
Rhy
ANC

4of 4

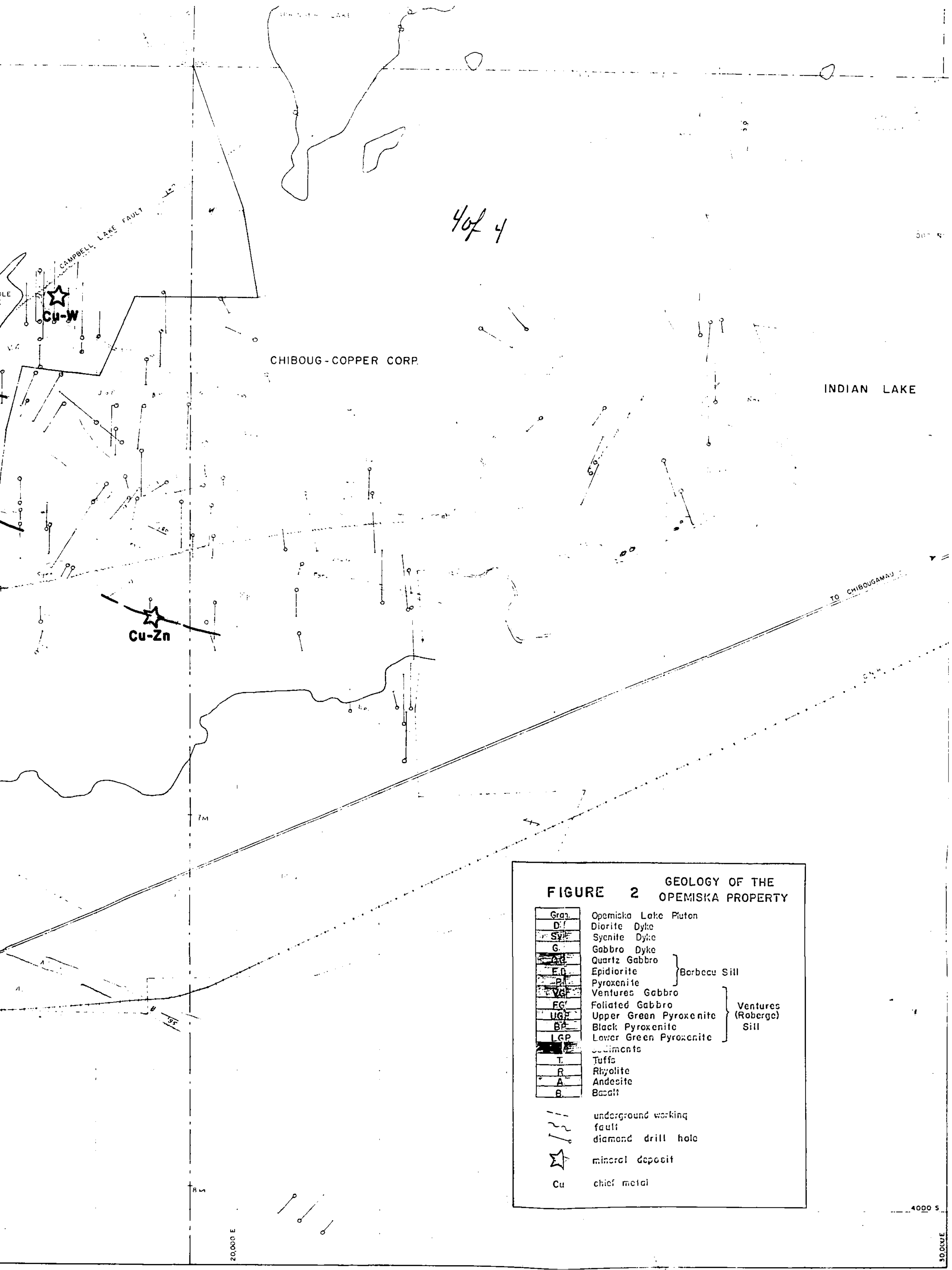
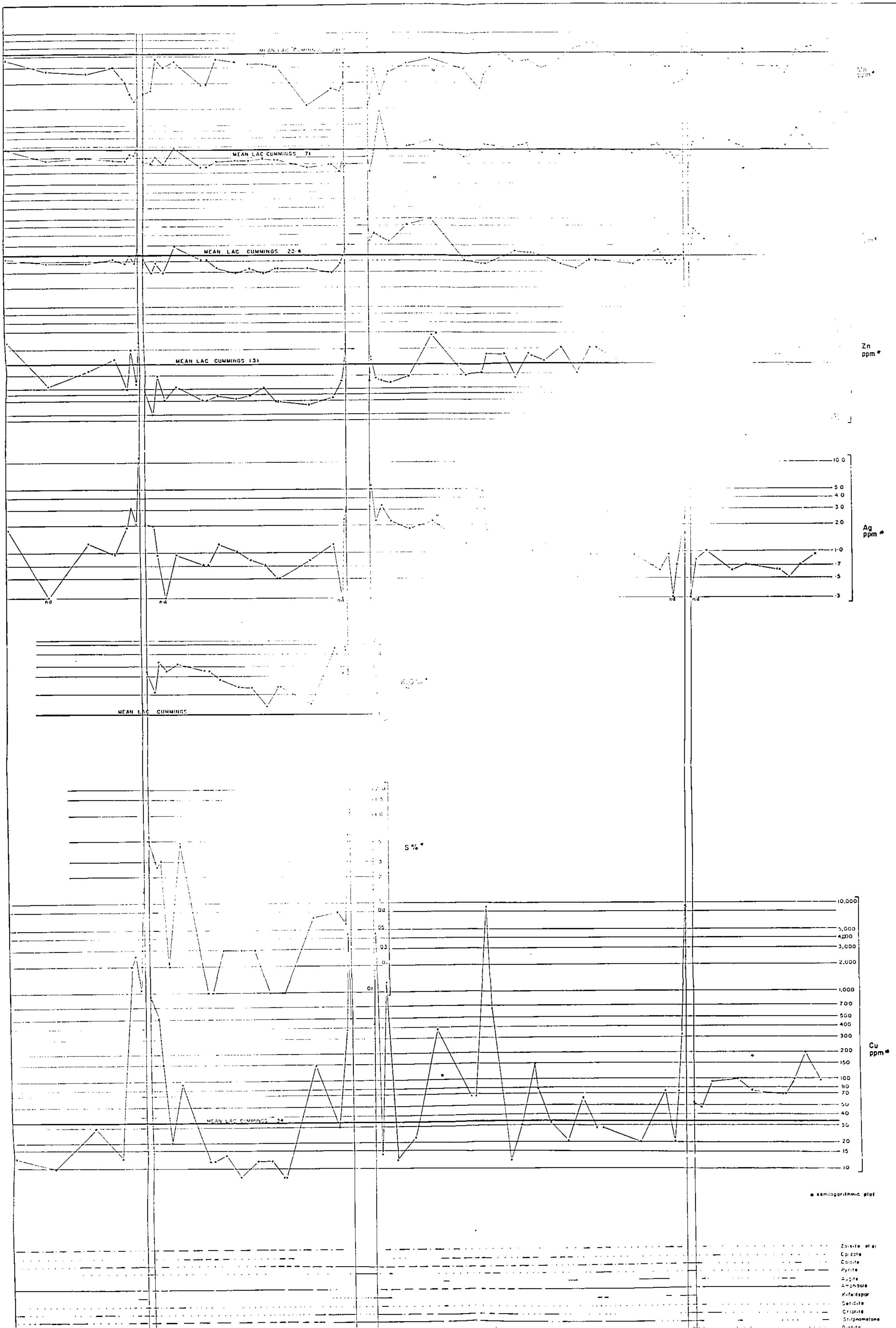


FIGURE 2 GEOLOGY OF THE OPEMISKA PROPERTY

1 of



MEAN LAC CUMMINGS 71
MEAN LAC CUMMINGS 22.4
MEAN LAC CUMMINGS 131
MEAN LAC CUMMINGS
MEAN LAC CUMMINGS 34
Mn ppm*
Zn ppm*
Ag ppm*
10.0
5.0
4.0
3.0
2.0
1.0
.7
.5
.3
nd
S %*
Cu ppm*
10,000
5,000
4,000
3,000
2,000
1,000
700
500
400
300
200
150
100
80
70
50
40
30
20
15
10
* semilogarithmic plot
Zoisite et al
Epidote
Calcite
Pyrite
Augite
Amphibole
K-feldspar
Sericite
Chlorite
Stilpnomelane

2 of 2

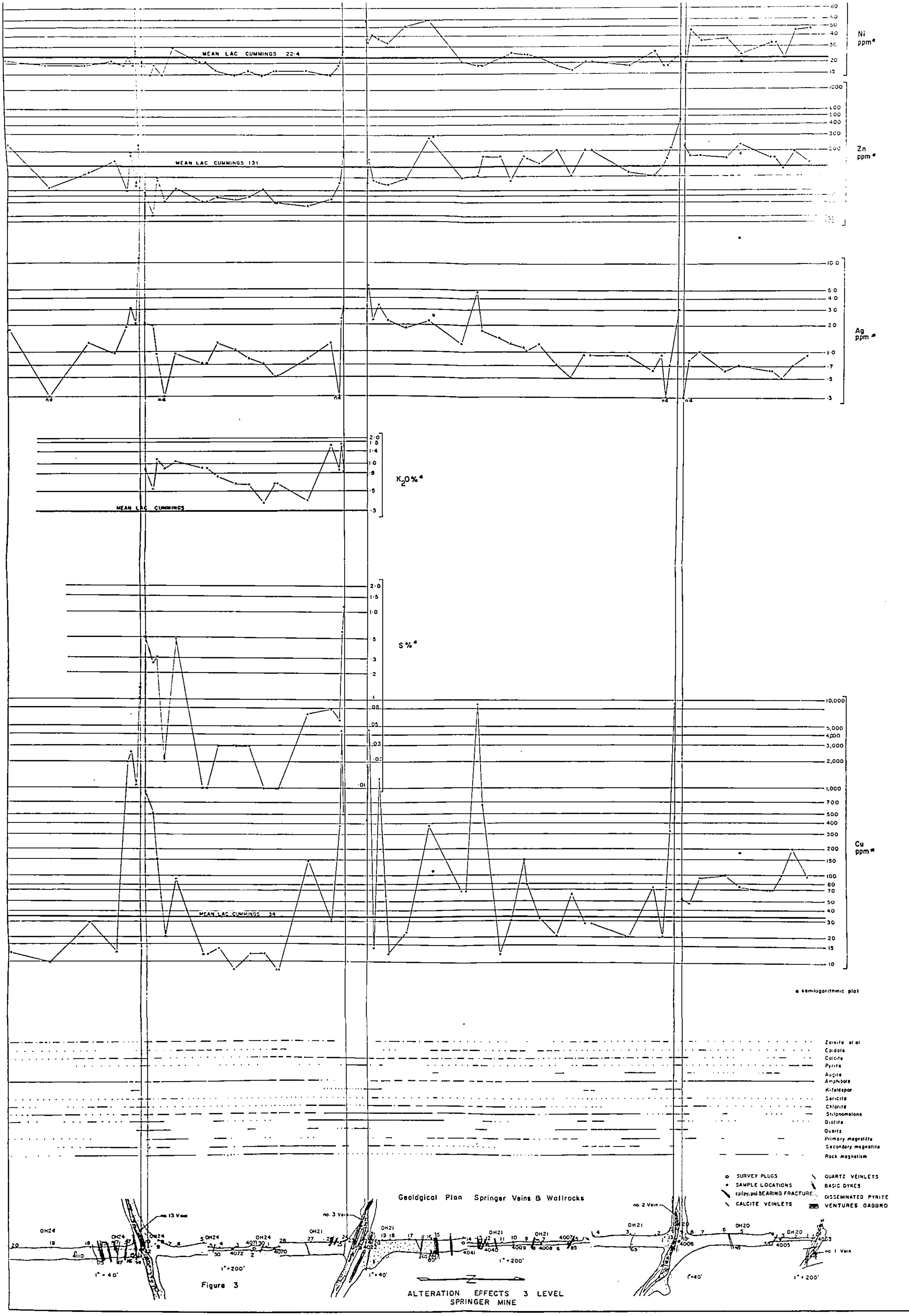
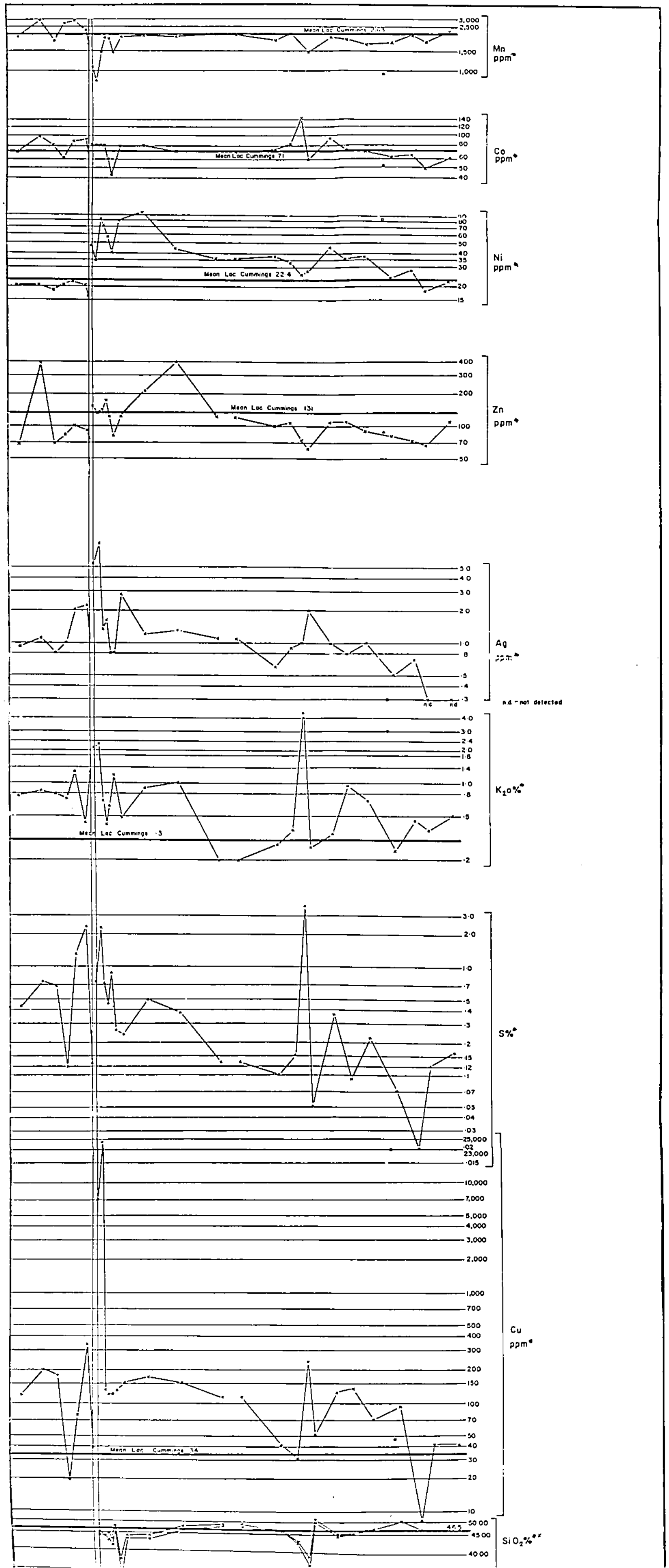
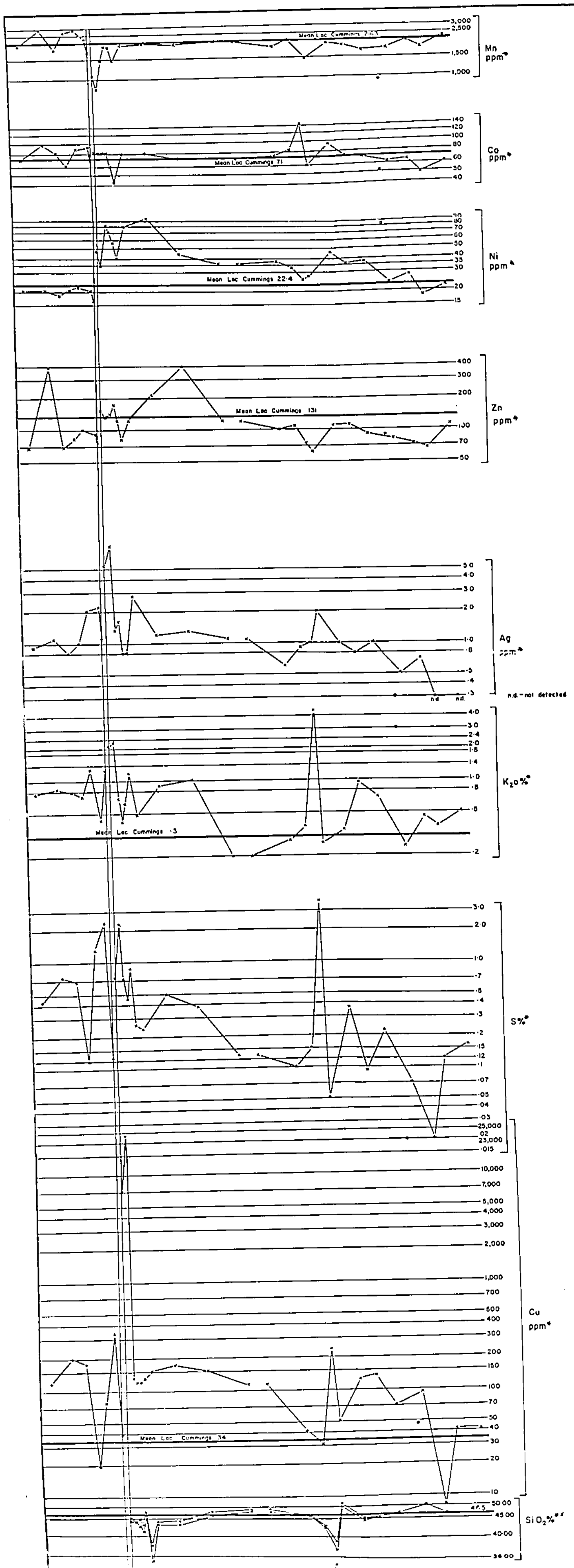


