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ONTARIO GEOLOGICAL SURVEY

Open File Report 5515

Metallogeny of the Grenville Province
Southeastern Ontario

by

T.R. Carter

1984

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Carter, T.R.

1984: Metallogeny of the Grenville Province, Southeastern Ontario, Ontario Geological Survey Open File Report 5515, 422p., 58 figures, 35 tables, and 14 photos.

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V. G. Milne, Director
Ontario Geological Survey

FOREWORD

This volume "Metallogeny of the Grenville Province, Southeastern Ontario" is a summary statement which concludes several years' intensive study of the mineral deposits.

Investigations began in 1977 as part of a Mineral Resources Assessment Project for the Pembroke-Renfrew area which was funded equally by the Federal Department of Regional Economic Expansion and the Ontario Ministry of Treasury and Economics under the Community and Resource Development Subsidiary Agreement. Initial work was published in 1980 by authors Carter, Colvine and Meyn (1980).

Additional studies of mineral deposits in the westerly segment of the Grenville Supergroup were undertaken in 1979-1983 as part of the base program of the Ontario Geological Survey. Since 1983 the preparation of this summary report, and compilation of the companion volume of mineral inventories by J. Malczak, has been part of the Southeastern Ontario Geological Survey, funded equally by the Federal Department of Regional Economic Expansion (DREE) and the Ontario Ministry of Natural Resources under the Minerals Program of the Eastern Ontario Subsidiary Agreement.

This work, completed over the past seven years, adds greatly to the knowledge of mineral deposits in the Grenville. It not only provides the most complete and modern records available but outlines an integrated framework for understanding and predicting favourable settings for new deposits.

V.G.Milne, Director
Ontario Geological Survey

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Abstract

Bedrock exposures of the Grenville Province in southeastern Ontario are dominated by the Grenville Supergroup, a Late Precambrian supracrustal sequence. The Grenville Supergroup is composed of a basal clastic sequence which lies with apparent unconformity on a basement gneiss complex of Middle to Late Precambrian age. It is followed by a thick volcanic sequence of uncertain relative age; and a thick overlying succession of intercalated carbonate and clastic sedimentary rocks. The Supergroup is intruded by a variety of intrusive rocks and unconformably overlain by the Flinton Group of metasedimentary rocks. Metamorphic grade nearly everywhere exceeds greenschist facies.

There are over 750 occurrences of metallic mineralization in the Grenville Supergroup and associated intrusive rocks in southeastern Ontario. Deposit types include stratiform carbonate-hosted zinc, stratabound pyritic sulfides in volcanic and sedimentary hosts, gold-quartz veins, quartz-magnetite ironstone, copper-nickel and iron-titanium in intrusive rocks, magnetite skarns, molybdenum in skarns and pegmatites, uranium and thorium in pegmatite veins, and calc-silicate gneisses, hematite veins, dolomite marble (magnesium), and barite-fluorite-celestite-galena-calcite veins. There has been significant production of iron, lead, zinc, magnesium, gold, and uranium.

Processes responsible for metal concentration in the area include: 1) syngenetic hydrothermal activity related both to volcanism and sedimentation; 2) epigenetic processes related to diagenesis, regional metamorphism, and igneous intrusive activity; 3) magmatic processes related to igneous intrusion; and 4) supergene concentration and enrichment. The genetic classification of the metallic mineral deposits presented here is based on genetic interpretation geneses and observed geological relationships. The deposit types have counterparts in the volcanogenic and sedimentary exhalative, Mississippi Valley type, magmatic, contact metasomatic, and lode gold deposits which are found in other parts of the world. Exploration criteria for these deposit types may be applicable in the Grenville Province with de allowance for the generally complex deformation and high metamorphic grade.

METALLOGENY OF THE GRENVILLE PROVINCE

SOUTHEASTERN ONTARIO

by

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with submissions by

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1984

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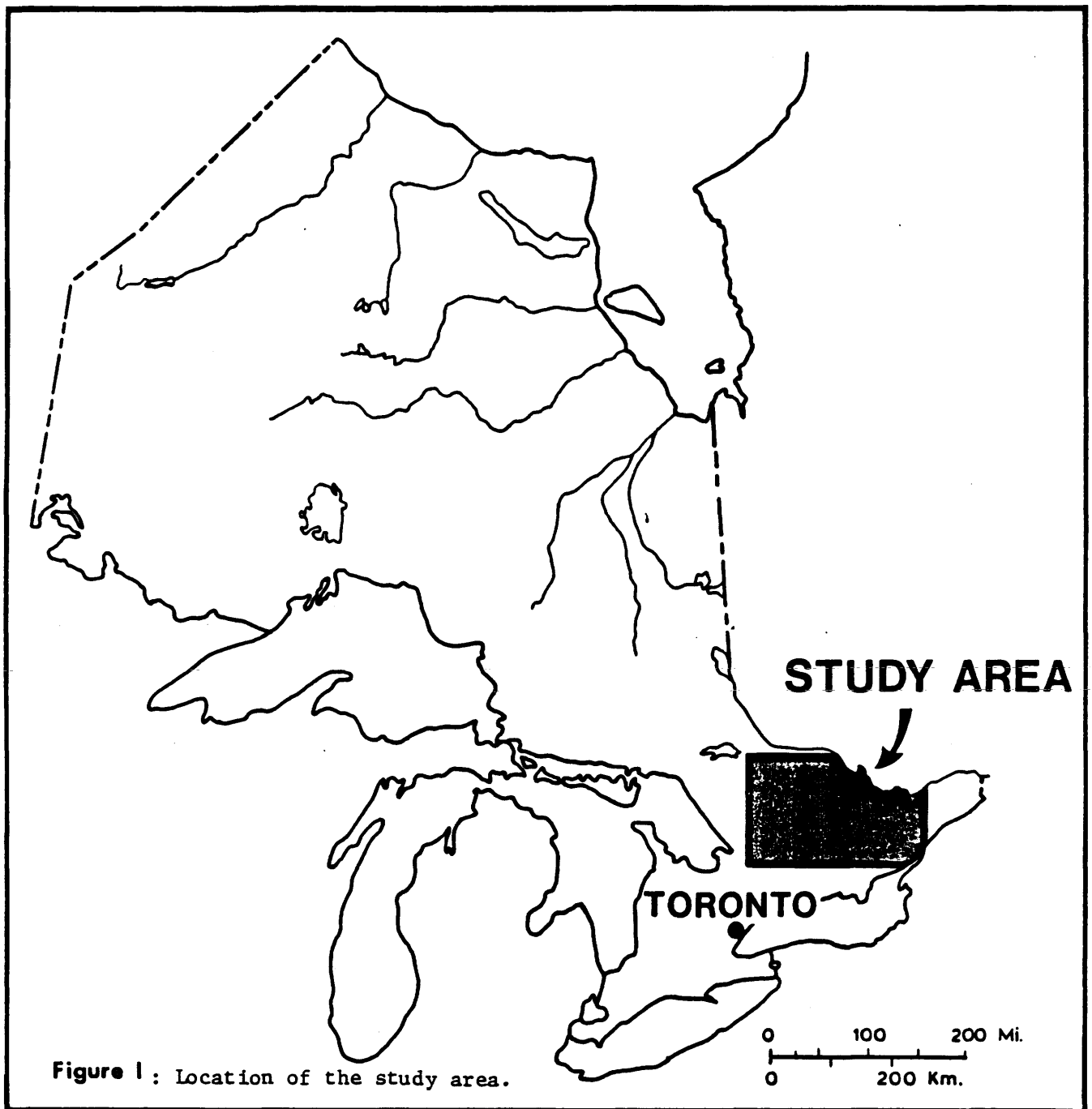
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Manuscript approved for publication by Janet Springer, Sub-Section Chief, Mineral Deposits Section, July, 1984.

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The study area comprises the entire outcrop area of the Grenville Supergroup in southeastern Ontario approximately bounded by the towns of Pembroke and Kingston, on the north and south respectively, the city of Ottawa to the east, and Lake Simcoe to the west, an area of approximately 30,000 km² (Fig. 1). Over 750 occurrences of metallic mineralization are known to occur in southeastern Ontario, including concentrations of iron, titanium, molybdenum, uranium, thorium, copper, lead, zinc, nickel, gold, and silver. This report provides a general outline of the geological features of the different types of metallic mineral deposits in the area. Origins are inferred from the geologic settings and an internally consistent genetic classification scheme is proposed. The similarities of these deposit types to more widely recognized deposit types, which elsewhere are major producers, are discussed. An attempt is also made to establish general exploration guidelines for each deposit type, to assess and prioritize their relative economic potential, and to relate formation of metallic mineralization to regional geologic events.

Southeastern Ontario is one of the oldest settled areas in Canada and is located adjacent to some of the most heavily populated and industrialized parts of Canada and the United States. The area is well developed with a modern network of



roads, railroads, hydroelectric power lines, and numerous towns and villages. It is underlain by Precambrian rocks of the Grenville Province containing numerous metallic mineral occurrences, whose history of geological study and mineral exploration and development date back over 150 years.

The area is currently largely ignored as a potential source of metals, except for sporadic exploration for uranium and zinc, and production of magnesium metal by Chromasco Ltd. from their Haley mine and reduction plant. This partly reflects the fact that much of the land base is privately held and exploration rights must be negotiated. There is also a widely held misconception that no significant mineral deposits can remain undiscovered in such an easily accessible area with such a long history of exploration. However, there are numerous cases in which major discoveries have been made in such areas, either as a result of application of new genetic models for ore formation, new technology, or simply more intensive exploration. The Navan lead-zinc deposit in Ireland, the Kuroko district copper-zinc deposits in Japan, the Valley porphyry copper district in British Columbia, the Kidd Creek copper-zinc-silver deposit near Timmins, and the recently discovered gold deposits in the Hemlo area of northern Ontario, are all examples of major discoveries in accessible areas with long histories of settlement and/or intensive mineral exploration. A second misconception is that no notable mineral deposits occur in the Grenville Province.

This ignores the fact that there has been significant production of uranium, iron, lead, zinc, gold, arsenic, and molybdenum from mines in southeastern Ontario (Table 1). In New York State mines in the Balmat-Edwards area have been in continuous production since 1915 and supply about ten percent of the annual zinc consumption of the United States. In the Province of Quebec major production has been attained from the Hilton iron mine, the New Calumet and Montauban zinc-lead-silver-gold mines, and the Reney Lake nickel-copper mine.

HISTORY OF STUDY

The present study was started in 1977 as part of a Mineral Resources Assessment Project, Pembroke-Renfrew Region, which was equally funded by the Federal Department of Regional and Economic Expansion, and the Ontario Ministry of Treasury and Economics under the Community and Resource Development Subsidiary Agreement. Initial work was completed in 1979 and results were published in 1980 (Carter, Colvine, and Meyn 1980). The author completed additional studies of mineral deposits throughout the rest of the Grenville Supergroup between 1979 and 1983, in a special project funded by the Ontario Geological Survey. During the course of these studies over 150 metallic mineral deposits were visited. Mapping of many of these mineral deposits was completed, at scales ranging from 1:15,840 (1 inch to 1/4 mile)

Table 1: Summary of production from major producing mines in southeastern Ontario.

Mine	Production Period	Ore Mined (short tons)	Average Grade	Concentrate/Metal Produced
Bicroft	1956-1963	2,571,766	0.087% U_3O_8	4,445,973 pounds U_3O_8
Canadian Dyno	1958-1960	659,403	0.062% U_3O_8	813,381 pounds U_3O_8
Greyhawk	1957-1959	80,247	0.068% U_3O_8	108,332 pounds U_3O_8
Madawaska	1957-1982	5,009,135	0.095% U_3O_8	9,498,368 pounds U_3O_8
Cordova	1892-1940	120,670	0.19 oz Au/ton	22,774 oz Au, 687 oz Ag
Deloro	1897-1902	39,143	0.26 oz Au/ton	10,360 oz Au
Chromasco	1943-present		~21% MgO	to end 1980 - 475,056,312 lb. Mg
Kingdon	1915-1931	905,000	3.32% Pb, minor Zn	76,821,409 lb. lead concentrate 857,312 lb. zinc concentrate
Long Lake	1973-1974	94,631	11.6% Zn	11,282,412 tons concentrate - 65.27% Fe
Hunt	1915-1918			96,660 lb. concentrate - 95% MoS_2

to 1:200. Detailed descriptions and maps are included in this report, in Carter et al. (1980), and in Malczak et al. (in preparation). The author also had opportunity to visit zinc deposits in the Mont Laurier area of Quebec, and to tour operating zinc mines in the Balmat area of New York, and the Madawaska uranium mine near Bancroft, before its closure in 1982.