Figure 3

ALTERATION EFFECTS 3 LEVEL
SPRINGER MINE

1 of 1

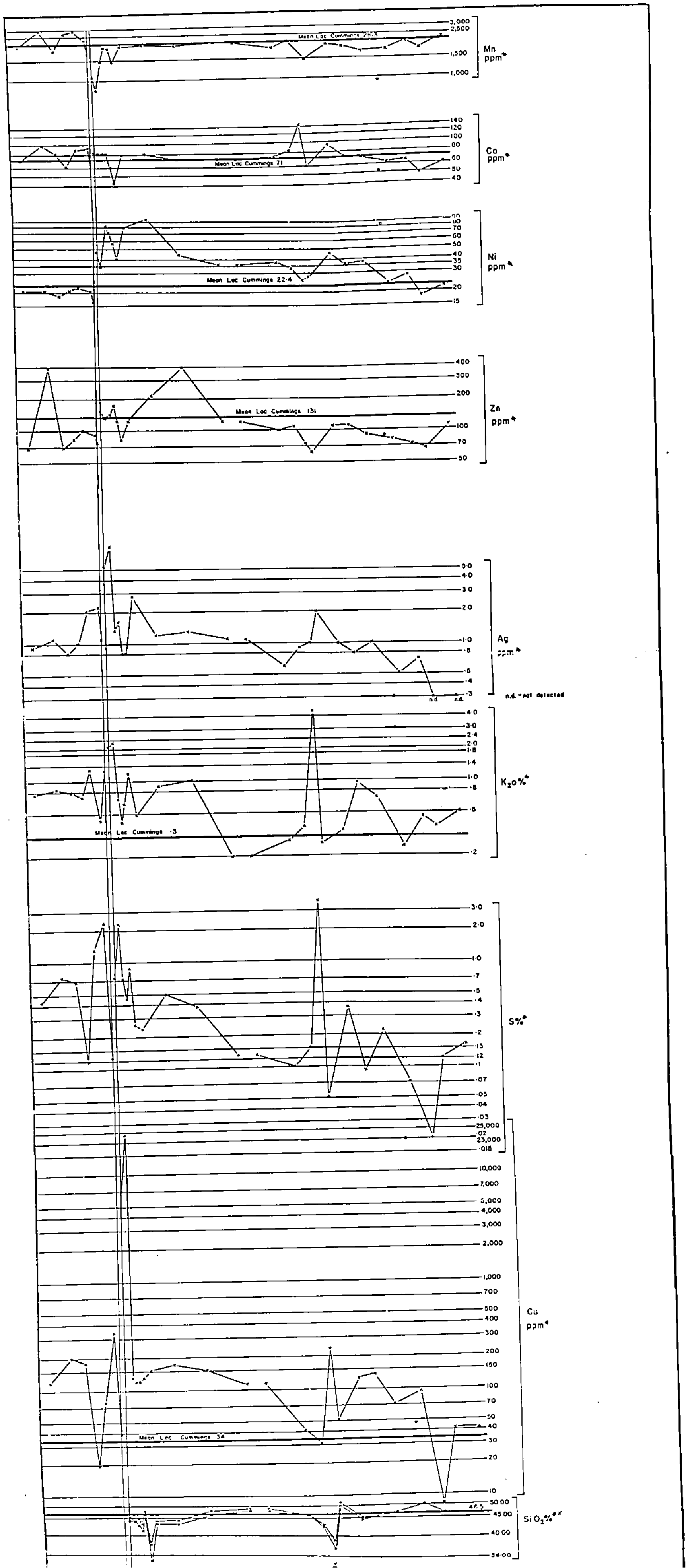

3,000
2,500
1,500
1,000
Mean Lac Cummings
Mn ppm*
140
120
100
80
60
50
40
Mean Lac Cummings 71
Co ppm*
90
80
70
60
50
40
35
30
20
15
Mean Lac Cummings 22·4
Ni ppm*
400
300
200
100
70
50
Mean Lac Cummings 131
Zn ppm*
5·0
4·0
3·0
2·0
1·0
·8
·5
·4
·3
n.d.
n.d.
Ag ppm*
n.d. - not detected
4·0
3·0
2·4
2·0
1·8
1·4
1·0
·8
·5
·2
Mean Lac Cummings ·3
K₂O%*
3·0
2·0
1·0
·7
·5
·4
·3
·2
·15
·12
·1
·07
·05
·04
·03
·02
·015
S%*
25,000
23,000
10,000
7,000
5,000
4,000
3,000
2,000
1,000
700
500
400
300
200
150
100
70
50
40
30
20
10
Mean Lac Cummings 34
Cu ppm*
50.00
45.00
40.00
46.5
SiO₂%**



3,000
2,500
Mean Loc Cummings
1,500
1,000
Mn ppm*
140
120
100
80
60
50
40
Mean Loc Cummings 71
Co ppm*
90
80
70
60
50
40
35
30
Mean Loc Cummings 22·4
20
15
Ni ppm*
400
300
200
Mean Loc Cummings 131
130
70
50
Zn ppm*
5·0
4·0
3·0
2·0
1·0
·8
·5
·4
·3
n.d.
n.d.
Ag ppm*
n.d.–not detected
4·0
3·0
2·4
2·0
1·8
1·4
1·0
·8
·5
Mean Loc Cummings ·3
·2
K2O%*
3·0
2·0
1·0
·7
·5
·4
·3
·2
·15
·12
·1
·07
·05
·04
·03
·02
·015
S%*
25,000
23,000
10,000
7,000
5,000
4,000
3,000
2,000
1,000
700
600
400
300
200
150
100
70
50
40
Mean Loc Cummings 34
30
20
10
Cu ppm*
50·00
46·5
45·00
40·00
36·00
SiO2%**

1 of

1 of



3,000
2,500
1,500
1,000
Mean Loc Cummings
Mn ppm*
140
120
100
80
60
50
40
Mean Loc Cummings 71
Co ppm*
90
80
70
60
50
40
35
30
20
15
Mean Loc Cummings 22·4
Ni ppm*
400
300
200
100
70
50
Mean Loc Cummings 131
Zn ppm*
5·0
4·0
3·0
2·0
1·0
·8
·5
·4
·3
n.d.
n.d.
n.d. = not detected
Ag ppm*
4·0
3·0
2·4
2·0
1·8
1·4
1·0
·8
·5
·2
Mean Loc Cummings ·3
K₂O%*
3·0
2·0
1·0
·7
·5
·4
·3
·2
·15
·12
·1
·07
·05
·04
·03
·02
·015
S%*
25,000
23,000
10,000
7,000
5,000
4,000
3,000
2,000
1,000
700
500
400
300
200
150
100
70
50
40
30
20
10
Mean Loc Cummings 34
Cu ppm*
50·00
47·5
45·00
40·00
36·00
SiO₂%*ˣ

2 of 2

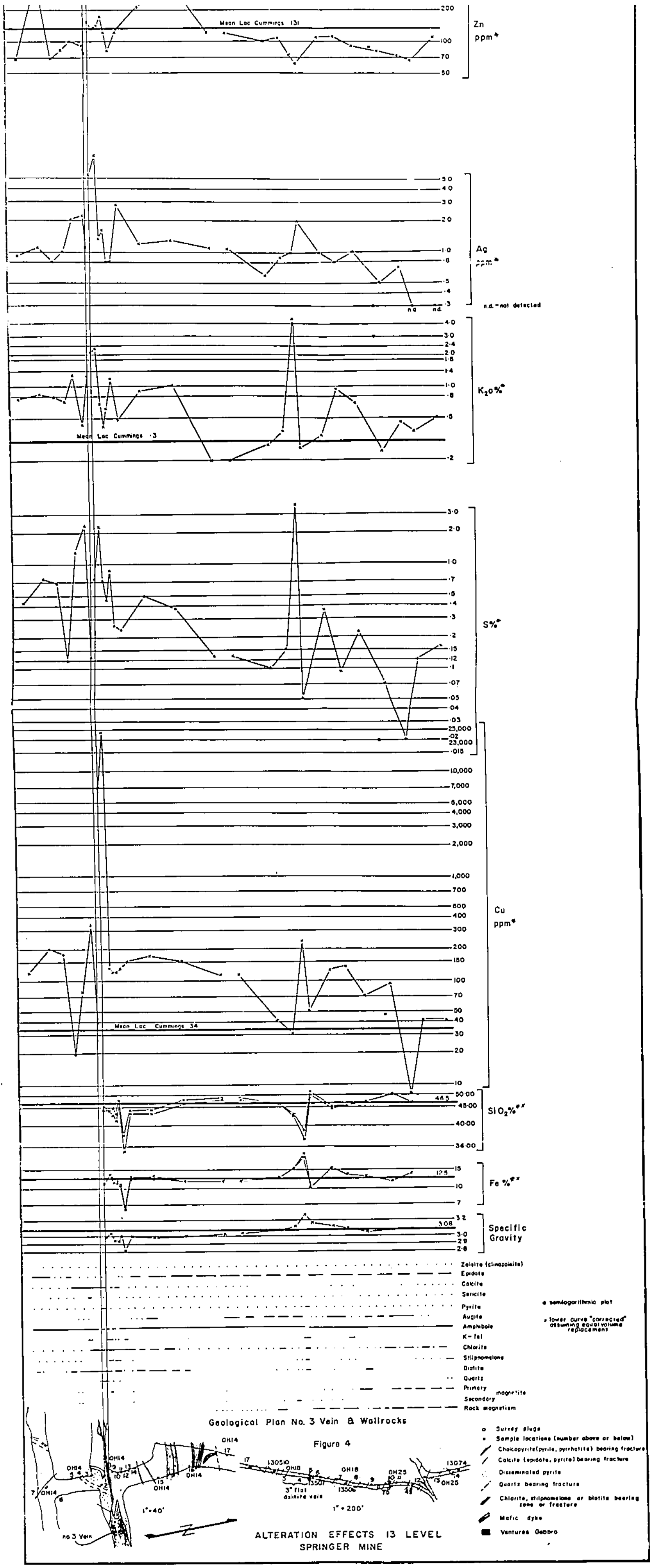
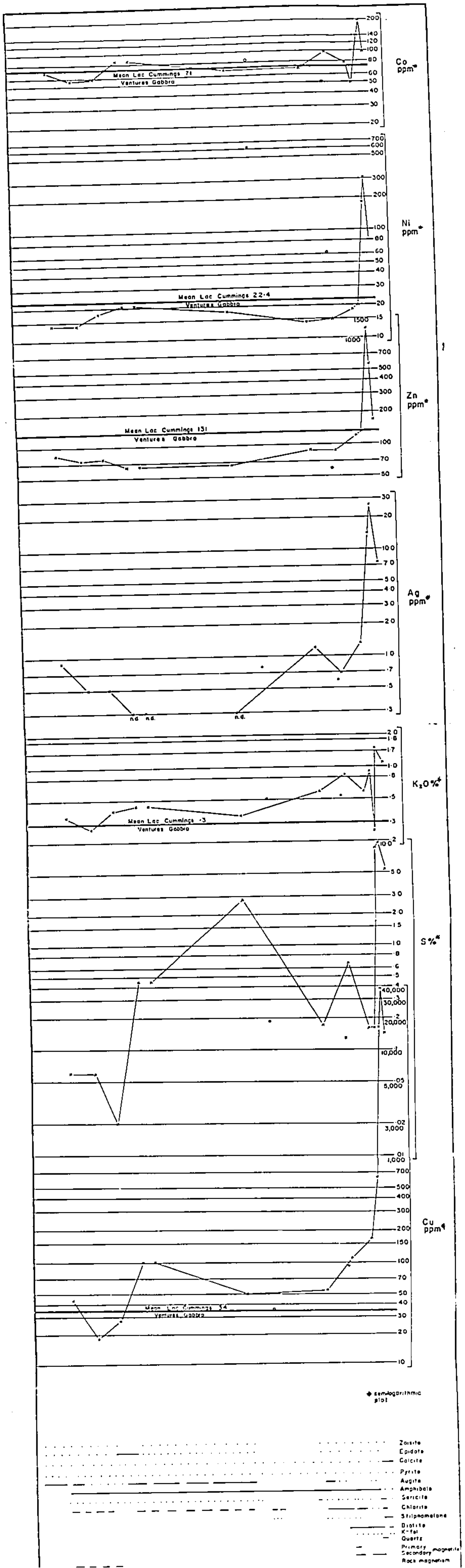