Geologic inventories of base and precious metal, iron, and molybdenum deposits (Carter et al. 1980) and uranium deposits (Masson and Gordon 1981) in the northern part of the area have been completed. A similar inventory of the geologic relationships of base and precious metal and molybdenum deposits in the southern part of the area is in preparation (Malczak et al.). An initial summary of geological and interpreted metallogenetic relationships of base metal, gold, and iron deposits in the entire area was completed by Sangster (1970) and Sangster and Bourne (1982). A similar study of molybdenum deposits was completed by Karvinen (1973). Numerous other mineral deposit studies of more limited scope have been completed by a variety of workers. An even greater number of geological studies, including geological mapping, have been completed. A complete list of these studies is included in the bibliography to this report.

Other sources of information include the results of exploration activities by numerous mineral exploration companies

and prospectors. Some of this information is available in the Assessment Files Research Office of the Ontario Geological Survey in Toronto. Unfortunately, however, most of it is retained in private files and is only available through voluntary contributions. Several important theses have been completed on the area, most of which are available at Ontario university libraries, particularly at Carleton University, Queen's University, University of Toronto, and University of Western Ontario. Some theses are also on file at the Mines Library of the Ontario Geological Survey.

ACKNOWLEDGEMENTS

As in any project of this scope, the assistance and cooperation of many people were instrumental in the successful completion of the study. Dr. A.C. Colvine of the Ontario Geological Survey directed the study during its initial stages and critically reviewed the final manuscript. The study benefitted from numerous discussions and informative field trips with other geologists. The author would like to thank S.B. Lumbers of the Royal Ontario Museum, E.G. Bright and J.B. Gordon of the Ontario Geological Survey, J.M. Moore of Carleton University, M. Gauthier of Ecole Polytechnique, S.L. Masson of Laurentian University, and the geological staff of the Balmat Division of St. Joe Zinc Co., in New York State.

Regional geological staff of the Ministry of Natural Resources, notably H.D. Meyn, D. Villard, and P. Kingston, were reliable sources of information and advice on mineral deposits in the area. The support staff of the Ontario Geological Survey were also essential in completion of this study.

The author gratefully acknowledges the information supplied by mining company officials, particularly D. Robertson of Billiton Canada, J.G.L. Sinclair of Selco Mining Corporation Ltd., W. Little of Cominco Ltd., J.V. Huddard of Algoma Steel Corp. Ltd., and R.L. Alexander of Madawaska Mines Ltd. R.L. Alexander, C. Verschuren, D. Villard and D. Robertson have contributed detailed descriptions of selected mineral deposits as part of this report, for which the author is most appreciative.

This project would have been impossible to complete without the assistance and cooperation of local residents in providing unhindered access to their properties. The author would like to thank Earl Sager of Madoc, Fred Inwood of Ireland, Norval Wilson of Hopetown, and Roger Young of Havelock, in particular. Capable assistance was provided in the field by Jim Provias, Scott Dawson, Mark Bradshaw, Brian Iwama and Pierre Charbonneau.

I. METALLOGENY

Geology of the Grenville Province, Southeastern Ontario

General Geology

The Grenville Province comprises a distinctive belt of rocks on the southeastern margin of the Canadian Shield, characterized by high-grade metamorphism, a northeast-trending structural fabric, and K-Ar ages averaging 950 Ma. In Ontario high-grade metamorphic rocks of the Grenville Province are separated from relatively low-grade rocks of the Superior and Southern Provinces to the northwest by the Grenville Front. To the southeast exposure is limited by the unconformably overlying Paleozoic sedimentary rocks of the St. Lawrence Platform. Rocks of Grenville age continue beneath this sedimentary cover sequence for an unknown distance to the south and east.

Two major sequences of supracrustal rocks have been identified by Lumbers (1982) southeast of the Grenville Front, in Ontario. The older succession is confined to the northern two-thirds of the Province, corresponding to the area designated by Wynne-Edwards (1972) as the Ontario Gneiss Segment. It consists mainly of deep-water siliceous clastic metasediments deposited during the Middle Precambrian between about 1800 and 2500 Ma ago. According to Lumbers (1978, 1982), the base of this sequence consists of coarse clastic metasediments that are correlative with the lower part of the Huronian Supergroup in the Southern Province. This is in agreement with Quirke and Collins (1930) who concluded that higher grade equivalents of

Southern Province rocks in the Sudbury area are exposed in the Grenville Province, immediately southeast of the Grenville Front. The Middle Precambrian metasedimentary succession was subsequently intruded by a complex suite of anorthosite rocks termed the Algonquin Batholith (Lumbers 1982, Schwerdtner and Lumbers 1980). Preliminary geochronological data indicate the major phases intrusion are between 1400 and 1500 Ma old (Krogh and Davis 1969b; Lumbers and Krogh 1977). The metasediments are preserved as small infolded remnants and xenoliths of paragneiss within the intrusive complex. All the rocks, including the intrusive rocks, have been deformed into a complex series of gneisses as a result of later metamorphism and deformation.

The younger accumulation of supracrustal rocks dominates the southeastern portion of the Grenville Province in Ontario and comprises part of the Central Metasedimentary Belt, as defined by Wynne-Edwards (1972). As several major stratigraphic subdivisions within stratified rocks of the Central Metasedimentary Belt in southeastern Ontario can be recognized, another term, the 'Grenville Supergroup', has been adopted (Moore and Thompson 1972, 1980; Wynne-Edwards 1972).

The principal exposures (Figure 2) comprise metamorphosed units of volcanic, carbonate, and calcareous and non-calcareous siliceous clastic sedimentary units. The Grenville Supergroup is the largest and thickest of the metavolcanic-metasedimentary sequences known to occur in the Grenville Province and contains the greatest concentration of metallic mineral deposits. This

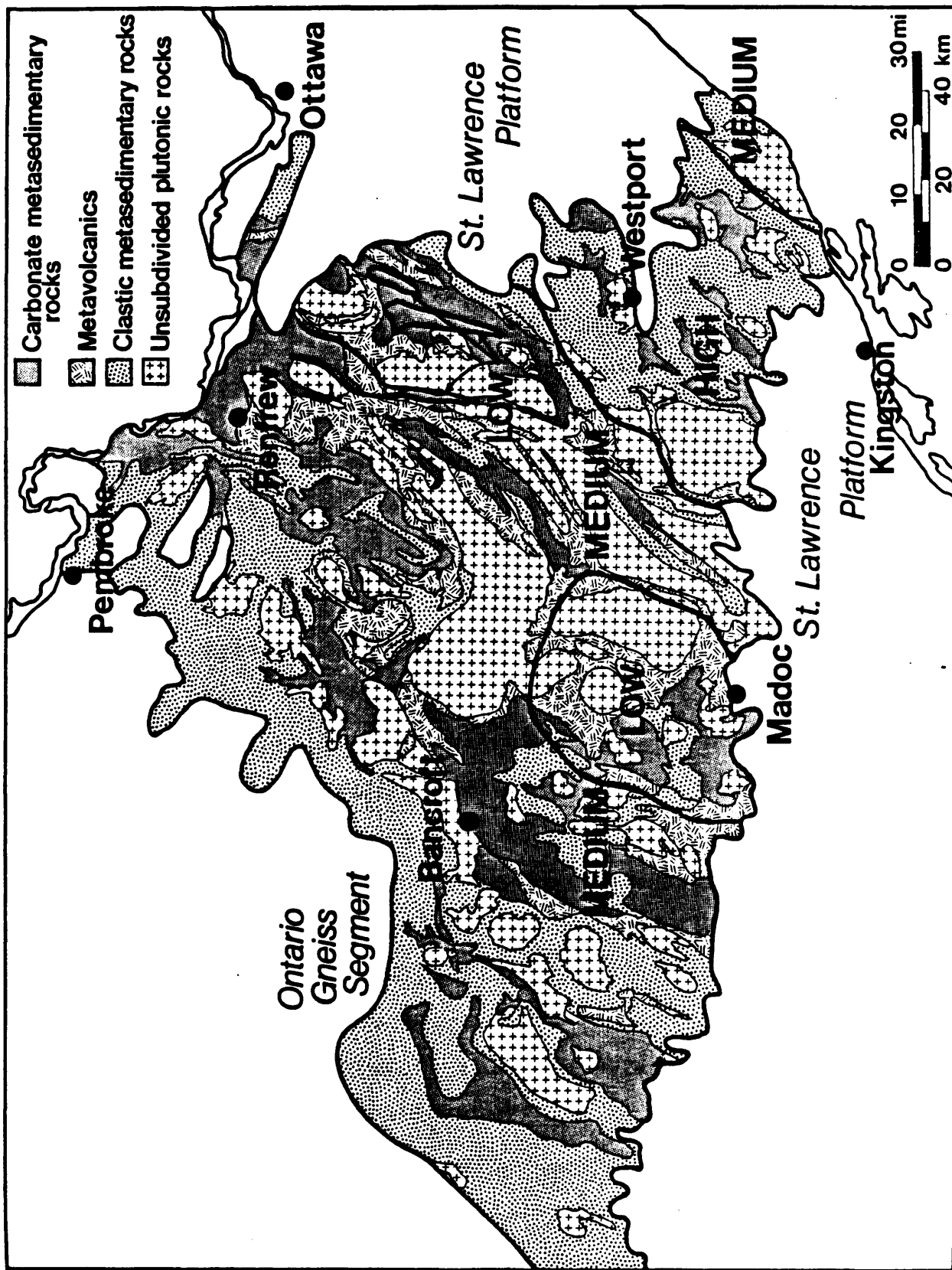


Figure 2: General geology of southeastern Ontario, adapted from Freeman (1978). Location of generalized isograds are indicated.

is the only part where stratigraphic units have been correlated over any significant area, and where the geologic history has been documented with any degree of certainty (Sangster and Bourne 1982). stratified rocks of the Grenville Supergroup are separated from the basement complex comprising a Middle Precambrian paragneiss-intrusive complex by a major northeast-trending zone of tectonic deformation. This zone of deformation is coincident with and obscures a major unconformity interpreted by Lumbers (1982) to separate the two supracrustal accumulations.

A second group of stratified surficial rocks, possibly correlative with the Grenville Supergroup, occurs in the Parry Sound area. The rocks consist of high grade metamorphic gneisses believed to represent deep water siliceous clastic sedimentary rocks, with local marble horizons. There is also a sequence of amphibolites and felsic gneisses tentatively identified as mafic to felsic metavolcanic rocks.

The Grenville Supergroup

Lithostratigraphic subdivisions of the Grenville Supergroup have been proposed by several workers in selected parts of the area (see Table 2). In many cases the stratigraphy is not formally defined and correlations between formations are not known with certainty. The term Anstruther Lake Group has been applied by Bright (1976, 1977) to describe a succession of metasedimentary gneisses believed to be at the base of the

Table 2: Table of formations for the portion of the Grenville Supergroup exposed in southeastern Ontario, (Hermon and Mayo Groups after Lumbers, 1967b, Flinton Group after Moore and Thompson, 1972; Moore and Thompson, 1980)

Group	Formation	Description
Flinton	Stewart	marble, graphitic marble
	Madoc	pelite
	Fernleigh	thin-bedded black shale and limestone, pyritic in part
	Meyers Cave	dolostone, limestone, dolostone conglomerate, black pyritic shale
Mayo	Lessard	calcareous and non-calcareous feldspathic sandstone
	Bishops Corners	basal, hematitic quartzite (locally cross-bedded)
		quartzite-pebble conglomerate and shale
		UNCONFORMITY
Mayo	Lasswade	marble, minor calcareous metasandstone and metasilstone, rare recrystallized chert
	Apsley	poorly sorted feldspathic metasandstone with upper and lower members of calcareous metasandstone and metasilstone
	Dungannon	80% marble; remainder mainly calcareous metasandstone and metasilstone, poorly sorted feldspathic metasandstone, and rare recrystallized chert; mafic metavolcanic flows and iron-formation rare near base of formation overlying Tudor metavolcanic rocks
Hermon	Burnt Lake	mainly rhyolitic, trachytic, dacitic, and andesitic metavolcanic rocks with minor metabasaltic flows; lensoid marble units and sandy siliceous metasedimentary rocks found locally
	Turriff	75% pillowed basaltic and andesitic metavolcanic flows; remainder dacitic and felsic flows and pyroclastic rocks, and minor iron-formation
	Vansickle	mainly poorly sorted feldspathic metasandstone locally with abundant marble, felsic and mafic Hermon metavolcanic rocks, metaconglomerate, and well sorted quartz-rich metasandstone; arkosic metasedimentary rocks commonly associated with felsic metavolcanic rocks
	Oak Lake	mainly metamorphosed felsic pyroclastic rocks and arkose with some mafic and felsic metavolcanic flows; rare marble and metaconglomerate in upper part of formation
	Tudor	mainly metamorphosed, pillowed, basaltic and andesitic flows

Grenville Supergroup in the Anstruther-Cardiff area, southwest of Bancroft. As described by Bright the group has an estimated thickness of about 1500 metres, and consists predominantly of siliceous clastic metasedimentary rocks. It may correlate with clastic units which Lumbers (1982) has identified at the base of the Grenville Supergroup in the Renfrew County area to the north. Lumbers' basal accumulation is characterized by basal arkose and impure sandstone, locally containing clasts similar to the underlying Algonquin Batholith. It is interpreted by Lumbers to lie unconformably in the metasedimentary and meta-igneous gneisses of the Ontario Gneiss Segment. The basal clastic succession passes upwards into a carbonate-rich sequence in the Renfrew area for which the stratigraphic relationships have not been defined. In contrast, according to Bright in the Anstruther-Cardiff area the Anstruther Lake Group grades upwards into a predominantly volcanic succession which is correlative with the Hermon Group.

The Hermon Group and the overlying Mayo Group, which are in large part coeval, have been defined by Lumbers (1967) in the Bancroft-Madoc area where they have a minimum combined thickness of about 8,200 metres. They are characterized by predominantly volcanic and carbonate sedimentary rocks respectively (Table 2), with intercalated siliceous clastic units. Although the base of the Hermon Group is not exposed in the Bancroft-Madoc area, a U-Pb age of 1310 ± 15 Ma reported by Silver and Lumbers (1966) for a felsic volcanic number of the lowermost Tudor Formation, is

widely considered as the age of the base of the Hermon Group in this area. Whole-rock Rb-Sr age dating of mafic metavolcanics of the Tudor Formation by Bell and Blenkinsop (1980) indicates deposition occurred about 1250 Ma ago, in good agreement with the earlier U-Pb determination. Dates for the Anstruther Lake Group or the basal clastic succession identified by Lumbers (1982) in the Renfrew County area do not exist.

The Tudor Formation, at the base of the Hermon Group (Table 2) consists principally of basaltic and andesitic flows. The local abundance of pillows and occasional thin marble horizons suggest a subaqueous environment of deposition. The Tudor Formation grades upwards into mainly felsic metavolcanics and immature feldspathic metaclastics of the Oak Lake and Vansickle Formations respectively. The Turriff Formation is interbedded with the upper part of the Vansickle Formation and is composed of pillowed basaltic and andesitic flows with subordinate felsic metavolcanics. The Burnt Lake Formation forms the top of the sequence and is composed predominantly of rhyolitic, trachytic, dacitic, and andesitic metavolcanics. According to Lumbers (1967) both the Turriff and Burnt Lake metavolcanics may represent domed volcanic complexes, satellites to the main Tudor volcanic centre which is thought to occur in eastern Grimsthorpe and western Anglesea Townships.

Three formations have been defined within the Mayo Group: the Dungannon, Apsley, and Lasswade Formations. The Dungannon is composed principally of impure calcitic and dolomitic marbles

with subordinate feldspathic metaclastic rocks. It conformably overlies formations of the Hermon Group. Locally, marbles of the Dungannon Formation show complex interfingering with metavolcanic and metaclastic rocks of the Oak Lake, Vansickle, and Burnt Lake Formations. The Apsley Formation overlies the Dungannon Formation and consists principally of a metagreywacke member lying between thin units of calcareous metaclastics rocks. The Lasswade marble forms the top of the Mayo Group in the Bancroft-Madoc area. It is essentially marble with thin units of metaclastic and occasional chert horizons.

In the Lavant-Darling area the author (Carter 1981) has identified two formations; the Joe Lake metavolcanics and the Lavant marble. The Joe Lake metavolcanics at the base of the sequence are principally basaltic and andesitic flows. These are interlayered with and pass gradationally upwards into the Lavant Formation, comprising essentially of calcitic and dolomitic marbles. On the basis of lithological and petrological similarities the Joe Lake Formation is tentatively correlated with the Tudor Formation, and the Lavant marble with the Dungannon Formation.

Stratigraphic relationships in the Frontenac Axis, in the southeastern part of the area, have been informally outlined by Wynne-Edwards (1967). The section is estimated to have a present thickness of 4600 metres and consists of intercalated quartzites, marbles, and quartzo-feldspathic gneisses of probable sedimentary origin. Correlation with the stratigraphy

of the rest of the Grenville Supergroup has not been attempted. Similar lithologic sequences are preserved in the Adirondack Lowlands in New York State, and in the Mont Laurier Basin in Quebec. Metavolcanic rocks are rare or absent in all three areas. Stratigraphic relationships are only locally defined in the Mont Laurier Basin or the Adirondack Lowlands.

The Flinton Group

The uppermost group of the Grenville Supergroup lies within evident conformity on the rocks below. It contains no metavolcanic rocks. The Flinton Group has been defined by Moore and Thompson (1972) and subsequently correlated with similar sequences throughout the southern part of the area (Moore and Thompson 1980). Northeast of Madoc it is preserved in a series of long, narrow synclines. Dominant lithologies include quartzite, conglomerate, and other calcareous and non-calcareous clastic metasedimentary rocks, with significant amounts of marble.

Six formations have been defined by Moore and Thompson (1980) within the Flinton Group (see Table 2). The Bishops Corners Formation is nearly continuous throughout the known areal extent of the Flinton Group and usually occurs at the unconformity. It consists of five members; pelitic schist, quartzite, quartzite pebble conglomerate, micaceous metasandstone, and white quartzite pebble conglomerate (see Plate 1). The Lessard Formation overlies the Bishops Corners Formation and consists of calcareous metaclastic rocks and



Plate 1: Pebble to cobble quartzite orthoconglomerate of the Flinton Group, near the village of Northbrook.

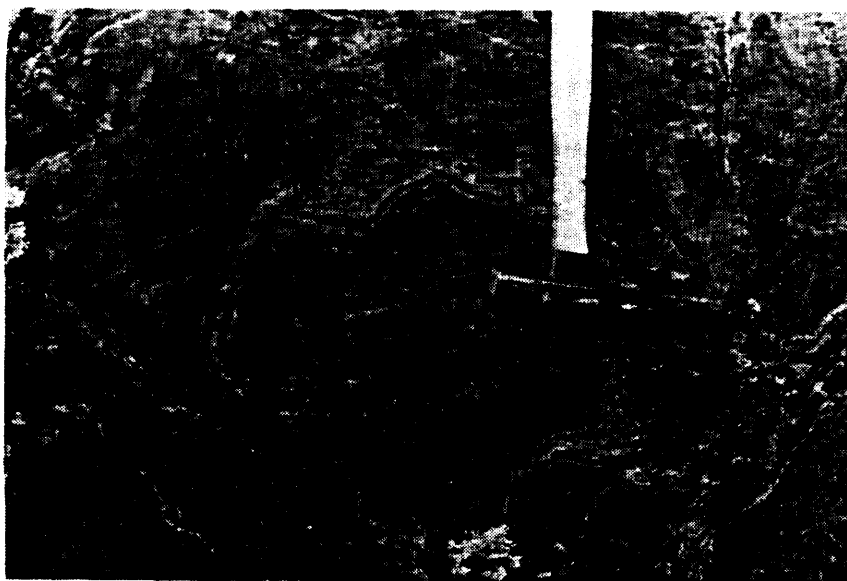


Plate 2: Pillowed mafic metavolcanics of the Hermon Group near the Blakely-Canadian Sulphur Ore pyrite deposits.

a pebble conglomerate with plutonic fragments. The Myer Cave, the lateral equivalent of the Bishops Corners Formation, consists of marble, carbonate-clast conglomerate and pelitic metaclastic rocks. The Fernleigh Formation composed essentially of calcareous pelitic metaclastic rocks, overlies the Myer Cave Formation. The Madoc Formation and the Stewart Formation are essentially pelitic schist, and dolomitic marble and graphitic calcite marble respectively. They overlie metaclastic rocks of the Skootamatta Formation which, along with the Ore Chimney Formation form informally defined stratigraphic units below or correlative with the Bishops Corners Formation.

The interpretation of the significance of the quartzite and quartzite pebble conglomerate of the Flinton Group has been a matter of considerable controversy. Moore and Thompson (1972, 1980) have presented convincing evidence that the basal sandstones and conglomerates of the Flinton Group rest unconformably on underlying stratified rocks of the Hermon and Mayo Groups. They report the presence of pebbles in the conglomerate that are texturally and lithologically similar to the adjacent Northbrook, Elzevir, and Addington granitic intrusions. They also report that although the underlying Hermon and Mayo Groups are cut by these and numerous other intrusions, only late pegmatites cut the Flinton Group. They conclude that the Flinton Group is significantly younger than the Hermon and Mayo Group, and was deposited between 1104 ± 25 Ma

and 1027 $\pm$ 25 Ma ago, the age of the Addington granite and late pegmatites respectively. There is no attempt to explain the presence of other intrusions which have considerably younger ages. Largely on the basis of the evidence cited above, Moore and Thompson (1980) make compelling arguments for the removal of the Flinton Group from the Grenville Supergroup.

The conclusions and observations of Moore and Thompson are consistent with those made earlier by Miller and Knight (1914). Ambrose and Burns (1956) and Lumbers (1967a,b) consider that the conglomerates are intraformational. Lumbers (1967a) reports that the conglomerates occur at several stratigraphic levels containing granitic pebbles and cobbles derived from felsic metavolcanics.

Intrusive Rocks

A large number of igneous intrusions have invaded the stratified rocks of both the younger and older supracrustal successions. Descriptions of these and their relationships are summarized principally from Lumbers (1982, 1967).

Most of the plutonic rocks cutting the older accumulation belong to an anorthosite suite ranging in age from about 1500 to 1100 Ma (Lumbers 1975; Lumbers and Krogh 1977). Between about 1300 and 1000 Ma ago a complex suite of intrusive rocks invaded the younger Grenville Supergroup. Five major suites are recognized, although not all plutonic rocks in the area have been assigned to a suite. In approximate order of decreasing age these comprise the following: 1) The oldest plutonic rocks

form a biotite diorite suite characterized by abundant dioritic rocks, tonalite, and sodic granitic and syenitic rocks, chiefly trondhjemite, granodiorite, albite granite, and albite syenite. They form epizonal to mesozonal intrusions that are dated at about 1250 Ma old (Silver and Lumbers 1966), and are most common in association with metavolcanic rocks. 2) A suite of anorthositic and tonalitic rocks and associated monzonitic and syenitic rocks. 3) A quartz-monzonite suite characterized by abundant quartz monzonite and only minor phases of other calc-alkalic intrusive rocks. 4) An alkalic suite confined mainly to a major complex near the northwestern margin of the Grenville Supergroup that is dominated by alkalic syenite and granite, with minor mafic alkalic rocks and nepheline syenite. 5) A syenite-monzonite suite characterized by abundant calc-alkalic syenite and minor monzonite, quartz monzonite, tonalite, and gabbro.

An anomalously young age of 1016 Ma is reported for the massive Westport pluton (Krogh and Hurley 1968). This is significantly younger than the age estimate of 1125 Ma reported by Silver and Lumbers (1966) for members of the quartz monzonite group, including the Westport pluton. Bell and Blenkinsop (1979) report an age of 1104 ± 15 Ma for the Addington granite, another member of the quartz monzonite suite. The Westport pluton may represent a late syntectonic or post-tectonic period of intrusive activity post-dating the quartz-monzonite suite.

Most plutons intruding the Grenville Supergroup rocks are generally concordant with regional structure, lack chilled margins, and only locally display discordant features such as dikes. Narrow thermal aureoles are developed around plutons in areas of low to moderate metamorphic grade. Outside these areas contact metamorphic effects are indistinct.

Metamorphism

Except for some late dikes of diabase, granite pegmatite, and a few small gabbro and syenite bodies, all of the Precambrian rocks have been affected by Late Precambrian metamorphism and tectonism commonly referred to as the "Grenvillian" or orogenic cycle, comprising at least two orogenic events (Moore and Thompson 1980). The latest metamorphism culminated approximately 1100 to 1000 Ma ago with the pressure-temperatures conditions of the upper almandine amphibolite facies throughout most of the area (Lumbers 1967, 1982). Granulite facies conditions were attained in parts of Frontenac Axis (Wynne-Edwards 1972) and the Ontario Gneiss Segment (Davidson et al. 1979). A major zone of greenschist facies rocks termed the Hastings "metamorphic low" occurs in the Madoc area, centred on the thickest accumulation of volcanic rocks (Fig. 2). Greenschist facies mineral assemblages are also present in thick marble sequences in McNab, Pakenham, Ramsay, and Lanark Townships, and in the marble-metavolcanic terrain in Lavant and Darling Townships south of the town of Renfrew (Carter 1981; Ewert 1978; Davidson et al. 1979). These are

defined principally by co-existing quartz and dolomite in siliceous dolomitic marbles, and albite-actinolite-chlorite assemblages in mafic metavolcanic rocks.

The Precambrian rocks have been affected by complex, multi-phase deformation, producing a strong northeasterly structural trend. A single foliation parallel to lithologic layering is predominant. Axial plane foliation is largely absent except in low grade metamorphic terrain. Northeast trending, southeast dipping fold units are the predominant structures. Locally these structures fold earlier isoclinal folds and have in turn been broadly warped about northwest trending axes.