Figure 4

ALTERATION EFFECTS 13 LEVEL
SPRINGER MINE

1 of


Co ppm*
200
140
120
100
80
60
50
40
30
20
Mean Lac Cummings 71
Ventures Gabbro
Ni ppm*
700
600
500
300
200
100
80
60
50
40
30
20
15
10
Mean Lac Cummings 22·4
Ventures Gabbro
Zn ppm*
1500
1000
700
500
400
300
200
100
70
50
Mean Lac Cummings 131
Ventures Gabbro
Ag ppm*
30
20
10
7
5
4
3
2
1
·7
·5
·3
n.d.
n.d.
n.d.
K₂O%*
2·0
1·8
1·7
1·0
·8
·5
·3
Mean Lac Cummings ·3
Ventures Gabbro
S%*
100
50
30
20
15
10
8
6
5
4
·3
·2
·1
·05
·02
·01
40,000
30,000
20,000
10,000
5,000
3,000
1,000
Cu ppm*
700
500
400
300
200
150
100
70
50
40
30
20
10
Mean Lac Cummings 34
Ventures Gabbro
* semilogarithmic plot
Zoisite
Epidote
Calcite
Pyrite
Augite
Amphibole
Sericite
Chlorite
Stilpnomelane
Biotite
K-fel
Quartz
Primary magnetite
Secondary magnetite
Rock magnetism

2 of 2

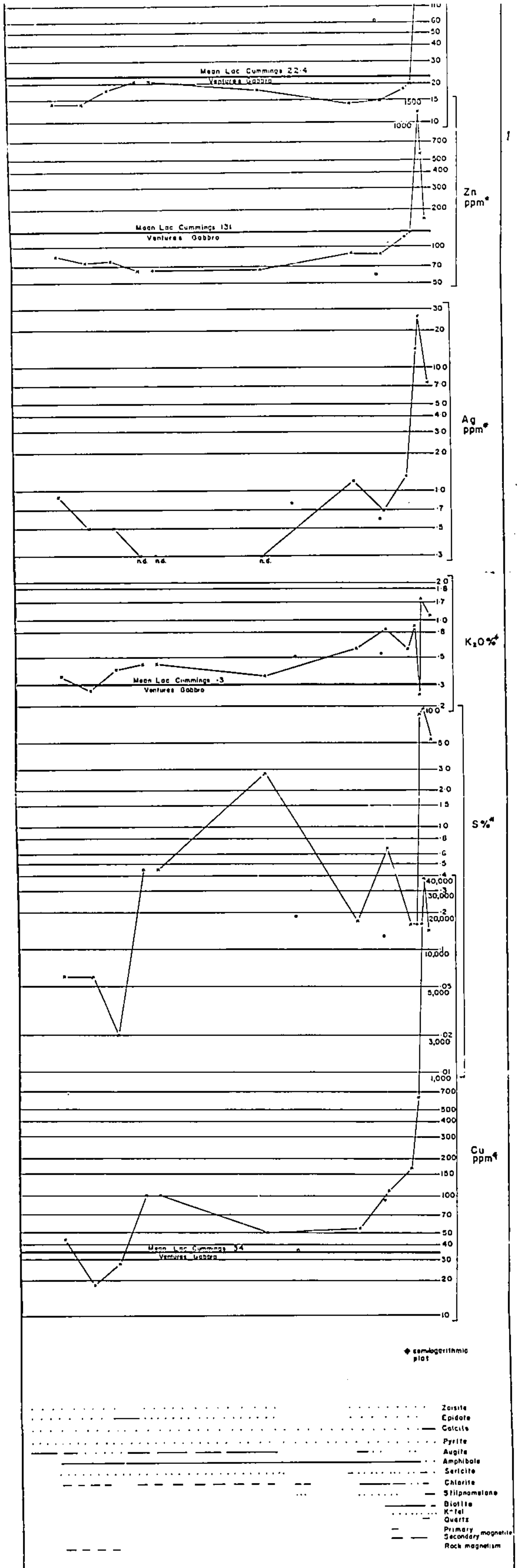
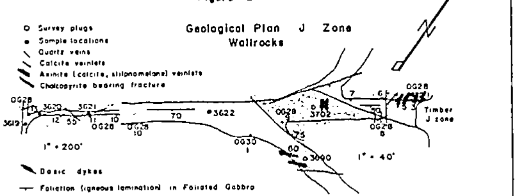


Figure 5



ALTERATION EFFECTS IN FOLIATED GABBRO ADJACENT J ZONE, 3 LEVEL PERRY MINE

1 of 1

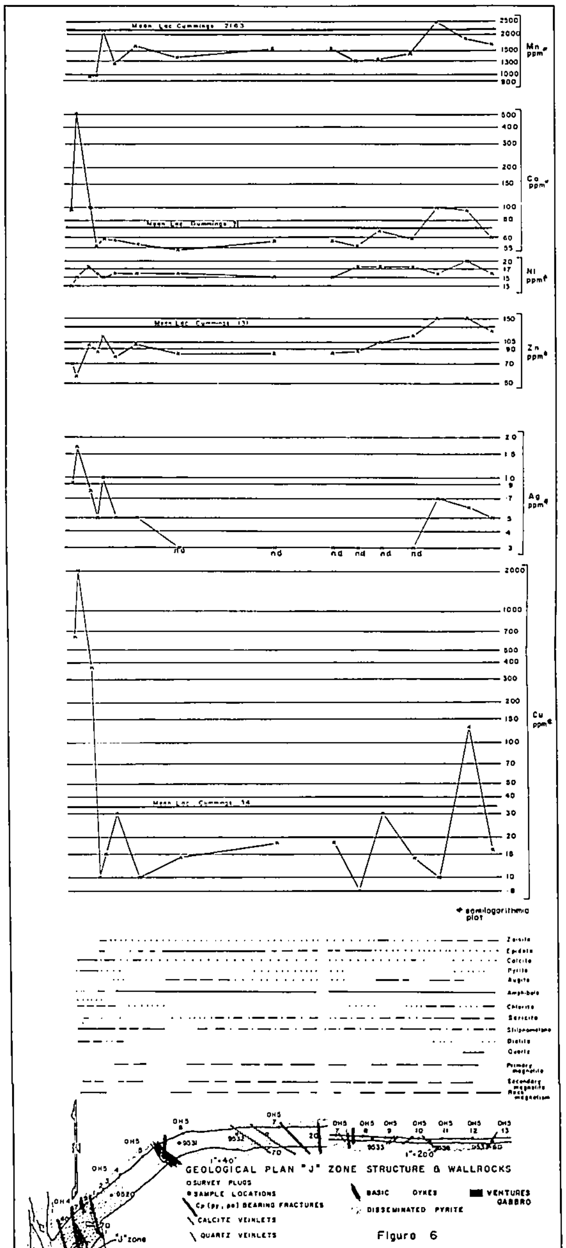
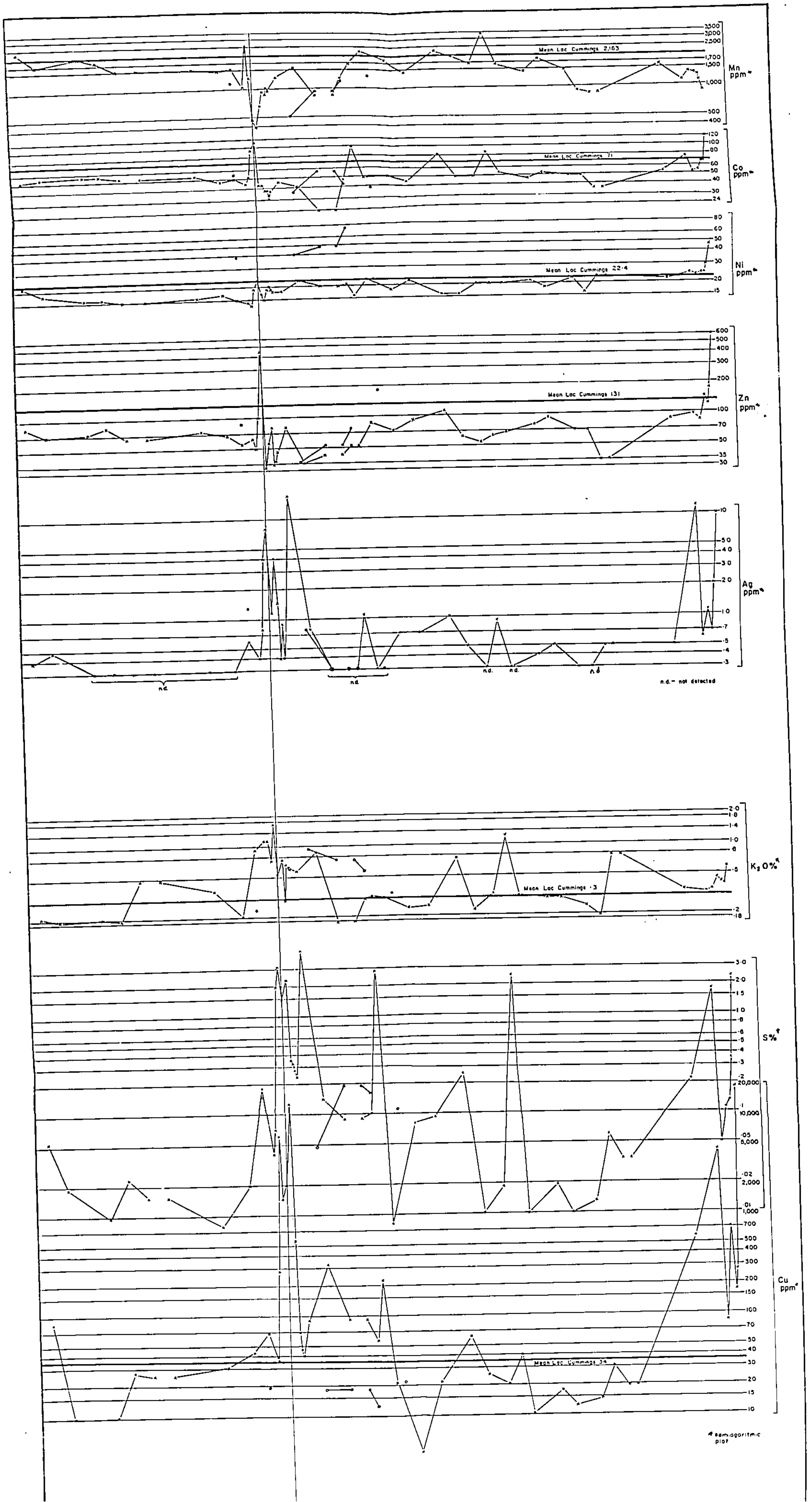
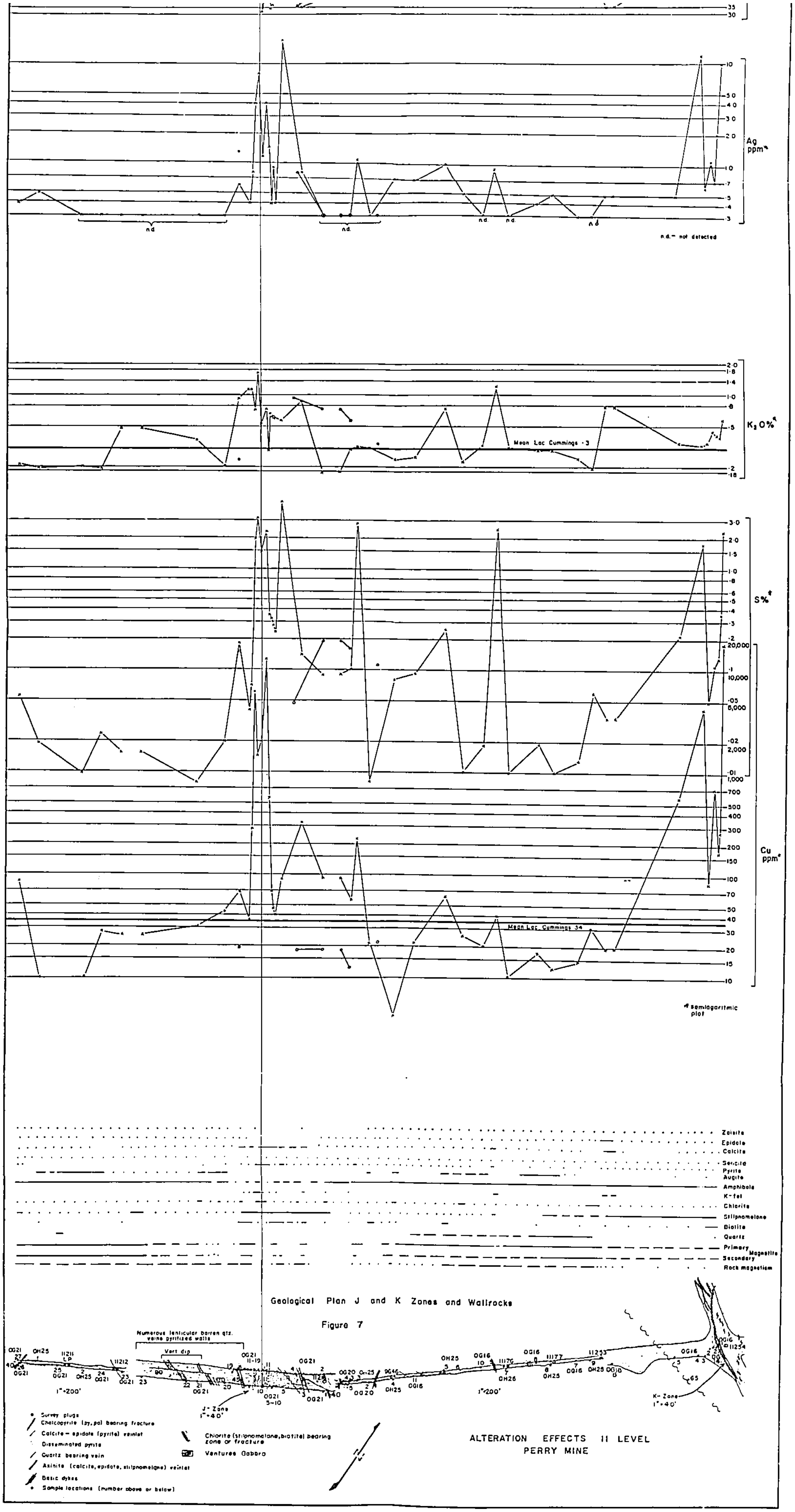


Figure 6

ALTERATION EFFECTS 9 LEVEL
PERRY MINE

1of


Mean Lac Cummings 2,163
3,500
3,000
2,500
1,700
1,500
1,000
500
400
Mn ppm*
Mean Lac Cummings 71
120
100
80
60
50
40
30
24
Co ppm*
80
60
50
40
30
Mean Lac Cummings 22·4
20
15
Ni ppm*
600
500
400
300
200
Mean Lac Cummings 131
100
70
50
35
30
Zn ppm*
10
5.0
4.0
3.0
2.0
1.0
·7
·5
·4
·3
Ag ppm*
n.d.
n.d.
n.d.
n.d.
n.d.
n.d. – not detected
2·0
1·8
1·4
1·0
·8
·5
Mean Lac Cummings ·3
·2
·18
K₂O%*
3·0
2·0
1·5
1·0
·8
·6
·5
·4
·3
·2
·1
·05
·02
·01
S%*
20,000
10,000
5,000
2,000
1,000
700
500
400
300
200
150
100
70
50
40
30
Mean Lac Cummings 34
20
15
10
Cu ppm*
* semi-logarithmic plot



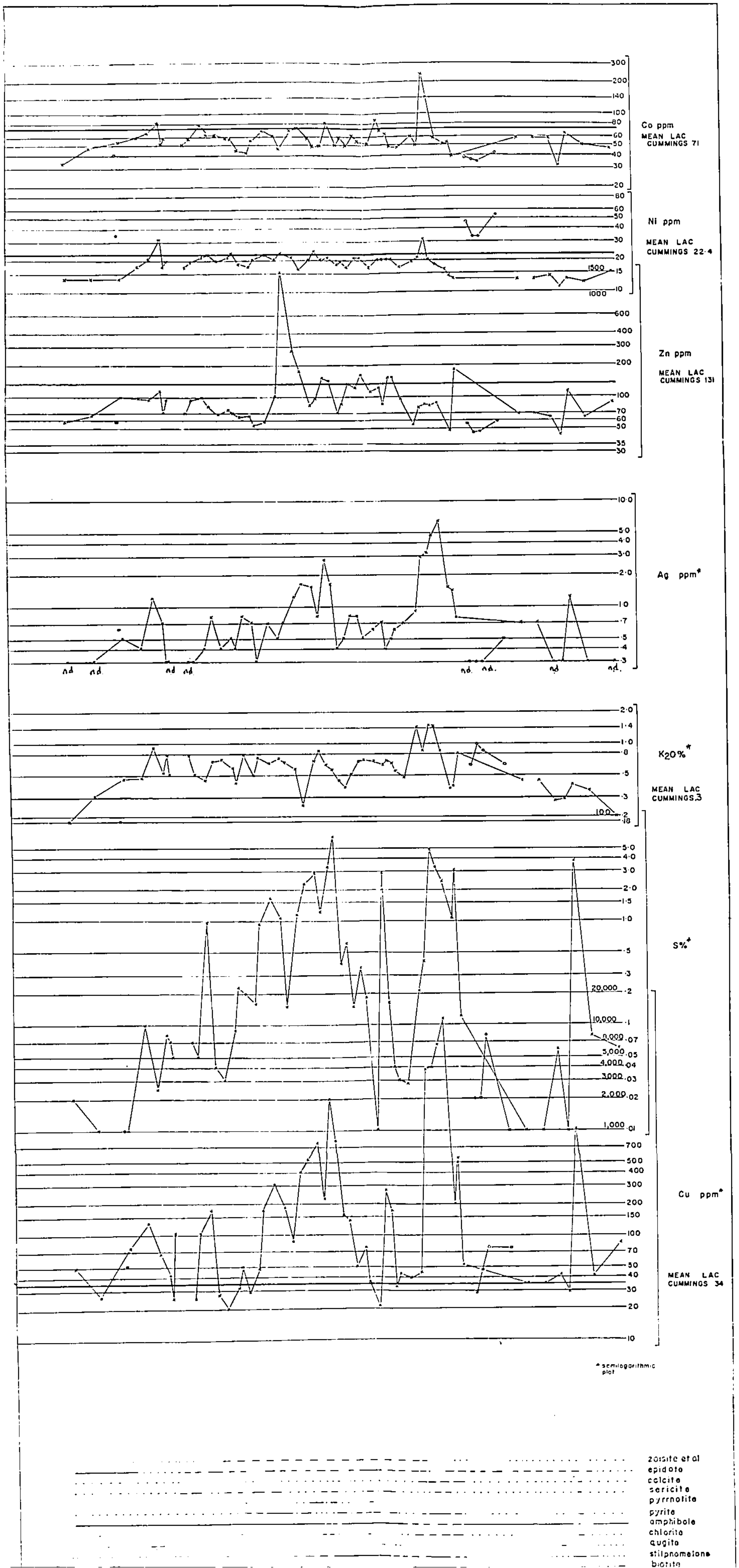
Geological Plan J and K Zones and Wallrocks

Figure 7

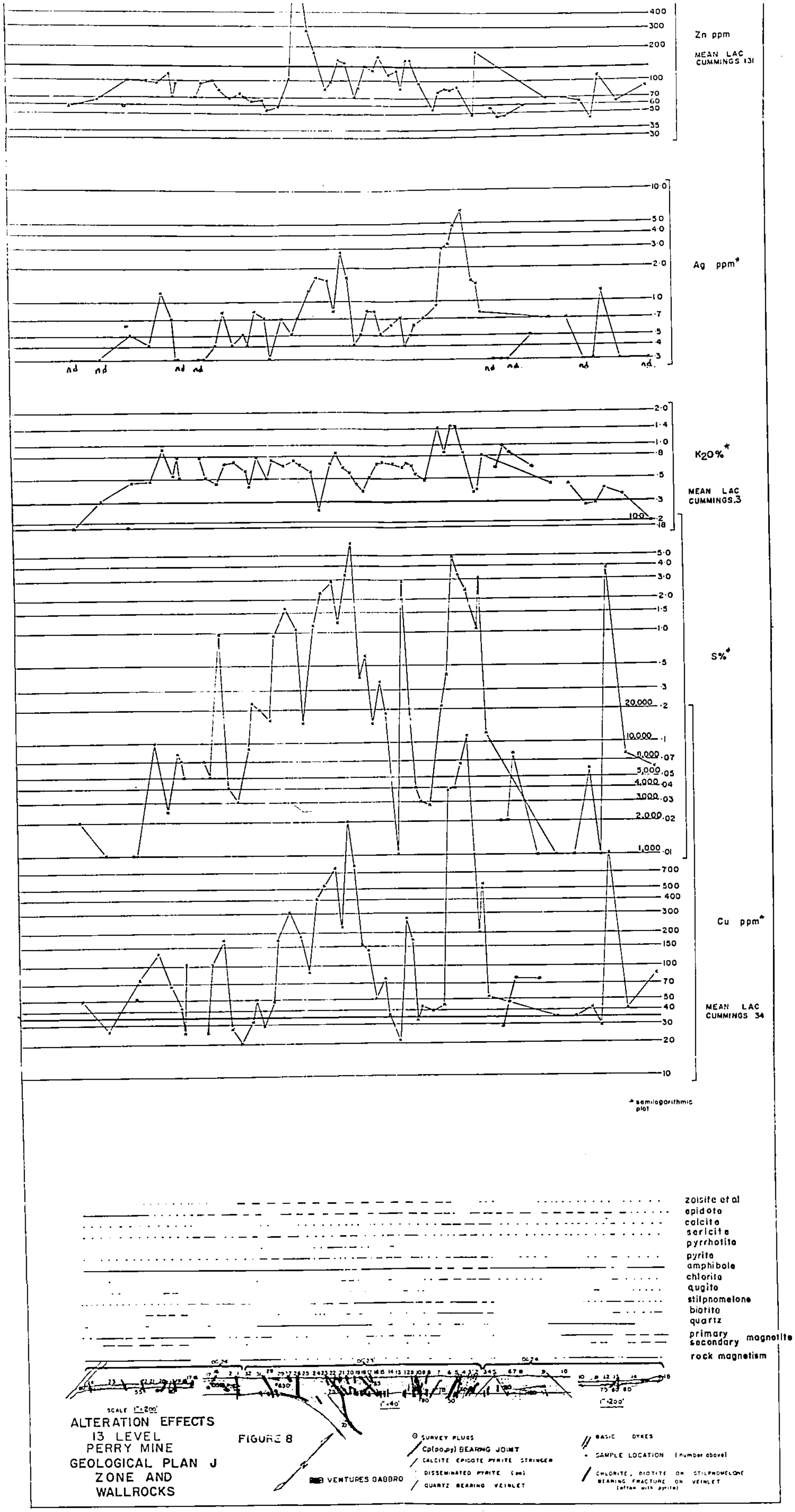
ALTERATION EFFECTS 11 LEVEL
PERRY MINE

2 of 2

1 of



300
200
140
100
80
60
50
40
30
20
Co ppm
MEAN LAC CUMMINGS 71
80
60
50
40
30
20
15
10
Ni ppm
MEAN LAC CUMMINGS 22·4
1500
1000
600
400
300
200
100
70
60
50
35
30
Zn ppm
MEAN LAC CUMMINGS 131
10·0
5·0
4·0
3·0
2·0
1·0
·7
·5
·4
·3
nd
nd
nd
nd
nd.
nd.
nd
nd.
Ag ppm*
2·0
1·4
1·0
·8
·5
·3
·2
K2O%*
MEAN LAC CUMMINGS.3
100
·10
5·0
4·0
3·0
2·0
1·5
1·0
·5
·3
·2
·1
·07
·05
·04
·03
·02
·01
S%*
20,000
10,000
9,000
5,000
4,000
3,000
2,000
1,000
700
500
400
300
200
150
100
70
50
40
30
20
10
Cu ppm*
MEAN LAC CUMMINGS 34
* semilogarithmic plot
zoisite et al
epidote
calcite
sericite
pyrrhotite
pyrite
amphibole
chlorite
augite
stilpnomelane
biotite