Regional Tectonic History

Basically similar outlines of the principal elements of the tectonic history of the Grenville Province in southeastern Ontario have been presented by Sangster and Bourne (1982) and Moore and Thompson (1980). Lumbers (1982, 1967a,b) has defined the geologic history of the Renfrew County area and the Bancroft-Madoc area. The relationships can be summarized as follows:

- 1) Consolidation of a Late to Middle Precambrian metasedimentary and meta-intrusive basement gneiss complex about 1400 to 1500 Ma ago.
- 2) Deposition of the Grenville Supergroup, about 1300 Ma ago. Volcanism commenced about 1300 Ma ago in the Bancroft-Madoc area, as determined by U-Pb age dating of the lowermost

Tudor Formation of the Hermon Group. Precise ages cannot be placed on the duration of the volcanism, on the commencement or duration of sedimentation, but they are inferred to have persisted until approximately 1225 to 1250 Ma ago.

- 3) Emplacement of a varied suite of plutonic rocks between about 1250 and 1100 Ma ago, with subsequent metamorphism and deformation.
- 4) Uplift, erosion, and deposition of the Flinton Group, about 1080-1050 Ma ago.
- 5) Deformation and regional metamorphism, producing a prominent northeast-trending structural fabric. Emplacement of pegmatite dikes and sills and the Westport granitic pluton, took place about 1050-1000 Ma ago.

Two contrasting models of the depositional environment of the Late Precambrian supracrustal sequence have been proposed. Baer (1976) advocates that the stratified rocks were deposited in an aulacogen whose margins roughly correspond with the present eastern and western margins of the Grenville Supergroup. As evidence he cites the alkalalic character of the volcanic rocks, the presence of continuous adjacent sialic crust, and the limited regional extent and thickness of the assemblage. However, as noted by Moore and Thompson (1980) there is abundant alternate evidence (i.e. Sethuraman and Moore 1973; Condie and Moore 1977; Brown et al. 1975; Carter 1981) that the metavolcanic rocks in the area are tholeiitic and calc-alkalic, rather than alkalalic. The volcanic succession

reaches a thickness of at least 9 km (Lumbers 1967a,b). In addition, although presently bounded by sialic crust, the initial eastern margin of the Grenville Supergroup is unknown.

Brown et al. (1975) propose that deposition of the Grenville Supergroup is best explained by a continental collision-subduction model. Moore and Thompson (1980) and Sangster and Bourne (1982) argue in favour of this model, an opinion shared by the author. Brown et al. (1975) have documented the presence of ultramafic rocks in the Late Precambrian supracrustal sequence northeast of Madoc which they interpret as obducted slices of oceanic crust. Thus, although the sequence rests on Late-Middle Precambrian sialic basement along the northwestern margin of the area,¹ the principal exposures of the Grenville Supergroup are founded on oceanic crust.

The thick marbles of the Dungannon and Lasswade Formations were presumably deposited in a shallow sea behind the island arc formed by the volcanic complex. It is suggested (Brown et al. 1975) that the mature clastic sediments of the Flinton Group represent the first good evidence of continentally derived sediments. Young (1980) has presented evidence from a global study of Grenville age rocks that supports an ocean closure - continental collision model for the Grenville orogeny.

Moore and Thompson (1980) consider that the depositional environment of the Flinton Group is consistent with a tensional regime. This would explain the limited extent of the Flinton

Group in the area. However, further mapping is necessary to define the northeasterly extent of the Flinton Group. Further study of the mature clastic-carbonate sequences exposed in the Frontenac Axis and the Mont Laurier Basin and correlation with the Flinton Group may reveal a genetic connection.

It must be emphasized that the preceding summary of geologic events and interpretation of the tectonic setting is preliminary, as key elements of the geology of the Grenville Province in southeastern Ontario have yet to be defined. Nevertheless, it establishes the general geologic environment within which the metallogeny of the area may be considered.

Summary of Metallic Mineralization

Classification

Rocks of the Late Precambrian supracrustal succession in southeastern Ontario and neighbouring parts of Quebec and New York State contain the greatest concentration of metallic mineral deposits in the Grenville Province. With the exception of the Parry Sound area (Hewitt 1967b) only minor concentrations of metallic mineralization are known in the Ontario Gneiss Segment of the area.

Metallic mineral deposits in the area have been previously described and classified according to their geologic associations and contained metals by the author (Carter et al. 1980; Carter and Colvine 1979). Sangster and Bourne (1982) have recently proposed an incomplete classification similar to that presented here. Their descriptions of the metallic

mineralization based on the work of Sangster (1972) which the detail presented here, are incomplete in their coverage of metallic minerals, and differ significantly in some cases from the observations and interpretations presented here.

The following classification (Table 3) is based on interpretation of the processes responsible for formation of the deposits. Descriptions and discussions of each deposit type follow.

1. SYNGENETIC VOLCANIC AND SEDIMENTARY DEPOSITS

1A. Stratabound Pyritic Sulfide Deposits

Over 30 stratabound pyritic sulfide deposits are documented within Grenville Supergroup rocks in southeastern Ontario (see Table 4, Fig. 3). The deposits occur scattered throughout the area and exhibit a wide variety of lithologic associations. Associated rock types include calcitic and dolomitic marble, siliceous clastic sedimentary rocks; rusty schists; felsic and mafic schists and gneisses, and mafic and, locally, felsic volcanic rocks. Pyrite is the principal sulfide mineral at all the deposits and forms disseminated to massive layers and lenses conformable with foliation and lithologic layering in the host rocks. Pyrrhotite, sphalerite, chalcopyrite, and concentrations of gold and silver are locally abundant, usually at deposits hosted by or associated with volcanic rocks.

Although the stratabound pyrite deposits exhibit a wide variety of lithological associations, it appears reasonable to conclude they were formed by similar processes in different

Table 3. Genetic classification of metallic mineral deposits
in the Grenville Province, Southeastern Ontario

1. SYNGENETIC VOLCANIC AND SEDIMENTARY DEPOSITS
 - A. Stratabound pyritic sulfides
 - B. Stratiform zinc
 - C. Stratiform Cu-Sb-Ag-Hg-barite
 - D. Stratiform quartz-magnetite ironstone
 - E. Stratiform magnesium
2. SYNGENETIC MAGMATIC DEPOSITS
 - A. Copper-nickel
 - B. Iron-titanium
3. EPIGENETIC DEPOSITS
 - A. Contact metasomatic iron
 - B. Gold-quartz vein
 - C. Metamorphic-metasomatic molybdenum
 - D. Uranium
 - E. Post-Ordovician Ba-F-Sr-Pb veins
4. SUPERGENE DEPOSITS
 - A. Hematite

Table 4: List of Stratabound pyrite sulfide deposits in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Lithological Association</u>
Kashwakamak Lake	Barrie			
Deer Lake	Belmont	27,28	I	rusty schist, argillite, sandstone, mafic volcanics
Caldwell	Blithfield	1,2	I	mudstone, sandstone
Gunter	Cashel	23	IV	metatuff, mafic volcanic
Little Salmon Lake	Cashel	22,23	VII	mafic schist, marble, greywacke
Minktrack Lake	Clarendon	25	XIV	marble, biotite and hornblende schists, rusty schist
Mississippi	Clarendon	25	VIII	rusty schist, marble, paragneiss
Stalker	Clarendon	39	VI	rusty schist, marble, paragneiss
Swamp Creek	Clarendon	26	II	rusty schist, marble, paragneiss
Turtle Lake	Clarendon	16	XII	rusty schist, marble, paragneiss
McIlwraith	Darling	5	IV	marble, gabbro
Brockville Chemical	Elizabethtown	19	II	granitic paragneiss
Shipman	Elizabethtown	37	II	quartzite, marble, granitic paragneiss
Sloan	Elizabethtown	18	II	
Hughes	Galway	10	XVIII	dioritic gneiss, marble
Galway	Galway	16	XIV,XV	gneiss, marble, rusty schist
Munro	Dungannon	16,17	II	slate, marble, amphibolite
Turriff	Dungannon	26	III	marble
Canada Mine	Hungerford	26	XII	marble, paragneiss, mafic volcanic
Hungerford	Hungerford	23	XII	garnetiferous paragneiss, marble, mafic volcanic
Hungerford Westrn	Hungerford	21,22	XII	garnetiferous paragneiss, marble, mafic volcanic
Ontario Sulphur	Hungerford	21	XI	
Donahue Creek	Kaladar	5	IX	quartzite, paragneiss, marble, mafic volcanic
Snooks	Loughborough	7	XIV	marble
Simon	Lyndoch	1	B	mafic volcanic, felsic volcanic, gabbro
Bannockburn	Madoc	25	VI	siliceous schist, marble
Blakely	Madoc	11	XI	garnetiferous schist, mafic volcanic, felsic volcanic
Canadian Sulphur Ore	Madoc	9	X	intermediate and felsic volcanics
Davis	Madoc	10	IX	marble
Forrell	Madoc	9	VII	marble
Caverly	Marmora	26	II	rusty schist, argillite, siltstone
Myers	Marmora	28	I	rusty schist, argillite, siltstone
Bertrim	Olden	15	VI	quartzite, marble, paragneiss
Sunday Lake	Palmerston	29	VIII,IX	
Bobcaygeon	Sommerville	1	XI	dioritic gneiss, marble

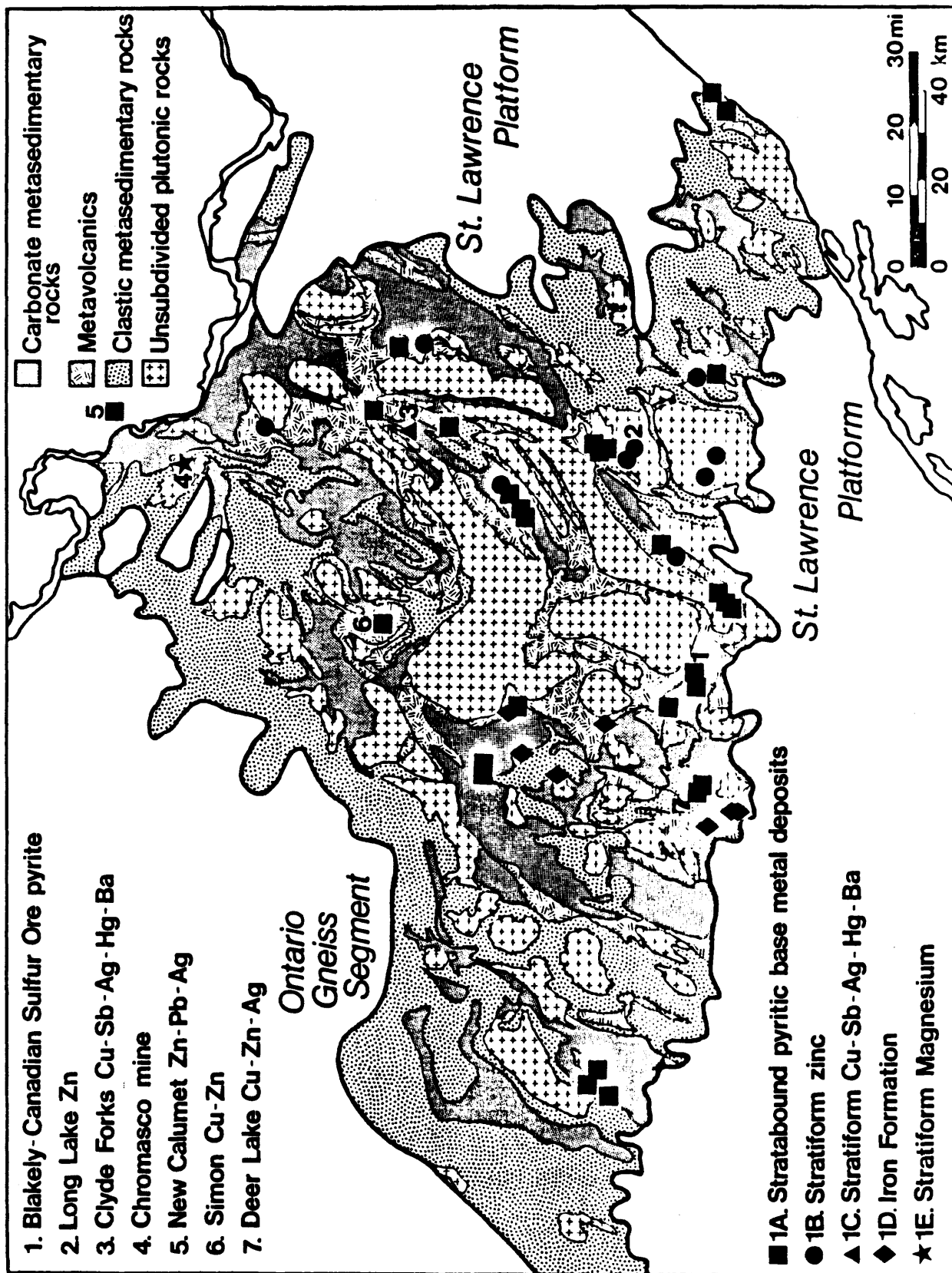


Figure 3: Distribution of syngenetic volcanic and sedimentary deposits in southeastern Ontario.

environments. Several generalizations can be made.