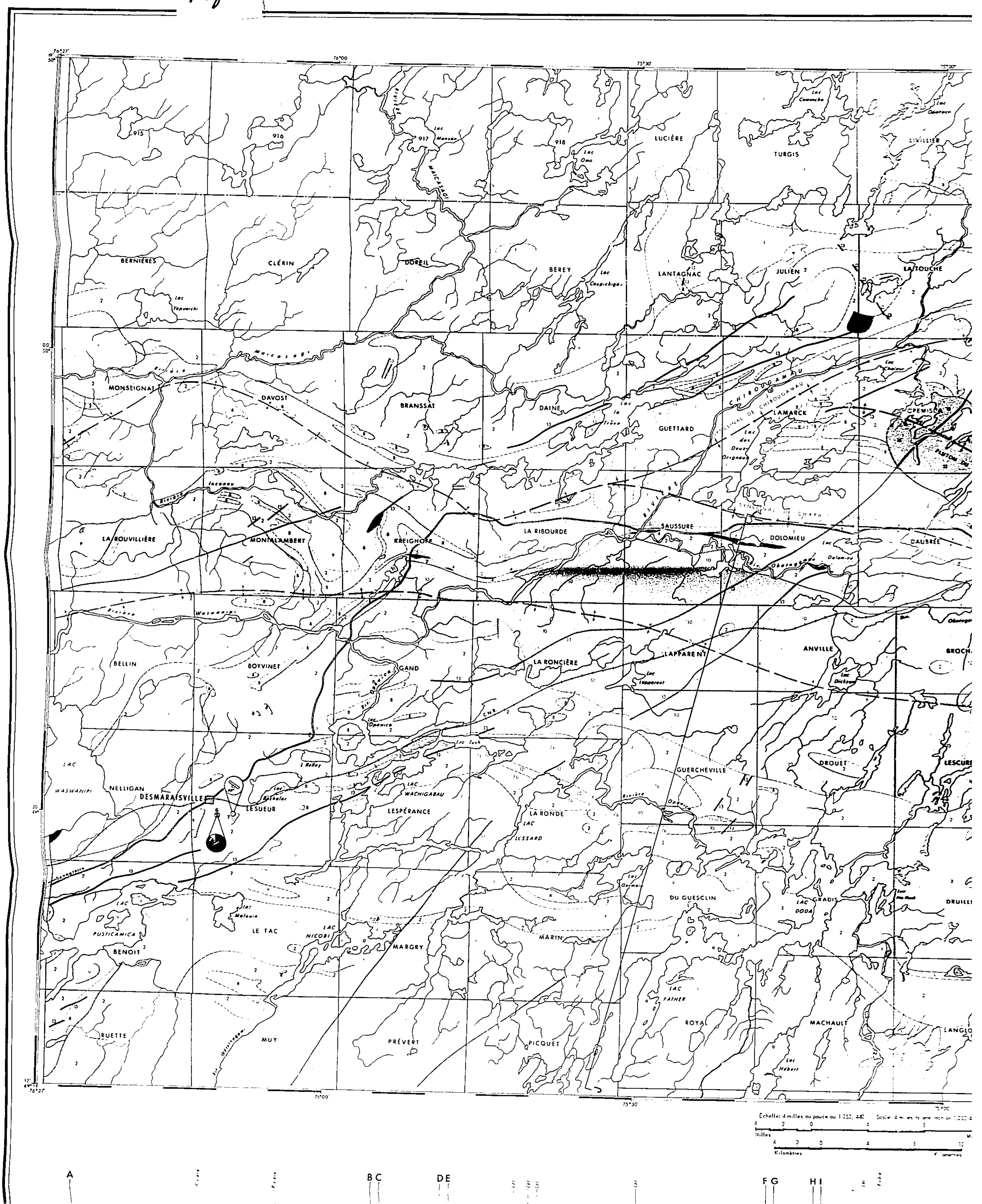


ALTERATION EFFECTS
13 LEVEL
PERRY MINE
GEOLOGICAL PLAN J
ZONE AND
WALLROCKS

FIGURE 8

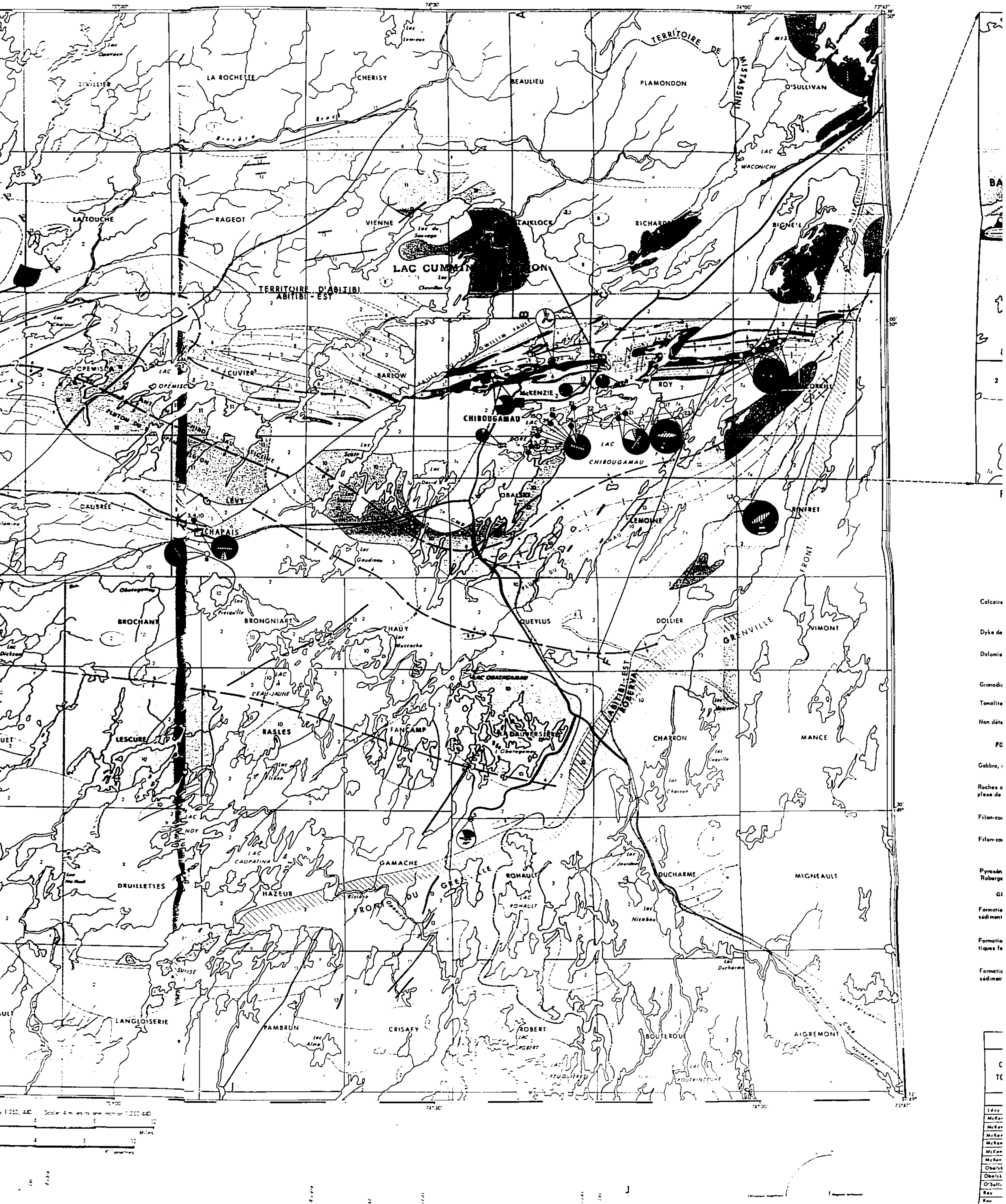
2 of 2

1 of

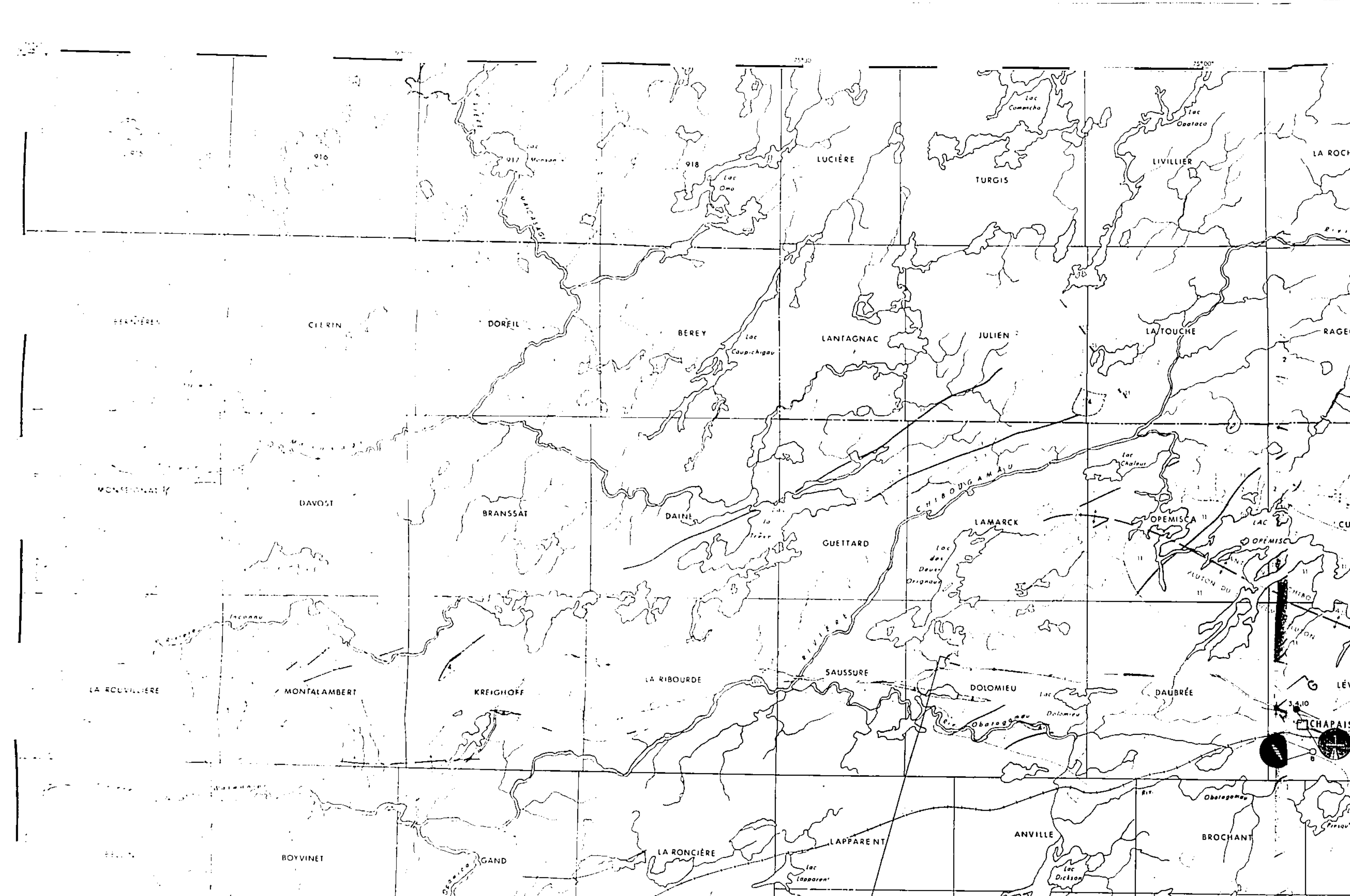

76°27'
49°50'
76°00
75°30'
915
916
917
918
Lac Mansan
MAICASAGI
Lac Omo
LUCIÈRE
TURGIS
Lac Comencho
Lac Opataca
BERNIÈRES
CLÉRIN
DOREIL
BEREY
Lac Caupichigau
LANTAGNAC
JULIEN
LA TOUCHE
Lac Yapwaichi
Maicasagi
Rivière
MONSEIGNAT
DAVOST
BRANSSAT
DAINE
Lac la Trêve
GUETTARD
LAMARCK
Lac des Deux Orignaux
CHIBOUGAMAU
SYNCLINAL DE CHIBOUGAMAU
OPEMISCA
PLUTON DU
Lac Chaleur
Rivière Inconnu
LA ROUVILLIÈRE
MONTALAMBERT
KREIGHOFF
LA RIBOURDE
SAUSSURE
DOLOMIEU
Lac Dolomieu
CAUBRÉE
SYNCLINAL DE CHAPAIS
Riv. Obatogamau
Rivière Waswanipi
BELLIN
BOYVINET
GAND
Riv. Opawica
LA RONCIÈRE
LAPPARENT
Lac Lapparent
ANVILLE
Lac Dickson
BROCHANT
Lac Opawica
Lac Tush
CNR
L. Bailey
LAC WASWANIPI
NELLIGAN
DESMARAISVILLE
LESUEUR
Lac Bachelor
LAC WACHIGABAU
LESPÉRANCE
LA RONDE
LAC L'ESSARD
Rivière Opawica
GUERCHEVILLE
DROUET
LESCURE
Rivière Sunnyvale
LAC PUSTICAMICA
Lac Malouin
LE TAC
LAC NICOBI
MARGRY
MARIN
Lac Germain
DU GUESCLIN
LAC DODA
GRADIS
DRUILLETTES
BENOIT
RUETTE
Riv. Wetetnagami
MUY
PRÉVERT
PICQUET
LAC FATHER
ROYAL
MACHAULT
LANGLOIS
Lac Hébert
49°15'
76°27'
75°00'
75°30'
75°00'
Échelle: 4 milles au pouce ou 1:253, 440
Scale: 4 miles to one inch or 1:253 440
Milles
Kilomètres
A
B C
D E
F G
H I

MINISTÈRE DES RICHESSES NATURELLES — DEPARTMENT OF NATURAL RESOURCES

DIRECTION GÉNÉRALE DES MINES — MINES BRANCH



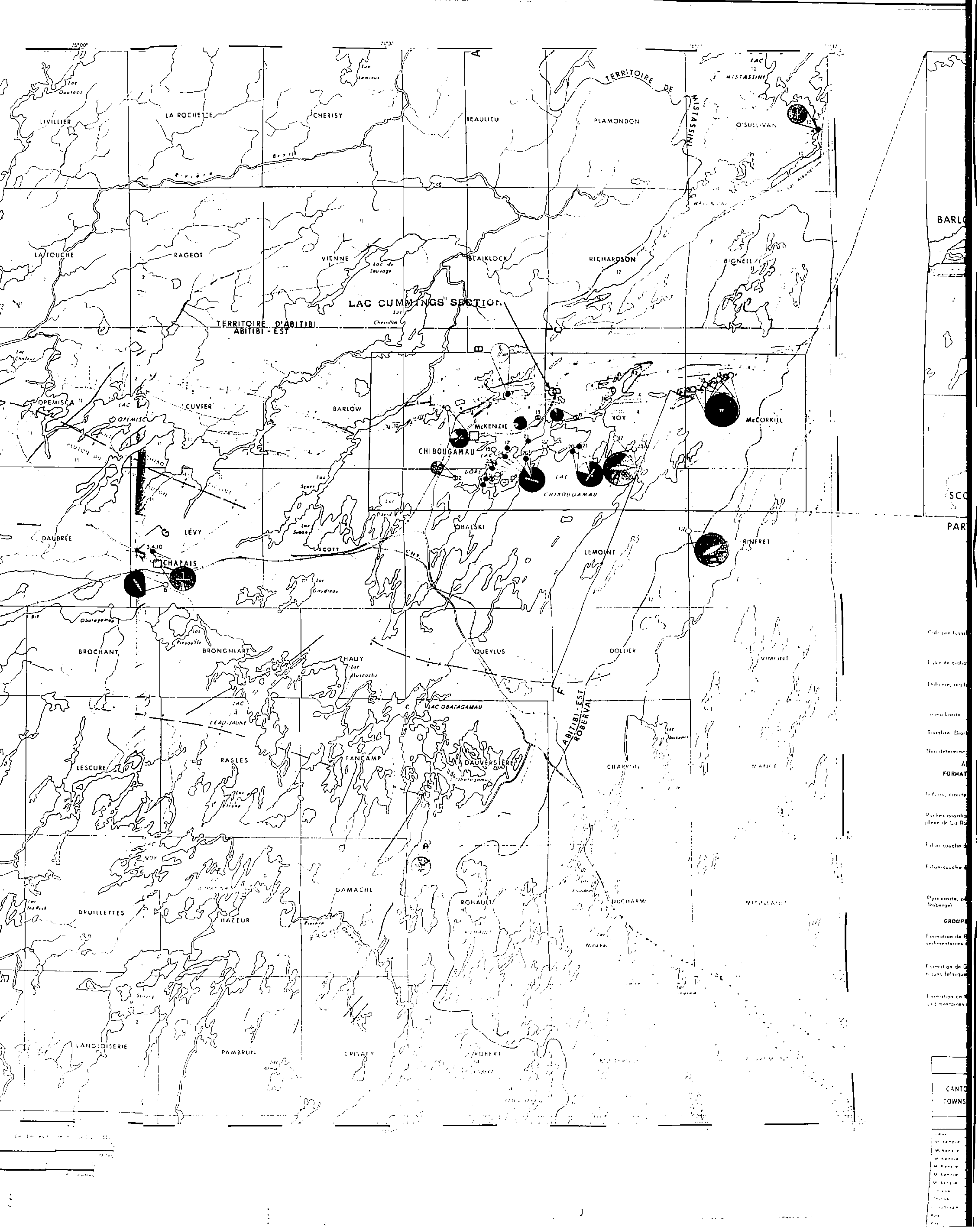
1 of



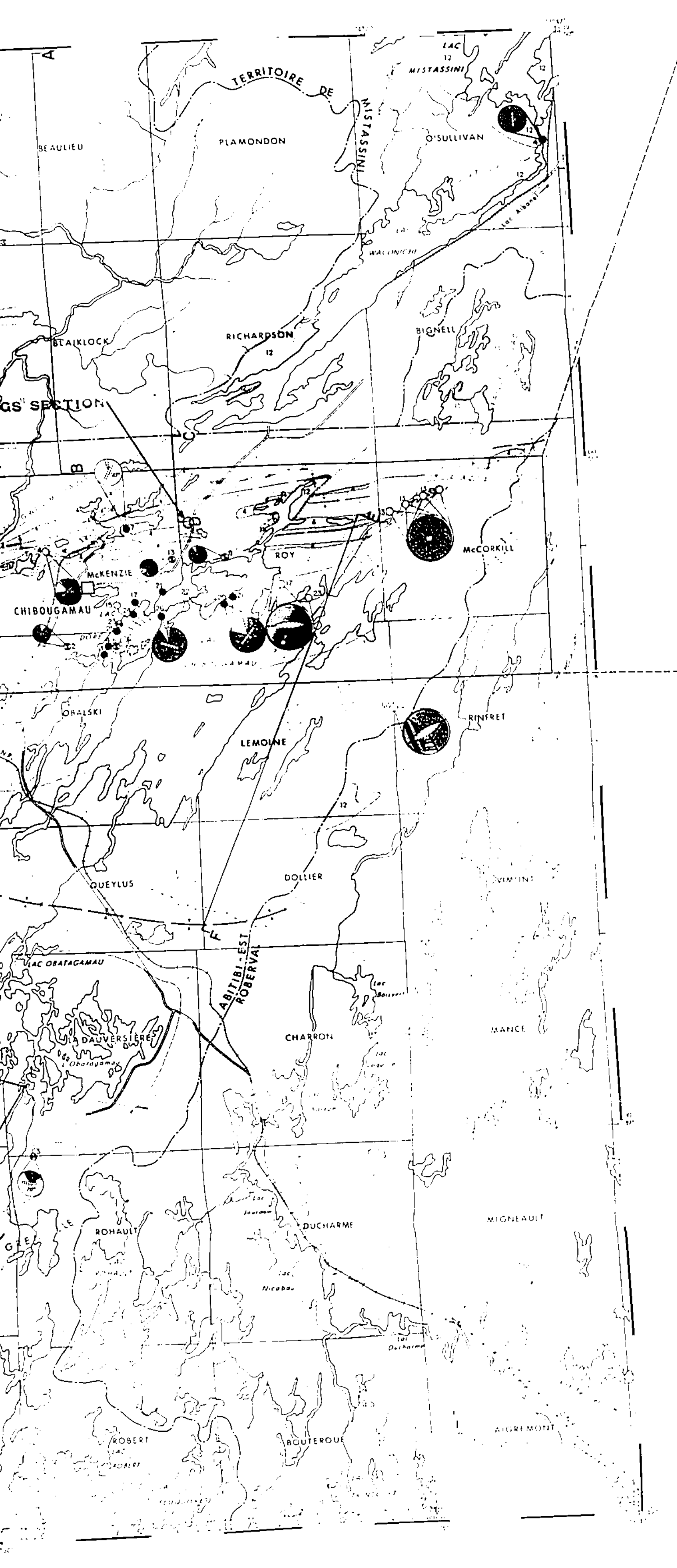
A BC DE FG HI

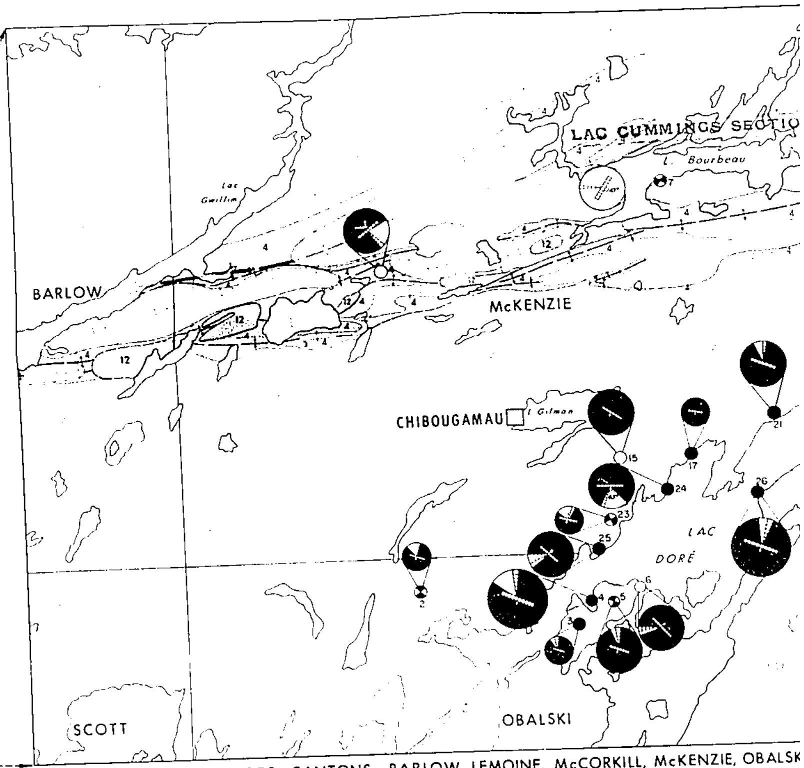
MINISTÈRE DES RICHESSES NATURELLES
DIRECTION GÉNÉRALE DES MINES

DEPARTMENT OF NATURAL RESOURCES
MINES BRANCH



2 of





PARTIE AGRANDIE DES CANTONS BARLOW, LEMOINE, McCORKILL, McKENZIE, OBALSK

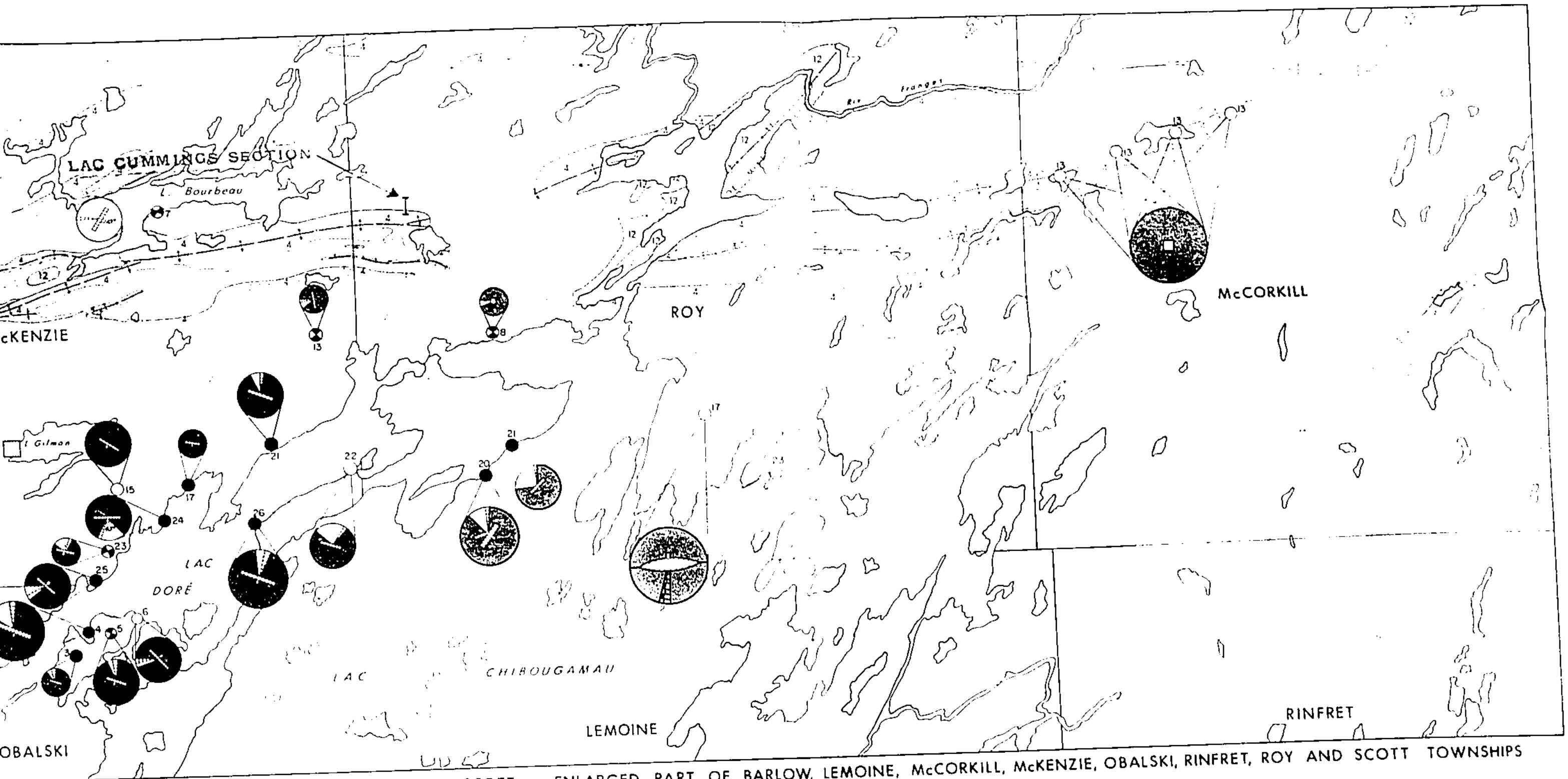
LÉGENDE – LEGEND

PALÉOZOÏQUE **ORDOVICIEN SUPÉRIEUR**		**PALEOZOIC** **LATE ORDOVICIAN**
Calcaire fossilifère	▨	Fossiliferous limestone
PRECAMBRIEN **PROTEROZOIQUE**		**PRECAMBRIAN** **PROTEROZOIC**
Dyke de diabase		Diabase dyke
Dolomie, argile, grès, conglomerat	12	Dolomite, siltstone, sandstone, conglomerate
ARCHEEN **ASSEMBLAGE GRANITIQUE**		**ARCHEAN** **GRANITIC ASSEMBLAGE**
Granodiorite		Granodiorite
Tonalite, Diorite		Tonalite, Diorite
Non déterminé		Undetermined
ASSEMBLAGE DE ROCHES VERTES **FORMATIONS INTRUSIVES** MAFIQUES		**GREENSTONE ASSEMBLAGE** **INTRUSIVE FORMATIONS** MAFICS
Gabbro, diorite		Gabbro, diorite
Roches anorthositiques: (7a) complexe de Lac Doré, (7b) complexe de La Ronde, (7c) complexe de Lac Michwacho		Anorthositic rocks: (7a) Lac Doré complex, (7b) La Ronde complex, (7c) Lac M[illegible] complex
Filon couche de Bourbeau		Bourbeau sill
Filon couche de Ventures		Ventures sill
ULTRAMAFIQUES		ULTRAMAFICS
Pyroxénite, péridotite et dunite serpentinisées (Filon couche de Roberge)	1	Pyroxenite, serpentinized peridotite and dunite (Roberge sill)
GROUPE DE ROY (volcanites et roches sedimentaires)		**ROY GROUP (volcanic and sedimentary rocks)**
Formation de Blondeau: roches pyroclastiques felsiques et roches sedimentaires associées, un peu de laves mafiques		Blondeau Formation: felsic pyroclastic and related sedimentary rocks, minor mafic lavas
Formation de Gilman: laves mafiques, un peu de roches pyroclastiques felsiques		Gilman Formation: mafic lavas, minor felsic pyroclastics
Formation de Waconichi: roches pyroclastiques felsiques et roches sedimentaires associées, laves mafiques dans le quart inférieur		Waconichi Formation: felsic pyroclastics and related sedimentary rocks, mafic lavas in the bottom quarter

╲ LAC CUMMINGS SECTION

TABLEAU DE

CANTON TOWNSHIP	NUMERO NUMBER •	NOM DE LA MINE NAME OF THE MINE	PR DEBUT START	 ARRÊT END	 TONNAGE	
		PRODUCTEURS – PRODUCERS 1969				
[illegible]	1,4,10	[illegible]EMISKA COPPER MINES [illegible]	[illegible]		[illegible]	[illegible]
McKenzie	[illegible]	THE PATINO MINING CORPORATION [illegible]	[illegible]		[illegible]	[illegible]
McKenzie	[illegible]	THE PATINO MINING CORPORATION [illegible]	[illegible]		[illegible]	[illegible]
McKenzie	[illegible]	CAMPBELL CHIBOUGAMAU MINES LTD. [illegible]	[illegible]		[illegible]	[illegible]
McKenzie	[illegible]	CAMPBELL CHIBOUGAMAU MINES LTD. [illegible]	[illegible]		[illegible]	[illegible]
McKenzie	[illegible]	THE PATINO MINING CORPORATION [illegible]	[illegible]		[illegible]	[illegible]
McKenzie	[illegible]	THE PATINO MINING CORPORATION [illegible]	[illegible]		[illegible]	[illegible]
[illegible]	1	[illegible] KAYRAND COPPER MINES LTD.	[illegible]		[illegible]	[illegible]
[illegible]	4	CAMPBELL CHIBOUGAMAU MINES LTD. [illegible] Mine)	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible] SULLIVAN [illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	CAMPBELL CHIBOUGAMAU MINES LTD. (Henderson)	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	THE PATINO MINING CORPORATION [illegible]	[illegible]		[illegible]	[illegible]
		ANCIENS PRODUCTEURS – FORMER PRODUCERS				
[illegible]	[illegible]	THE [illegible] MINES LTD.	[illegible]	[illegible]	[illegible]	[illegible]