1. The mineralized zones are invariably conformable with lithologic layering and foliation in the host rocks.
2. Except for the Simon deposit, pyrite is the principal sulfide mineral.
3. Distribution of the deposits is stratigraphically controlled. Most occur in the upper parts of the Hermon Group or in lower parts of the overlying Mayo Group.
4. Mineralization is hosted by both metavolcanic and metasedimentary rocks. Most deposits are enclosed within siliceous clastic metasediments and are spatially related to major volcanic sequences.
5. Sulfide mineral textures are the result of recrystallization.

In detail the geological relationships are diverse. It is convenient to describe the deposits in three groups.

1. The Simon deposit in Lyndoch Township is the only example of the first type in southeastern Ontario (Simon Copper-Zinc Prospect, (mineral deposit description 1, Fig. 17) this report). It occurs within a wide belt of Hermon Group mafic metavolcanic rocks with minor intercalated marble and quartzite, that extends from Denbigh Township northwards into Lyndoch Township. There are two mineralized zones at the deposit, termed the north and south prospects. Mineralization at the south prospect, the main copper-zinc deposit, consists of disseminated to massive chalcopyrite, pyrrhotite, and minor

pyrite, and sphalerite contained in a conformable lens averaging about 3 metres thick, 180 metres long, and continuous to a depth of at least 107 metres as indicated by diamond drilling.

Mineralization at the north prospect consists of minor chalcopyrite and pyrrhotite disseminated within a lens of massive magnetite up to 1 metre thick and 5 metres long.

Amphibolite is the most common rock type at both prospects and encloses the mineralized zones. A few narrow interbeds of quartz-feldspar gneiss that may represent felsic tuffs or siliceous clastic beds occur within the amphibolites near the mineralized zones. A small body of gabbro that is part of a larger pluton has intruded the amphibolites near the two prospects, and pegmatite dikes are intrusive into all the other rock types.

2. Deposits of the second type are essentially similar except that the sulfides are generally more abundant and pyrite is the principal sulfide. Mineralization is also associated with a wider variety of rock types including marbles, metaclastics, and metavolcanics. Metavolcanics and volcanic-derived clastic metasedimentary rocks are normally present at or near most of the deposits. The Blakely and Canadian Sulphur Ore Mineral deposits description 2, Figure 17, this report) deposits are good examples of the volcanic-hosted type. Mineralized zones at the two deposits occur about 2 km apart, hosted by felsic and intermediate metavolcanic rocks within a complex succession of intercalated volcanoclastic metasediments, felsic to intermediate volcanics, garnitiferous amphibolite, and rusty

schist. Coarse felsic and intermediate pyroclastic rocks occur near both deposits. The host succession occurs at the top of a thick, locally pillowed succession of mafic metavolcanic rocks of the Tudor Formation. It is immediately overlain by a thick, bedded sequence of dolomitic and calcitic marbles and subordinate siliceous metaclastic rocks that belong to the Mayo Group (see Plates 2,3,4,5).

Pyrite is the principal sulfide mineral at both the Blakely and Canadian Sulphur ore deposits and forms disseminated to massive, faintly banded layers and lenses within a rock composed almost exclusively of cloudy white, aphanitic to fine-grained quartz. At the Canadian Sulphur Ore deposit these zones of siliceous pyrite range from 1 to 9 metres wide and up to 20 metres long, hosted by a rusty-weathering horizon within intermediate metavolcanic rocks. At the Blakely deposit it forms lenses up to 5 metres wide and 16 metres long hosted by rusty schist at the contact between felsic to intermediate metavolcanics and garnetiferous amphibolite. According to Miller and Knight (1913) the Canadian Sulphur Ore deposit is virtually free of copper, nickel, gold, lead, and arsenic. Local concentrations of sphalerite, jamesonite, chalcopyrite, and arsenopyrite, with associated gold and silver occur at the Blakely deposit (see Verschuren, this report). A selected highly mineralized surface sample collected by Verschuren contained 1.3 oz. Ag per ton, 0.03 oz. Au per ton, 8.96 percent Zn, 0.34 percent Sb, and 0.205 percent As. One of several

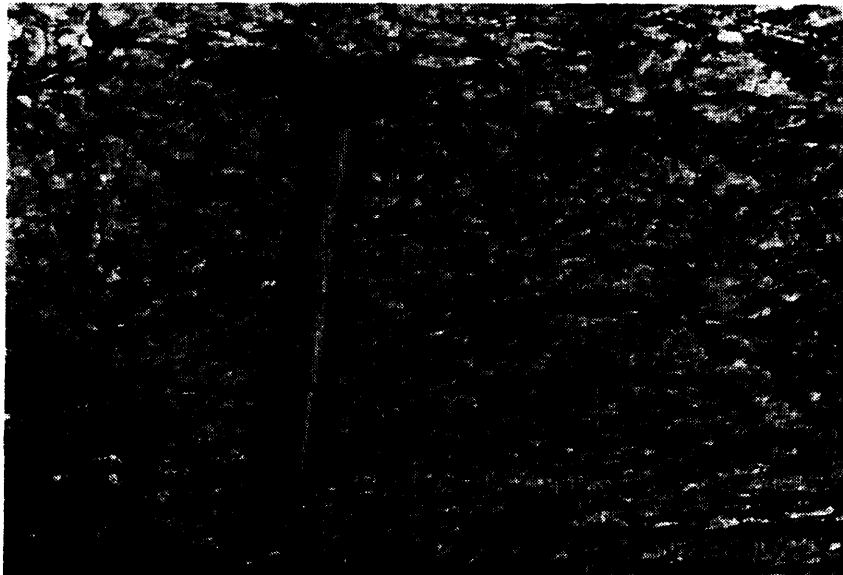


Plate 3: Felsic pyroclastic metavolcanic rock of the Blakely pyrite deposit.

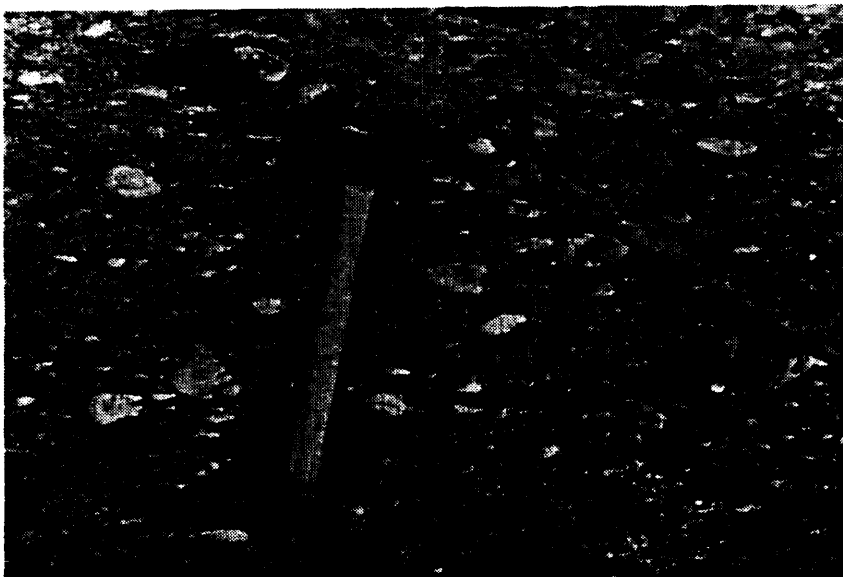


Plate 4: Volcanic derived debris flow at the Blakely-Canadian Sulphur Ore deposits. Clasts are felsic-intermediate volcanic material in a mafic matrix.

diamond drill holes completed by Syngenore Exploration Ltd. at the Blakely deposit intersected 15 cm of massive sulfides grading 297.1 oz. Ag per ton, 0.46 oz. Au per ton, 2.15 percent Cu, 5.40 percent Pb, and 3.79 percent Sb. Other deposits hosted by known volcanic rocks include the Gunter, Bannockburn, and Sunday Lake deposits.

Several deposits hosted by carbonate sedimentary rocks, include the Little Salmon Lake, McIlwraith, Hughes, Turriff, Snooks, Davis, Farrell, and Bobcaygeon deposits. The Davis and Farrell deposits lie a few kilometres along strike from the Canadian Sulphur Ore deposit, and occur at approximately the same or slightly higher stratigraphic position. At both occurrences lenses of disseminated to massive pyrite are enclosed within marble host rocks. Geologic and stratigraphic relationships are similar at the Turriff occurrence, in Dungannon Township, and the Little Salmon Lake occurrence in Cashel Township. Small amounts of arsenopyrite and chalcopyrite occur at the Turriff deposit, in addition to the pyrite. A grab sample of sulfides from the deposit is reported by Hewitt and James (1955) to have contained 0.02 oz. Au per ton and 0.25 percent copper. The McIlwraith deposit consists of a lens of massive pyrite enclosing lenses of fine-grained quartz within marble along the contact with a wide sill of gabbro. The deposit occurs stratigraphically above a major sequence of mafic volcanic rocks, termed the Joe Lake Volcanics by Carter (1981), which has been tentatively correlated with the Tudor Formation.



Plate 5: Graded beds of felsic to intermediate tuff near the Blakely pyrite deposit.



Plate 6: Laminated calcitic marble in the Long Lake area.

The Snooks, Hughes, and Bobcaygeon deposits occur enclosed within marbles in major mixed carbonate-clastic sequences. A major succession of volcanic rocks occurs in Harvey Township (Morton 1978) near the Hughes occurrence. Documented volcanic rocks are not known to occur near either the Bobcaygeon or Snooks deposits.

Several deposits are hosted by or closely associated with siliceous clastic metasedimentary rocks, including the Caldwell, Brockville Chemical, Shipman, Sloan, and Bertrim deposits. The Caldwell deposit is the largest and was mined as a source of pyrite between 1918 and 1930. Mineralization at the deposit consists almost exclusively of disseminated to massive pyrite contained in three en echelon lenses that vary up to 30 metres in width, and extend over a strike length of 366 metres. Within the mineralized zone pyrite is usually intimately intergrown with fine-grained to aphanitic grey-white quartz. At surface exposures the pyrite commonly weathers out, leaving a honeycomb matrix of quartz. According to Wilson (1921), who visited the mine while it was in operation, calcite is also a common constituent in the sulfide bodies and pyrrhotite is locally present. The mineralized zone is gradational into the country rocks and disseminated pyrite is abundant in the enclosing rocks near the sulfide lenses.

The pyrite bodies at the Caldwell deposit form conformable, lenticular deposits enclosed conformably within well-layered amphibolites in a sequence of amphibolites and

quartzo-feldspathic paragneisses. The amphibolite is composed essentially of hornblende and plagioclase, with locally abundant garnets, and is interpreted to be a mudstone unit. The paragneiss is also a well-layered rock and is composed of fine-grained quartz, feldspar, and biotite. The layering is believed to represent primary sedimentary bedding, consequently the rock is interpreted to be a sandstone. The deposit is distal from known accumulations of volcanic rocks.

The Brockville Chemical, Shipman, and Sloan deposits occur in Elizabethtown Township in the Frontenac Axis, remote from major documented volcanic sequences. All three deposits, as described by Janes (1952), consist of conformable layers and lenses of disseminated to massive pyrite enclosed within granitic gneisses of probable sedimentary origin. The gneisses are part of a metasedimentary succession that typically consists of interlayered quartzite, granitic paragneiss, and marble. The pyrite bodies are gradational into the enclosing gneisses. Calcite and pyrrhotite are commonly associated with pyrite at the Shipman prospect.

The geologic setting of the Bertrim deposit, as described by Harding (1951) is similar to the above three deposits. Mineralization consists of lenses of disseminated pyrite contained largely within quartzite. The mineralized zone is flanked by marble and greywacke and is about 15 metres wide and more than 60 metres long. A major sequence of amphibolites mapped by Wolff (1982) as mafic to intermediate metavolcanics

occurs immediately to the south.

Within the Clare River synform, the Canada Mine, Hungerford, Hungerford Western, Ontario Sulphur, and Donahue Creek deposits form a distinctive group. The former four deposits have been described by Janes (1952), Sangster (1971), Fraleck (1907), Hopkins (1916), and Wilson (1912), and the following description is summarized from these sources. The deposits occur over a strike length of about 4 kilometres along the north flank of the Clare River synform near its closure, east of the village of Tweed. They form a series of conformable lenses of disseminated to massive pyrite "within intermediate to basic gneisses between the lower basic volcanics and the first persistent marble horizon" (Sangster 1971, p.90-91). The massive portions of the Hungerford and Ontario Sulphur deposits were mined in the late 1800's and early 1900's. Only disseminated pyrite is presently exposed at the surface.