OINE, McCORKILL, McKENZIE, OBALSKI, RINFRET, ROY ET SCOTT — ENLARGED PART OF BARLOW, LEMOINE, McCORKILL, McKENZIE, OBALSKI, RINFRET, ROY AND SCOTT TOWNSHIPS

LEOZOIC
ORDOVICIAN

CAMBRIAN
OTEROZOIC

ARCHEAN
TIC ASSEMBLAGE

TONE ASSEMBLAGE
TIONS

Doré complex, (7b) La Ronde
complex

TRAMAFICS

peridotite and dunite (Roberge sill)

(volcanic and sedimentary rocks)

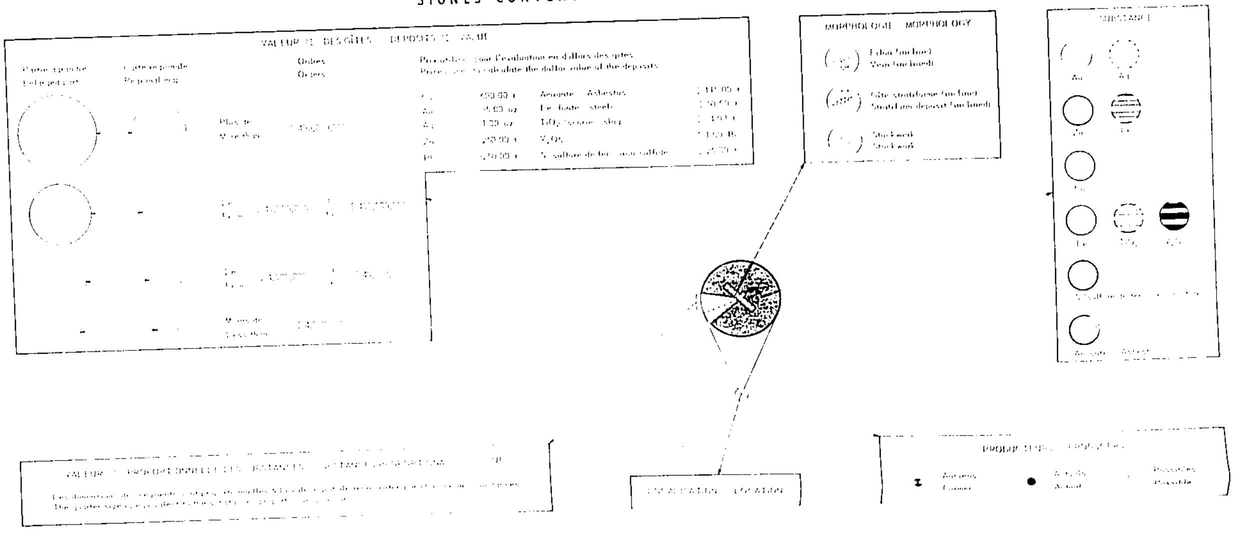
pyroclastic and related sedimentary

flows, minor felsic pyroclastics

felsic pyroclastics and related sedimentary
Cotton quarter

GS SECTION

SIGNES CONVENTIONNELS — SYMBOLS



Procédure pour l'évaluation en dollars des gîtes
Procedure to calculate the dollar value of the deposits

[illegible]	400.00 t	Amiante — Asbestos	[illegible]
Au	35.00 oz	Fe fonte — steel	[illegible]
Ag	1.20 oz	TiO2 scorie — slag	[illegible]
Zn	220.00 t	V_2O_5	[illegible]
[illegible]	250.00 t	S sulfure de fer — iron sulfide	[illegible]

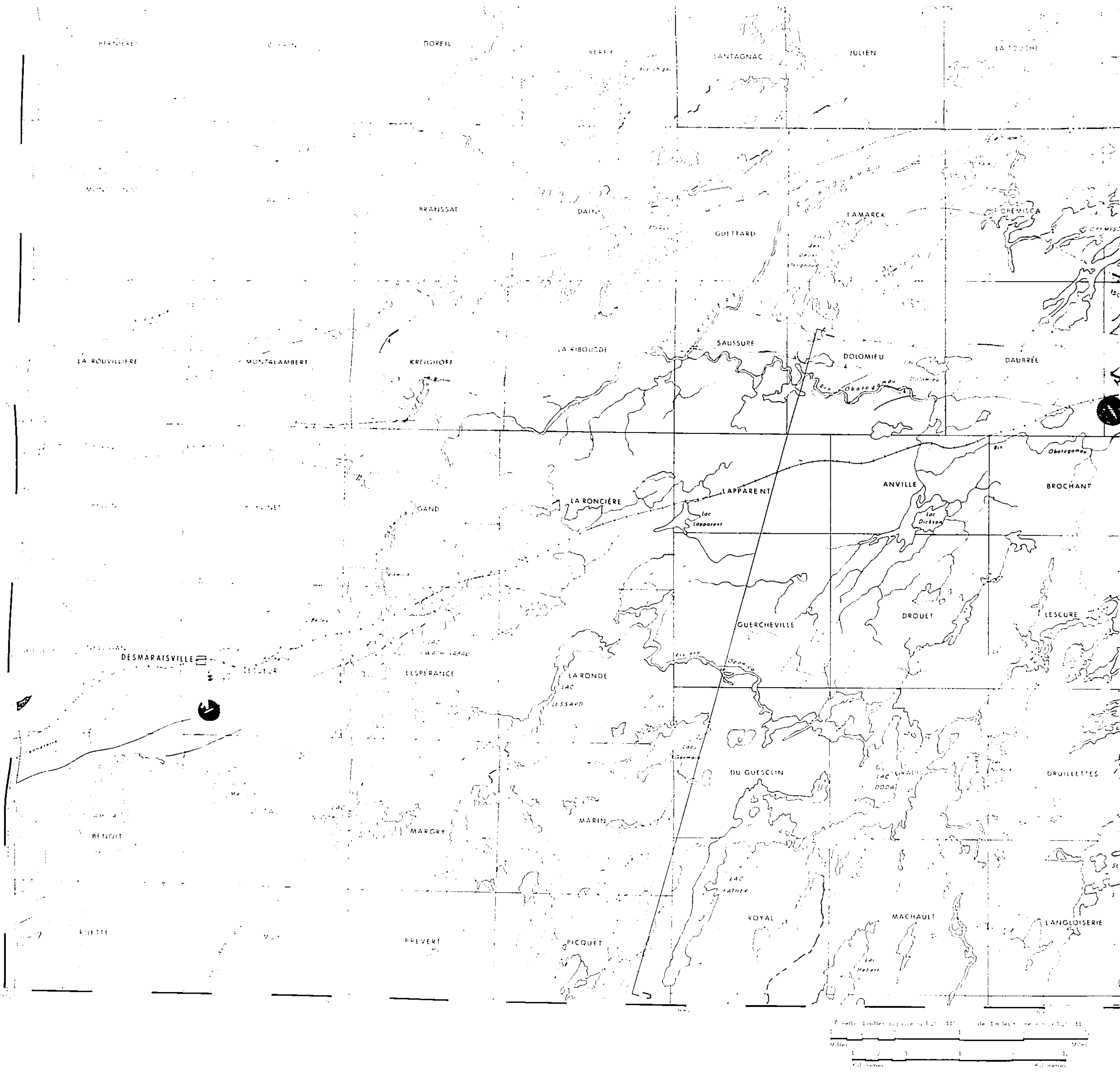
TABLEAU DE STATISTIQUES MINERALES IMPORTANTES — TABLE OF IMPORTANT MINERAL STATISTICS

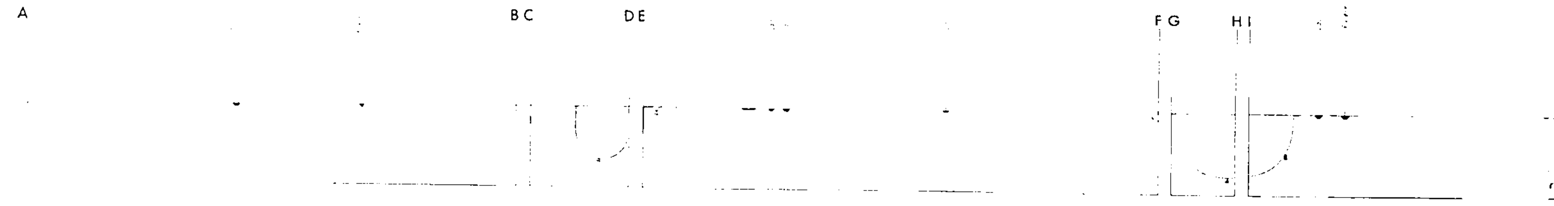
TONNAGE ET TENEUR — TONNAGE AND GRADE

PRODUCTION						RESERVES			TOTAL (PRODUCTION ET AND RESERVES)		SOURCE
DEBUT START m a y	ARRÊT END m a y	TONNAGE	TENEUR — GRADE	TAUX RATE T j — T d	EN DATE DE AS OF m a y	TONNAGE	TENEUR — GRADE	EN DATE DE AS OF	TONNAGE	TENEUR — GRADE	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ODUCERS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]