The lowermost unit in the synform near the deposits is a massive to foliated, medium-grained, locally pillowed amphibolite. This is overlain by a rock of similar, but less mafic composition which grades into a quartzo-feldspathic unit composed largely of oligoclase (60-80 percent), with subordinate quartz (20-30 percent) and biotite. Siliceous calcitic and dolomitic marble overlie the quartzo-feldspathic unit. All the mineralization observed by Sangster (1971) occurs within quartzo-feldspathic paragneiss and consists of pyrite disseminated in bands parallel to the foliation. According to

Fraleck (1907), Hopkins (1916), Wilson (1917) and Janes (1952), mineralization at the deposits consists of disseminated to massive pyrite. Calcite is reported to occur as a gangue mineral at all the deposits; pyrrhotite occurs at the Canada Mine, and quartz and pyrrhotite at the Hungerford deposit. According to Hopkins three parallel lenses of massive pyrite occur at the Hungerford deposit. The north lens was the largest and was mined over a length of 620 feet to a maximum depth of 575 feet, and varied from 6 to 22 feet in width.

The Donahue Creek prospect occurs about 20 km to the northeast within the same portion of the Clare River synform. Disseminated to locally massive pyrite and pyrrhotite form zones of gossan up to 15 metres wide within quartzose paragneisses in an alternating sequence of marble and paragneiss which lies structurally above a thick unit of mafic volcanic rocks and amphibolites. Disseminated chalcopyrite and sphalerite occurs in association with the pyrite and pyrrhotite at the prospect and a sample is reported to have contained 2.88 percent Cu and 0.16 percent Zn (McConnell 1975). A deposit of disseminated sphalerite in dolomitic marble, the Spry zinc prospect, occurs about 1 km along strike to the southwest.

3. Concordant zones of rusty-weathering schist are common throughout southeastern Ontario within supracrustal rocks of the Grenville Supergroup. Examples identified in the present study include the Deer Lake (Mineral deposit description 3, Figure 17 this report), Minktrack Lake, Mississippi, Stalker, Swamp Creek,

Turtle Lake, Galway, Caverly, Myers, Munro, and Kashwakamak Lake deposits. Numerous other similar deposits probably occur in the area but it has not been possible to document them all. Rusty schists generally consist of beds of fine-grained siliceous clastic metasedimentary rocks that contain abundant disseminated pyrite and pyrrhotite, locally abundant graphite, and minor sphalerite and chalcopyrite. Total sulfide content typically ranges from about 5 to 20 percent.

The Caverly, Deer Lake, and Myers deposits are the most economically significant and best documented. They are located about 20 km northwest of Madoc, on the boundary between Marmora and Belmont Townships. They all occur at approximately the same stratigraphic level within an extensive, complexly folded sequence of thinly bedded argillite, siltstone, sandstone, and tuffs immediately overlying a thick sequence of Huronian Group mafic metavolcanic rocks. The clastic sequence passes upwards through a mixed sequence of marbles and metaclastics into a thick carbonate succession dominated by dolomitic and calcitic marbles. The deposits consist of thick, stratiform units of rusty-weathering schist within the clastic sequence. They grade with decreasing sulphide content, into unmineralized units both across and along strike. The rusty schists consist of argillites, siltstones, sandstones, and tuff that contain disseminated pyrite, pyrrhotite, sphalerite, chalcopyrite, and graphite. In thin section the rusty schists consist essentially of a foliated intergrowth of very fine-grained to fine-grained

(0.01-0.2 mm) sericite, quartz, plagioclase, biotite, and minor chlorite, garnet, and carbonate. The sulfides occur as randomly scattered grains, or form narrow massive streaks parallel to the foliation. Some large, ragged, framboidal grains containing abundant inclusions of chlorite and sericite were also observed by the author.

Sangster (1971) has described the Kashwakamak Lake pyritic schist. It forms a stratiform unit up to 30 metres thick that extends over a strike length of about 26 km from Bishops Corners in Anglesea Township, across Barrie Township to the village of Ardoch, in Clarendon Township. It occurs within a mixed sequence of carbonate and pelitic sedimentary rocks. The schist is a rusty-weathering, thinly layered rock composed principally of quartz, white mica, graphite, and pyrite. The pyrite occurs as very fine disseminations, as narrow conformable seams, and as ovoid, nodular masses a few cm in length.

Economic Potential

Massive pyrite bodies at several of the deposits were mined as sources of sulphur in the late eighteenth and early nineteenth centuries. The first production is reported to have occurred at the Brockville Chemical Company's mine in Elizabethtown Township, starting in 1868 and continuing until 1879. Records of the quantity and grade of shipments are not available but the ore was utilized for making sulfuric acid (Janes 1952). Available records indicate production was subsequently attained from several other deposits, ceasing in

1930 with the closing of operations at the Caldwell mine of Canadian Pyrites Ltd. at Flower Station (see Table 5). All pyrite mined in eastern Ontario during this interval was utilized in the manufacture of sulphuric acid. Weathered gossan caps consisting of hematite and limonite occurred at surface over many of the deposits prior to exploration and development of the pyrite bodies. Janes (1952) reports production of 11 carloads of ore averaging 38 percent Fe from the gossan cap overlying the Bannockburn deposit, between 1898 and 1900.

Despite this past record of production, current market conditions and the size and grade of the deposits indicate they have little potential as possible future sources of iron or pyrite for acid manufacture. They are judged to have much better potential as possible sources of gold, silver, copper, and zinc as outlined below.

Anomalous amounts of copper, zinc, silver, and gold occur in many of the rusty schists in the area. The most significant concentrations are recorded in the Deer Lake and Caverly deposits. The mineralized zone at the Deer Lake deposit is thickened in the nose of a syncline within vertically to steeply dipping metasediments. The zone is approximately 600 metres long and up to 200 metres wide. A total of eight diamond drill holes ranging from less than 30 to 260 metres in length have been completed on the prospect (personal files, C.R. Young, Havelock, Assessment Files Research Office, Ontario Geological Survey, Toronto). Mineralization was encountered over the

Table 5: Summary of production from pyrite deposits in southeastern Ontario.

<u>Deposit</u>	<u>Production Period</u>	<u>Production</u>	<u>Grade</u>
Caldwell	1916-1930	5810 tons	?
McIlwraith	1899-1920	3 carloads	43% S
Brockville Chemical	1868-1879	?	?
Sloan	?	80 tons	40% S
Hungerford	1903-?	?	35% S
Ontario Mine	1908-1911	4821 tons	36.5% S
Bannockburn	1898-1900	11 carloads	38% Fe
	1900-1906	580 tons/month	40% S
Blakely	1905-1906	65 carloads	45% S
Canadian Sulphur Ore	1908-1919	?	40% S

entire length of all eight drill holes, with values ranging from 0.01 to 0.1 percent Cu, 0.04 to 1.13 percent Zn, and trace to 0.5 oz. Ag per ton. A series of representative chip samples collected by the author from the main mineralized zone contained similar concentrations of copper, zinc, and silver, in addition to trace to 0.01 oz. of Au per ton. One sample collected by the author from a surface outcrop at the southern edge of the deposit contained 0.02 oz. Au per ton, 2.74 oz. Ag per ton, 0.67 percent Cu, and 0.14 percent Zn. In addition, assays of up to 6.28 percent Zn over a core length of 30 cm are reported from one diamond drill hole.

The mineralized zone at the Caverly deposit is at least 200 to 300 metres in length and about 100 metres wide. It strikes east and dips vertically. Four diamond drill holes totalling 390 metres have been completed, one by C.R. Young and three by Coniagas Mines Ltd. Mineralization, which was encountered over the entire length of all four drill holes, yielded values of 0.01 to 0.16 percent Cu, 0.10 to 1.69 percent Zn, trace to 0.33 oz. Ag per ton.

The Caverly and Deer Lake deposits contain significant amounts of copper, zinc, silver, and gold. Based on the available assay results average metal contents of about 0.03-0.04 percent copper, 0.3-0.5 percent Zn, 0.2 oz. Ag per ton, and trace to 0.1 oz. Au per ton are estimated. Tonnage on the order of about 40 to 50 million tons is indicated at the Deer Lake deposit (Syngenore Explorations, personal files of

C.R. Young, Havelock). Both deposits are probably uneconomic at present due to their low grades but it is possible that additional exploration might reveal high-grade zones in the deposits, as suggested by some isolated assay results. More importantly, however, the Deer Lake and Caverly examples demonstrate that rusty schists shows potential for concentrations of base and precious metals of mineable size and grade. Typical widths and strike lengths of rusty schists are conducive to low-cost, open-pit mining methods, lowering the average grade requirements. Potentially large or very large tonnages may also be expected.

Types 1 and 2 of pyrite deposits are typically smaller in size, both in dimensions and tonnage, and mineralization is more massive; consequently higher grades might be expected. The most significant concentration of metals occurs at the Simon deposit where disseminated to massive chalcopyrite, pyrrhotite, and minor pyrite and sphalerite forms a conformable lens 180 metres long averaging 3 metres in thickness. This lens is estimated to contain 253,000 tons of 1.09 percent copper to a depth of 107 metres (Young-Davidson Mines, Report to Shareholders, 1966). The average zinc content has not been estimated, but representative samples collected by the author contained up to 3.4 percent zinc. The mineralized zone is reported to be open at depth.

Significant concentrations of base and precious metals, principally copper and zinc, also occur at the Blakely, Turriff, and Donahue Creek deposits, as outlined previously.

Deposits of mineable size and grade have not yet been identified in the Grenville Province in southeastern Ontario. However, the New Calumet deposit in Quebec, which is hosted by a calc-silicate horizon enclosed in mafic metavolcanic rocks of the Grenville Supergroup, produced 3.5 million tons of Zn-Pb-Ag ore between 1943 and 1969 (Sangster 1970). Its geological relationships are similar to the Simon deposit. There is judged to be a good potential for discovery of deposits of similar size in southeastern Ontario.

The observed geological relationships indicate that the sulfide mineralization was deposited contemporaneously with the enclosing metasedimentary or metavolcanic rocks, and was metamorphosed along with them. Similar conclusions were reached by Sangster (1971). Many of the deposits are closely associated with metavolcanic rocks and some occur at or proximal to recognized volcanic centres; i.e. the Blakely-Canadian Sulfur Ore deposits. Where base metal concentrations occur, copper and zinc are most common. Quartz is a common gangue mineral at many of the deposits and probably represents metamorphosed chert. These relationships are commonly accepted to be diagnostic of a volcanogenic exhalative origin, similar to deposits such as the Kidd Creek Cu-Zn-Ag mine at Timmins, in northern Ontario. Sulfides at deposits of this type are considered to have

precipitated in a subaqueous environment during quiescent periods in volcanic activity. Alteration pipes indicative of hydrothermal feeder vents have not been documented at any of the Grenville pyrite deposits, but these may have been obscured by metamorphism.

Some deposits, such as the Simon are volcanic-related, but others occur within metasedimentary sequences remote from major volcanic centres. For these, contained metals and sulfur may be sedimentary or biogenic in origin and sulphur isotopic analyses of pyrite from the deposits may help identify the source of sulphur.

Deposits in the Parry Sound area (Wilcox and Bayshore Cu-Zn (Mineral deposit description 4, this report)) and in Quebec (New Calumet Zn-Pb-Ag, Montauban Zn-Pb, Au-Ag) are considered to be similar in origin to the stratabound pyrite deposits of southeastern Ontario. The New Calumet deposit occurs within the Grenville Supergroup, but stratigraphic relationships are not defined at the other deposits. All these deposits are hosted by metavolcanic rocks or calc-silicate horizons within metavolcanic sequences. All are considered to be volcanogenic exhalative in origin.

1B. Stratiform Zinc Deposits

Geology: Nine documented zinc deposits or groups of deposits occur in rocks of the Grenville Province in southeastern Ontario. All of them occur in the eastern part of the area, within a generally north-trending belt of rocks (see Fig. 3,

Table 6). In addition, in the last five years Sulpetro Minerals has reportedly discovered other zones of zinc mineralization, both in the same belt of rocks and in other parts of the area. Except in the Long Lake area the zinc deposits are widely scattered. Consequently it has not yet been attempted to establish stratigraphic relationships between individual zones of mineralization. However, where stratigraphic relationships have been defined at individual occurrences the host rocks lie within the Mayo Group of metasedimentary rocks. All of the deposits occur remote from, and apparently stratigraphically above, major volcanic sequences.

The deposits are essentially monometallic; zinc is generally the only metal occurring in economically significant amounts, with minor amounts of lead and silver. Mineralization consists principally of sphalerite and pyrite, with minor to locally abundant galena and pyrrhotite. Common gangue minerals include dolomite, calcite, tremolite-actinolite, diopside, and quartz. The sulfides form disseminated to massive layers that are invariably conformable with compositional layering in the host rocks. The mineralization is hosted by carbonate rocks within belts of intercalated carbonate and siliceous clastic metasedimentary rocks.

In detail, the nine documented deposits have differing modes of occurrence and can be grouped into three associations, outlined below. Descriptions of the better examples of each type are included (Long Lake mineral description 5, Renprior 6).

Table 6: List of stratiform zinc deposits in
southeastern Ontario.

<u>Deposit</u>		<u>Township</u>	<u>Lot</u>	<u>Con.</u>
Renprior		Admaston	1,2	III, IV
Thirty Island Lake		Bedford	5	III
Ardoch		Clarendon	33	II
Wilkinson		Hinchinbrooke	6	XII
Spry		Kaladar	3	VIII
Clyde River		Lanark	25	VI
Benn	] Long — Lake Area	Olden	4	III
Hawley		Olden	1	VI
Mountain Grove		Olden	8	II
Smith		Olden		
Long Lake Mine		Olden	3	V, VI
Slave Lake		Sheffield	10, 11	XV, XVI

(1) At the Thirty Island Lake, Wilkinson, Slave Lake, Long Lake mine, and the Long Lake area zinc deposits, mineralization occurs within lenses and belts of coarse-grained marble contained wholly or partly within large complex igneous plutons of gabbroic, monzonitic, and granitic compositions. Calcitic marble is the predominant rock type of these marble belts, and hosts the zinc mineralization at all except the Wilkinson occurrence and one of the occurrences in the Long Lake area group. The exceptions are hosted by dolomitic marble. Dolomitic marble occurs within all the marble horizons near most of the deposits, either as well-defined lenses and locally mappable horizons, or as scattered zones gradational into calcitic marble. Siliceous layers consisting of variable proportions of quartz, diopside, and tremolite-actinolite are also common.

The Slave Lake deposit and the Long Lake mine and associated deposits of the Long Lake area were studied in some detail by the author in 1981 (see Carter 1981). Six mineralized zones identified at the Slave Lake deposit occur within a complexly deformed northwest-striking unit of calcitic marble which is a roof pendant in the Hinchinbrooke 'Gneiss', a large, circular granitic intrusion (see Fig. 4). Calcitic marble is by far the most common rock type in this marble belt, with minor amounts of dolomitic marble and a zone of amphibole-biotite-plagioclase gneiss. The calcitic marble is a white, medium- to coarse-grained (2-6 mm) rock composed

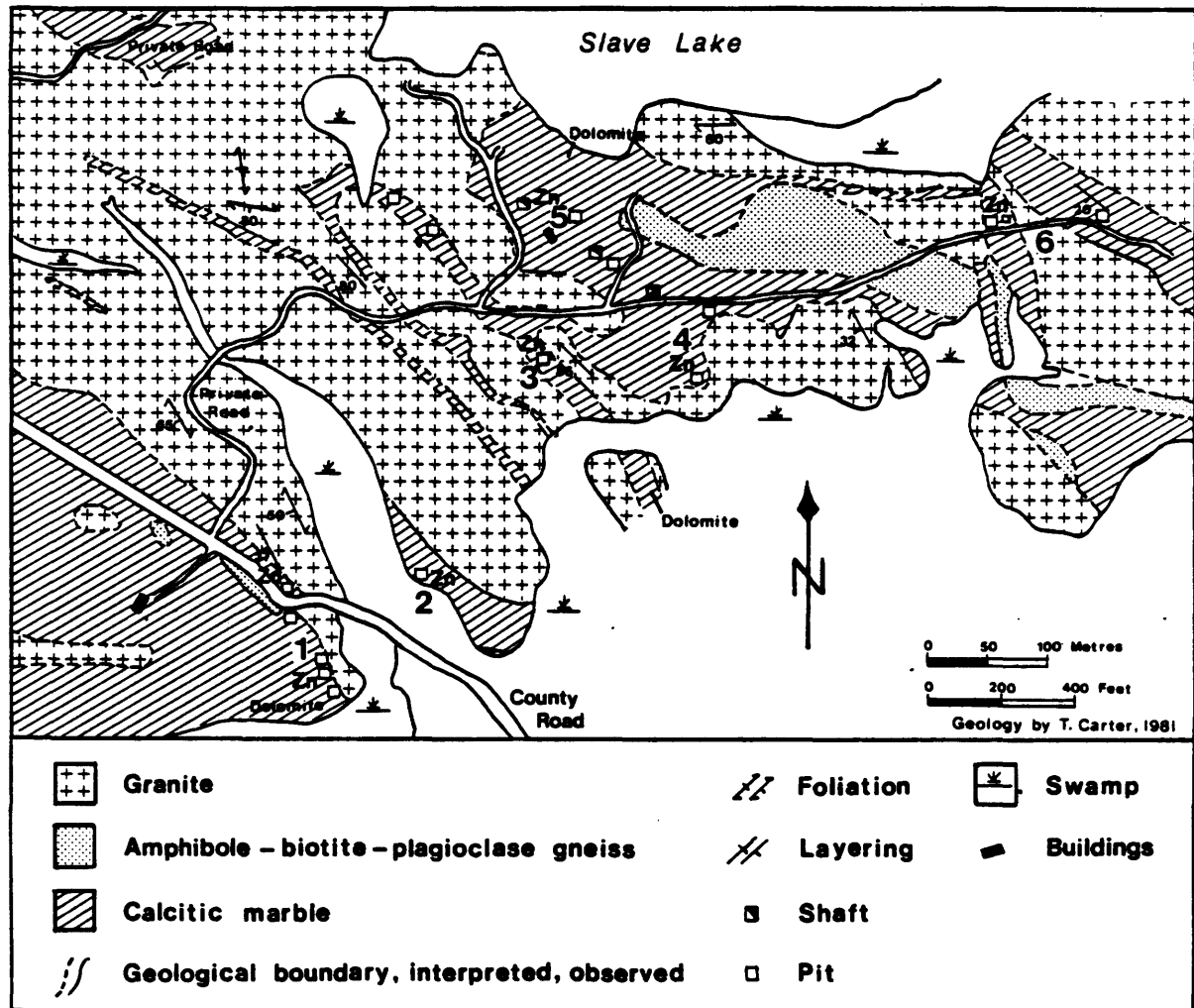


Figure 4: Geology of the Slave Lake zinc deposit.

essentially of calcite with accessory dolomite, graphite, phlogopite, serpentine, and tremolite-actinolite. The marble is massive to poorly layered, the layers being defined by variations in grain size and shades of grey. Dolomitic marble occurs in only a few outcrops and is similar to the calcitic marble, into which it is gradational.

Mineralization at the Slave Lake deposit consists of sparsely disseminated to nearly massive, medium- to coarse-grained (2-5 mm) dark brown sphalerite and subordinate pyrite in calcitic marble. The sulfides usually form well-defined conformable layers averaging 10 cm in thickness and containing approximately 30 percent sphalerite. A chip sample across such a layer in zone 2 contained 19.6 percent Zn, 42 ppm Pb, and less than 0.1 oz. Ag per ton. A grab sample of massive sulfide mineralization collected from a surface dump in zone 2 contained 44.3 percent Zn, 17 ppm Pb, 430 ppm Cu, and 980 ppm Cd. The maximum exposed width of zinc mineralization at the deposit is 2 metres, in a pit in zone 4. Lengths of the mineralized zones are usually not as well defined, but in zone 1 zinc mineralization was observed sporadically over a strike length of at least 100 metres.

In the Long Lake area zinc mineralization was observed in outcrop in five different places by the author (Fig. 5, nos. 1-5) including the Long Lake mine deposit (No. 3), and within isolated marble boulders in 2 locations (nos. 6 and 7). The deposits occur within a belt of marble which forms a large

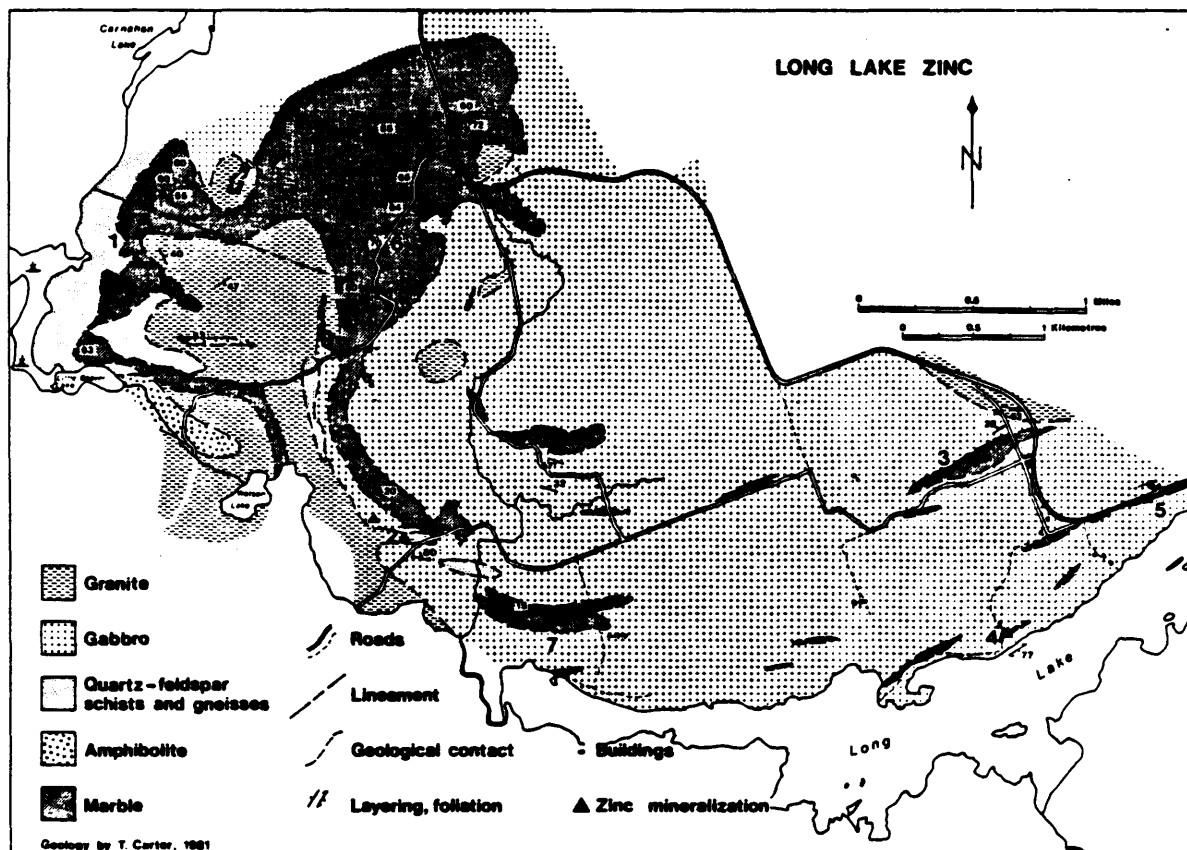


Figure 5: Geology of the Long Lake area.

embayment within the western flank of the Mountain Grove gabbro, and also occurs as a series of discontinuous lenses scattered throughout the southern margin of the intrusion. The marble lenses are elongate parallel to the contacts of the pluton, conformable with foliation in the gabbro and layering in the marble. Four major types of marble are identified: 1) very coarse-grained (>1 cm) calcitic marble, 2) thinly laminated calcitic marble, 3) layered siliceous calcitic marble, and 4) dolomitic marble. The four types usually grade into one other. They are not subdivided on the geological map (Fig. 5) due to the scale, but locally the different marble types can be traced over considerable distances (see Plate 6, 7).

Mineralization generally occurs in conformable layers as consists of variable amounts of disseminated, dark brown to black sphalerite, pyrite, and locally abundant pyrrhotite, often with abundant associated diopside and/or tremolite. Mineralization is hosted by calcitic marble at occurrences 1, 2, 3, and 4, usually within or in association with siliceous layers or lenses on the marble. At the Long Lake mine (no. 3) the mineralized zones are transitional along strike into siliceous layers in the marble. Dolomitic marble occurs close to occurrences 1, 2, and 4, and some minor amounts of sphalerite occur within dolomitic marble at showing no. 2. At showing no. 5 the zinc mineralization occurs within a calc-silicate lens contained within well-layered dolomitic marble. The associations are not clear but in general it appears that zinc



Plate 7: Laminated siliceous calcitic marble, consisting of alternating pure calcite and tremolitic calcite marble.