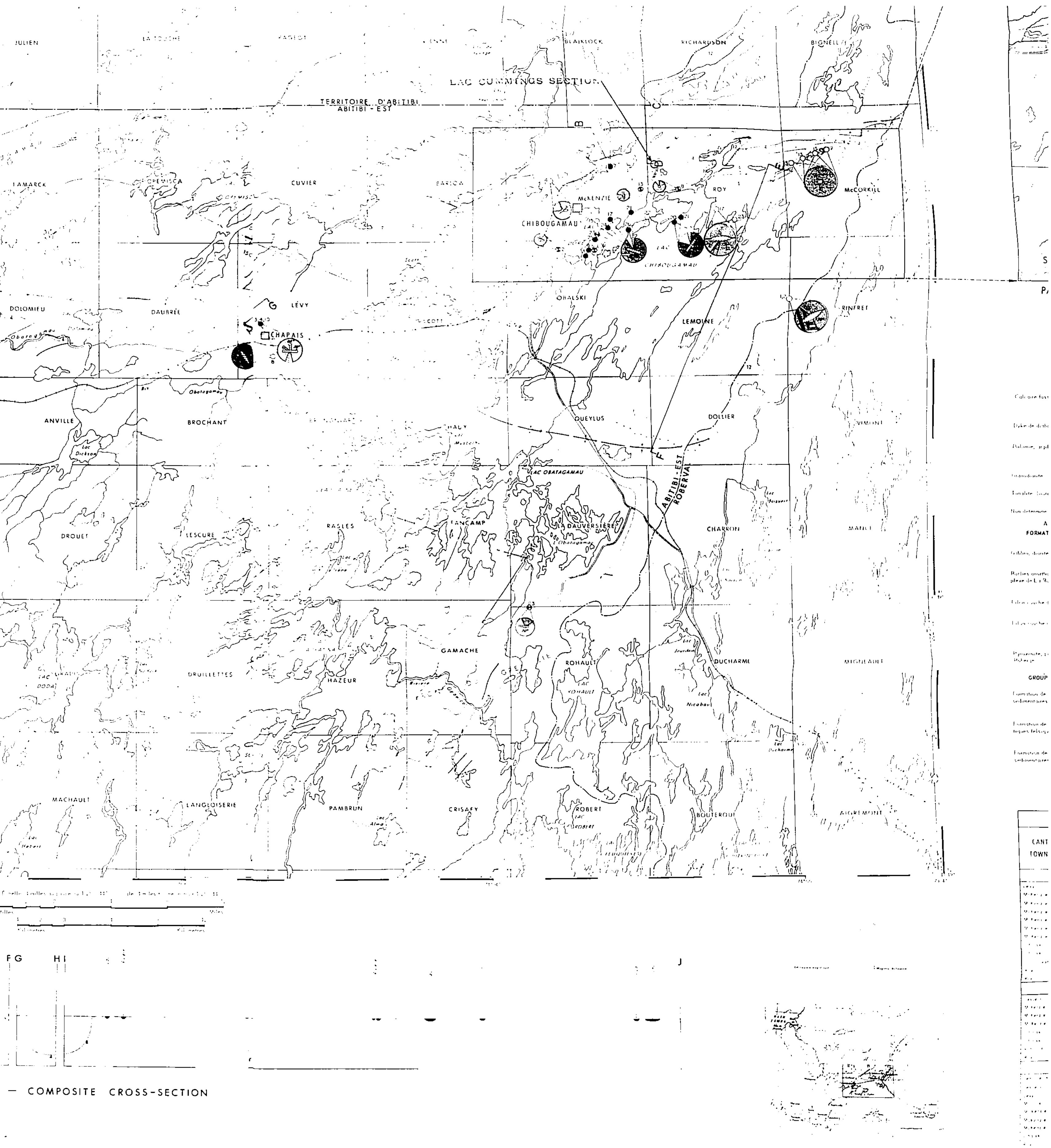
COUPE TRANSVERSALE COMPOSÉE — COMPOSITE CROSS-SECTION

3 of

GÉOLOGIE ET PRINCIPAUX GÎTES MINÉRAUX
DISTRICT DE CHIBOUGAMAU

1686

GEOLOG

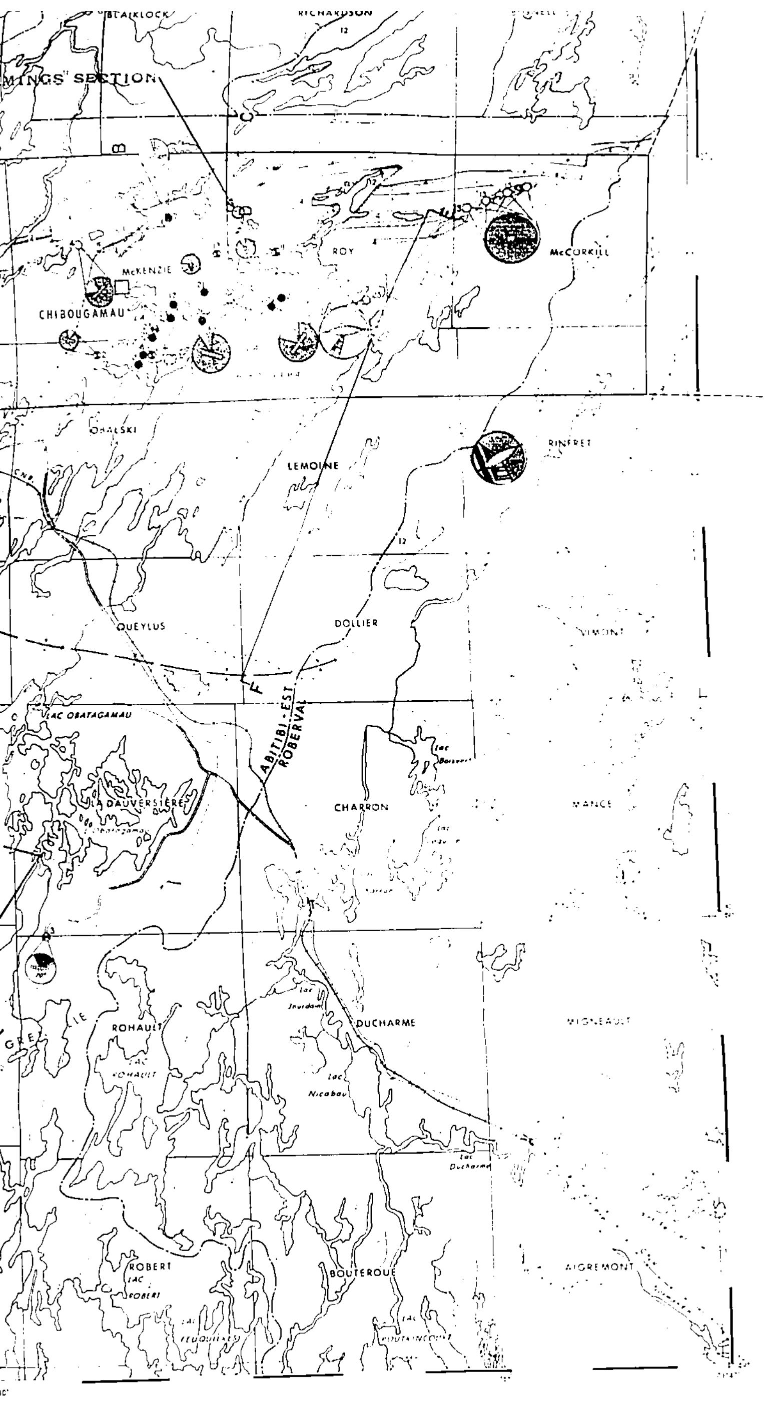


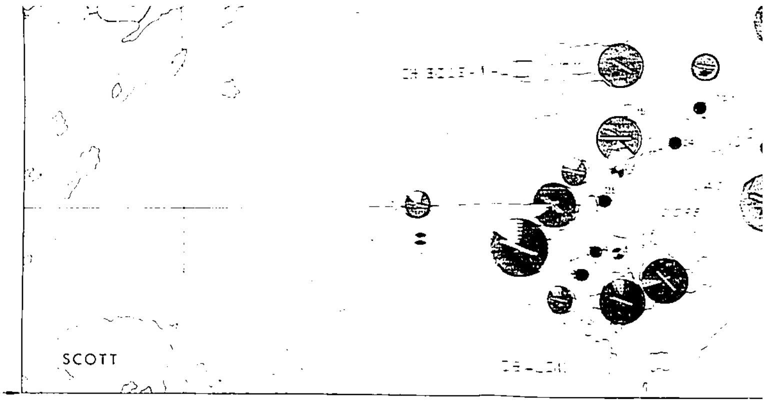
— COMPOSITE CROSS-SECTION

GEOLOGY AND PRINCIPAL MINERAL DEPOSITS

CHIBOUGAMAU DISTRICT

686





PARTIE AGRANDIE DES CANTONS BARLOW, LEMOINE, McCORKILL, McKENZIE, OB

LEGENDE — LEGEND

PALEOZOIQUE

ORDOVICIEN SUPÉRIEUR

Calcaire fossilifère	■	[illegible]

PRECAMBRIEN

PROTEROZOIQUE

Dyke de diabase		[illegible]
Dolomie, argile, grès, conglomérat	12	[illegible]

ARCHEEN

ASSEMBLAGE GRANITIQUE

Granodiorite		[illegible]
Tonalite, Diorite		[illegible]
Non déterminé		[illegible]

ASSEMBLAGE DE ROCHES VERTES

FORMATIONS INTRUSIVES

MAFIQUES

Gabbro, diorite		[illegible]
Roches anorthositiques: (7a) complexe de Lac Doré, (7b) complexe de La Ronde, (7c) complexe de Lac Michwacho		[illegible]
Filon-couche de Bourbeau		[illegible]
Filon-couche de Ventures		[illegible]

ULTRAMAFIQUES

Pyroxénite, péridotite et dunite serpentinisées (Filon-couche de Roberge)	1	[illegible]

GROUPE DE ROY (volcanites et roches sédimentaires) — ROY GROUP (volcanic and sedimentary rocks)

Formation de Blondeau: roches pyroclastiques felsiques et roches sédimentaires associées, un peu de laves mafiques		[illegible]
Formation de Gilman: laves mafiques, un peu de roches pyroclastiques felsiques		[illegible]
Formation de Waconichi: roches pyroclastiques felsiques et roches sédimentaires associées, laves mafiques dans le quart inférieur		[illegible]

\ LAC CUMMINGS SECTION

TABLEAU D

CANTON TOWNSHIP	NUMERO NUMBER *	NOM DE LA MINE NAME OF THE MINE	ARRÊT END	TONNAGE
		PRODUCTEURS — PRODUCERS 19[illegible]		
Lévy	3, 4, 10	OPEMISKA COPPER MINES (QUEBEC) LTD		[illegible]
McKenzie	17	THE PATINO MINING CORPORATION [illegible]		
McKenzie	21	THE PATINO MINING CORPORATION [illegible]		[illegible]
McKenzie	24	CAMPBELL CHIBOUGAMAU MINES LTD [illegible]		[illegible]
McKenzie	25	CAMPBELL CHIBOUGAMAU MINES LTD [illegible]		[illegible]
McKenzie	26	THE PATINO MINING CORPORATION [illegible]		[illegible]
McKenzie	28	THE PATINO MINING CORPORATION [illegible]		[illegible]
Obalski	1	CHIB-KAYRAND COPPER MINES LTD		[illegible]
Obalski	4	CAMPBELL CHIBOUGAMAU MINES LTD [illegible]		[illegible]
O'Sullivan	4**	[illegible]		[illegible]
Roy	20	CAMPBELL CHIBOUGAMAU MINES LTD [illegible]		[illegible]
Roy	21	THE PATINO MINING CORPORATION [illegible]		[illegible]
		ANCIENS PRODUCTEURS — FORMER PRODUCERS		
Lesueur	6	THE CONIAGAS MINES LTD	[illegible]	[illegible]
McKenzie	7	NORBEAU MINES QUEBEC LTD	[illegible]	[illegible]
McKenzie	11	[illegible] MINES LTD	[illegible]	[illegible]
McKenzie	23	QUEBEC CHIBOUGAMAU GOLDFIELDS LTD	[illegible]	[illegible]
Obalski	2	UNITED OBALSKI MINING CO LTD	[illegible]	[illegible]
Obalski	5	CAMPBELL CHIBOUGAMAU MINES LTD [illegible]	[illegible]	[illegible]
Rohault	3	KEY ANACON MINES LTD	[illegible]	[illegible]
Roy	9	GRANDROY MINES LTD	[illegible]	[illegible]
		PRODUCTEURS POSSIBLES — POSSIBLE PRODUCERS		
Lemoine, Rinfret	1, 2	SOUS ÉTUDE PAR LE MINISTÈRE DES RICHESSES NATURELLES UNDER STUDY BY THE DEPARTMENT OF NATURAL RESOURCES		
Lesueur	7	QUEBEC STURGEON RIVER MINES LTD		
Lévy	8	OPEMISCA EXPLORERS LTD		
McCorkill	1**	McADAM MINING CORPORATION LTD		
McKenzie	4	TACHE LAKE MINES LTD		
McKenzie	15	THE PATINO MINING CORPORATION [illegible]		
McKenzie	22	BATEMAN BAY MINING CO		
Obalski	6	QUEBEC CHIBOUGAMAU GOLDFIELDS LTD [illegible]		
Roy	1, 21	CHIBIRON MINING CORPORATION		

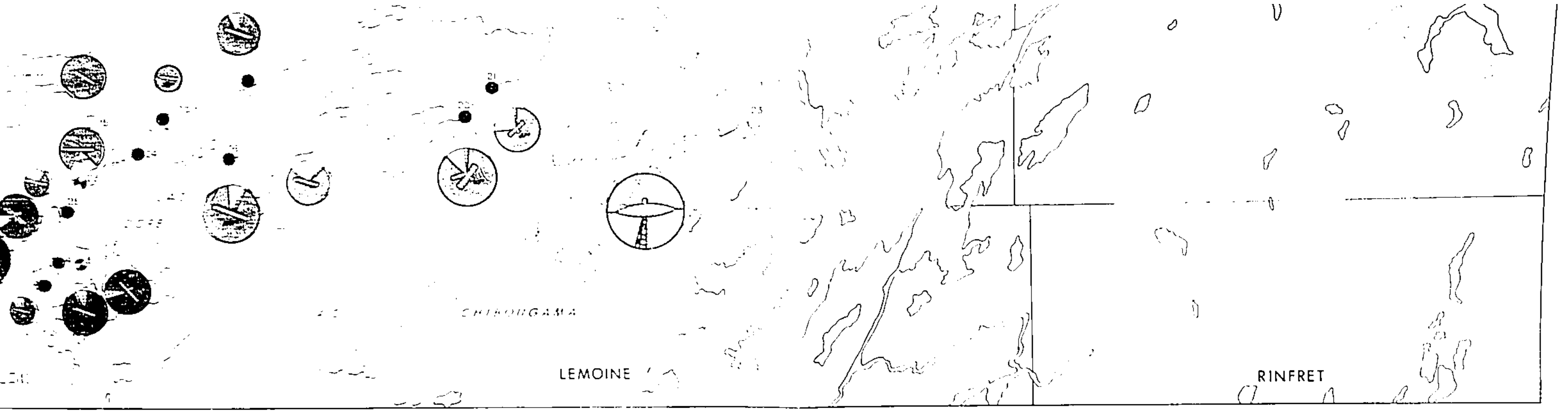
* [illegible]
These numbers refer to [illegible]

** [illegible]
These numbers [illegible]

AL DEPOSITS

4 of 4

MINERAL DEPOSITS SERVICE
Department of Natural Resources, Quebec



McCORKILL, McKENZIE, OBALSKI, RINFRET, ROY ET SCOTT — ENLARGED PART OF BARLOW, LEMOINE, McCORKILL, McKENZIE, OBALSKI, RINFRET, ROY AND SCOTT TOWNSHIPS

SIGNES CONVENTIONNELS — SYMBOLS

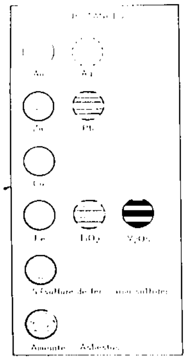
Prix utilisés pour l'évaluation en dollars des gîtes
Prices used to calculate the dollar value of the deposits

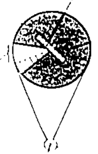
Cu	600.00 t	Amiante – Asbestos	$ 115.00 t
Au	35.00 oz	Fe (fonte – steel)	$ 50.00 t
Ag	1.00 oz	TiO_2 scorie – slag	[illegible]
Zn	250.00 t	V_2O_5	[illegible]
Pb	250.00 t	Sulfure de fer – iron sulfide	[illegible]

Filon incliné
Vein inclined

Gîte stratiforme incliné
Stratiform deposit inclined

Stockwerk
Stockwork





LOCALISATION – LOCATION

PRODUCTEURS – PRODUCERS

Anciens
Former

Actuels
Actual

Possibles
Possible

Geological contact

Fault

Road

TABLEAU DE STATISTIQUES MINÉRALES IMPORTANTES — TABLE OF IMPORTANT MINERAL STATISTICS

TONNAGE ET TENEUR — TONNAGE AND GRADE

PRODUCTION					RESERVES			TOTAL (PRODUCTION ET AND RESERVES)		SOURCE
ARRÊT END	TONNAGE	TENEUR – GRADE	TAUX-RATE T_j – T d	EN DATE DE AS OF m–m–y	TONNAGE	TENEUR – GRADE	EN DATE DE AS OF m–m–y	TONNAGE	TENEUR – GRADE	
	[illegible]	[illegible]	[illegible]	12/1968	[illegible]	[illegible]	12/1968	[illegible]	[illegible] approx. 0.464 oz/t Ag	Rapp. Ann. Rept
					[illegible]	[illegible]	12/1968	[illegible]	[illegible]	Rapp. Ann. Rept
	[illegible]	[illegible]	410	12/1967	[illegible]	[illegible]	12/1967	[illegible]	2.50% Cu, 0.022 oz/t Au, approx. 0.216 oz/t Ag	Rapp. Ann. Rept
	[illegible]	[illegible]	[illegible]	6/1968	[illegible]	[illegible]	[illegible]	2,764,411	2.17% Cu, 0.080 oz/t Au, approx. 0.270 oz/t Ag	Rapp. Ann. Rept
	[illegible]	[illegible]		6/1968	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] approx. 1.50 oz/t Ag	Rapp. Ann. Rept
	[illegible]	[illegible]	[illegible]	12/1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] approx. 0.261 oz/t Ag	Rapp. Ann. Rept
	[illegible]	[illegible]	[illegible]	12/1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] approx. 0.260 oz/t Ag	Rapp. Ann. Rept
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rapp. Ann. Rept
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rapp. Ann. Rept
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	Survey of Mines
	[illegible]	[illegible]	1500	6/1965	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rapp. Ann. Rept
	[illegible]	[illegible]	550	12/1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rapp. Ann. Rept
[illegible]	[illegible]	[illegible]	[illegible]	12/1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rapp. Ann. Rept
[illegible]	[illegible]	[illegible]	[illegible]	12/1967	[illegible]	[illegible]	12/1967	[illegible]	[illegible]	Rapp. Ann. Rept
[illegible]	[illegible]	[illegible]		5/1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Northern Miner
[illegible]	[illegible]	[illegible]	125	7/1967				[illegible]	[illegible]	Rapp. Ann. Rept
[illegible]	[illegible]	[illegible]	250	2/1966				[illegible]	[illegible]	Rapp. Ann. Rept
[illegible]	[illegible]	[illegible]	[illegible]	6/1968	[illegible]	[illegible]	6/1968	[illegible]	[illegible]	Rapp. Ann. Rept
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Survey of Mines
[illegible]	[illegible]	[illegible]	[illegible]	6/1968	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Rapp. Ann. Rept

MAP PREPARED BY CARTOGRAPHY SERVICE, 1972