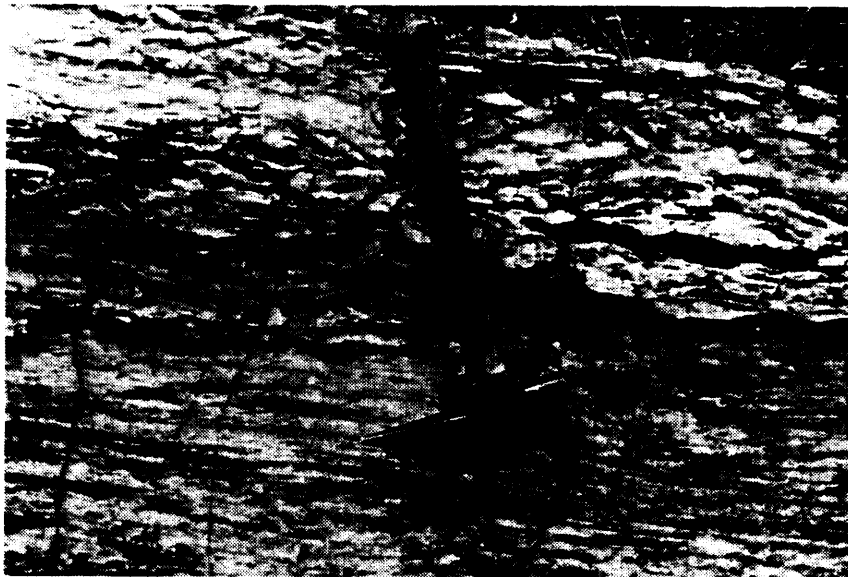


Plate 8: Siliceous bed (quartz-tremolite) in dolomitic marble near the Spry zinc occurrence, Kaladar Township.

mineralization in the Long Lake area occurs preferentially in association with siliceous zones in calcitic (less commonly dolomitic) marble, often near minor layers or lenses of dolomitic marble. However, it should be noted that no known outcrops of dolomitic marble occur near the Long Lake mine.

(2) At the Renprior, Clyde River, and Spry zinc occurrences, mineralization consists of conformable layers, lenses, and poorly defined zones of disseminated to massive sphalerite, pyrite, and rare galena in dolomitic and siliceous dolomitic marble. Discrete siliceous lenses and layers often occur within the host marbles (Plate 8). Silicate mineralogy is appropriate to regional metamorphic grade and may include diopside, tremolite-actinolite, quartz, serpentine, and phlogopite-muscovite. The host rocks occur within successions of intercalated calcitic and dolomitic marbles, siliceous marbles, paragneisses, and rare quartzites. Mafic rocks interpreted to be volcanic in origin occur near all these deposits, at stratigraphic positions underlying the mineralized zones. However, all these deposits are remote from known volcanic centres.

The Spry zinc deposit occurs within the central portion of the Clare River synform. It is hosted by siliceous dolomitic marble within a succession of intercalated calcitic marble, dolomitic marble, siliceous dolomitic marble, and metasandstone (see Fig. 6). There are two mineralized zones. The main zone consists of several parallel, stratiform layers of disseminated

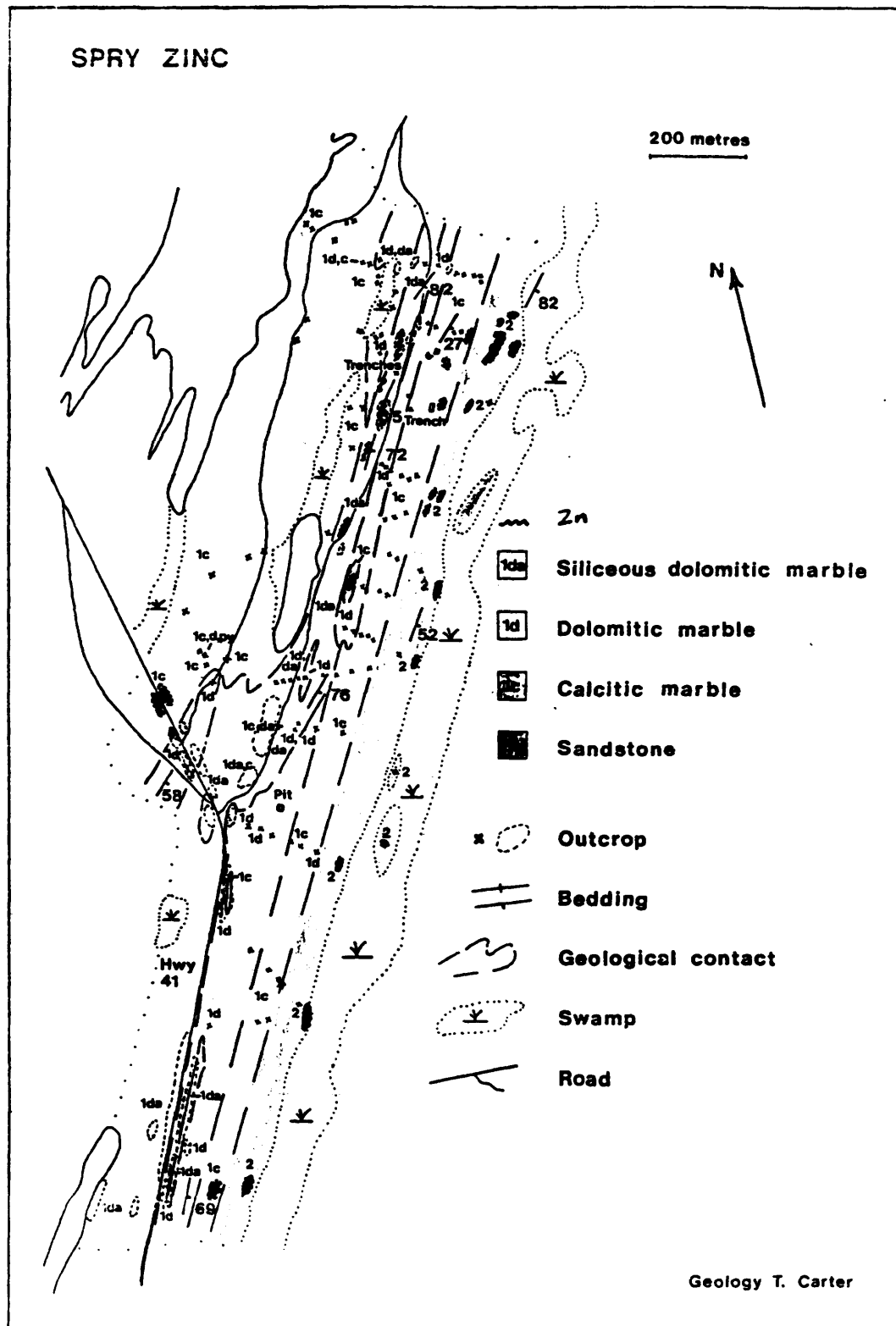


Figure 6: Geology of the Spry zinc deposit.

dark yellow to light brown sphalerite with very minor pyrite within well-layered siliceous dolomitic marble (Plate 9). Mineralization occurs over widths of up to 5 metres and has been traced continuously along strike for at least 500 metres. A representative chip sample across 5 metres of the main zone contained 3.88 percent Zn, 10 ppm Pb, and trace amounts of Ag. A grab sample taken from the richest mineralized layer contained 19.8 percent Zn, 78 ppm Pb, 186 ppm Cu, 840 ppm Cd, and trace Ag. The second mineralized zone occurs 700 metres to the south and consists of a narrow (3-10 cm) stratiform layer of disseminated dark grey sulfosalt grains, probably zinkenite, and a few very thin layers of disseminated, light yellow sphalerite. A grab sample of well-mineralized marble collected by the author contained 9600 ppm Pb, 9000 ppm Zn, 5000 ppm Sb, and 0.60 oz. Ag per ton.

The Renprior zinc deposit occurs within a series of intercalated dolomitic, calcitic, and siliceous dolomitic marbles, and paragneisses, similar to the Spry deposit. Mineralization consists of disseminated sphalerite, pyrite, and rare galena contained in stratiform layers. In general, the mineralization is spatially related to the boundaries of dissimilar rock types, such as calcitic and dolomitic marbles, and occurs in elongate, easterly plunging lenses containing up to 29 percent Zn. Four zones of mineralization have been outlined along a strike length of 1000 metres. The geology and mineralized zones are described in detail by Robertson (mineral



Plate 9: Stratiform layers of disseminated sphalerite (dark) in siliceous dolomitic marble, at the Spry zinc occurrence in Kaladar Township.



Plate 10: Fragment of a laminated, siliceous bed in dolomitic marble at the Madoc talc mine, in Madoc Township. It may represent a metamorphosed stromatolite.

deposit description 6, this volume).

(3) The Ardoch zinc occurrence occurs within a sequence of intercalated paragneiss and calcitic, dolomitic, and siliceous dolomitic marble. It is similar to the second group of deposits except that the mineralization is hosted by calcitic marble. The calcitic marble host rock is a very fine-grained (<1 mm), very thinly layered (<1 cm) rock with accessory amounts of tremolite, muscovite, quartz, and graphite. Mineralization consists of dispersed fine grains of sphalerite and pyrite which occur in scattered, discontinuous, narrow layers in the marble. The sulfide layers are generally less than 1 cm wide, varying up to a maximum of 10 cm in width, and are conformable with the layering in the marble. Individual layers can only be traced for a few metres and occur sporadically over an area several hundred metres in length.

Similar deposits: Similar relationships are observed in the better exposed and more intensively studied zinc deposits of adjacent portions of the Province of Quebec and the State of New York. The ore deposits of Balmat-Edwards area of New York constitute the most economically important metallic mineral deposits in the Grenville Province. The deposits occur within the Grenville Supergroup near the eastern margin of the Adirondack Lowlands. In the Balmat area orebodies occur on the northwest side of a band of gneiss which is continuous to the Edwards area 16 km to the northeast. The Edwards orebodies occur on the southeast side of the gneiss. In both areas

orebodies consist of stratiform layers and lenses of disseminated sphalerite and pyrite, with minor amounts of galena, pyrrhotite, and chalcopyrite. Gangue minerals in the ore zones include quartz, calcite, dolomite, barite, anhydrite, and diopside and tremolite which are often altered to serpentine and talc. In the Balmat area the known ore-bearing horizons occur over a stratigraphic range of approximately 550 metres within a repetitive sequence of metasedimentary rocks characterized by alternation of almost pure dolomites and very siliceous units. Lenses and layers of quartz, serpentine-diopside, and diopside are not uncommon in the 'pure' dolomites. The siliceous units include dolomitic and calcitic marbles, serpentinous or siliceous marbles, and quartzose and micaceous rocks. A pyritic schist occurs near the base of the sequence. A major unit of tremolite-anthophyllite-serpentine-talc schist, which is the source of all talc mined in the area, occurs near the top of the sequence and can be traced from Balmat to Edwards. Purple anhydrite occurs erratically in the schist, becoming more abundant at depth. At the 2100 foot level in the Balmat No. 2 mine pure anhydrite occupies the entire 15 metre horizon. There is no apparent lithologic control on localization of orebodies; mineralization is hosted by both 'pure' dolomites and siliceous dolomitic units. Rather, analysis of mine structures (Lea and Dill, 1968; Dill and DeLorraine 1978) indicates that orebody sites are principally controlled by structure.

The detailed studies conducted by several workers in the Balmat-Edwards area (Lea and Dill 1968; Dill and DeLorraine 1978) suggests that the mineralization was deposited as at least 15 stratabound massive sulfide bodies, syngenetically with their enclosing sediments. The repetitive nature of the stratigraphic sequence probably reflects repetition of favourable depositional conditions at several time intervals. The present complex geometric patterns of the orebodies are believed to be the result of subsequent metamorphism and deformation.

In the Grenville Province in Quebec, detailed mapping along the western margin of the Mont Laurier Basin, (Gauthier and Brown 1979, 1980) indicates that 'monometallic' zinc deposits in the area occur at specific stratigraphic horizons, possibly a single horizon (Gauthier 1982), within a succession of clastic and dolomitic and calcitic carbonate metasediments. The principal concentrations occur within calc-silicate horizons (siliceous dolomite) at the transitional contact between metaclastic beds and dolomitic marble. The deposits occur distal from any major volcanic sequences, although amphibolite horizons are known to occur near some of the deposits. Mineralization consists of massive sphalerite, with pyrite, pyrrhotite, and minor chalcopyrite, and galena. Disseminated sphalerite and minor galena sometimes occur within the dolomitic marble. The mineralized zones are conformable with their host rocks. In proposing a sedimentary and/or diagenetic model for

deposition Gauthier and Brown (1980) stress the lithological and local stratigraphic controls on localization. Gauthier further (1980) proposes that they are submarine exhalations in origin.

Summary and Discussion: Stratiform zinc deposits in southeastern Ontario exhibit a variety of geological relationships, but have several common features. The deposits are (1) hosted by carbonate metasedimentary rocks in mixed carbonate-clastic sequences; (2) are commonly associated with siliceous zones in the marbles; (3) are remote from major volcanic centres; (4) have been metamorphosed, with metamorphic mineral assemblages similar to their host rocks; (5) have a simple sulphide mineralogy - principally sphalerite and pyrite; and (6) have mineralized zones that are fundamentally stratiform and conformable with their host rocks.

These relationships resemble those exhibited by the Quebec and New York deposits, and it is reasonable to assume that the three groups of deposits were formed by similar processes. The observed geological relationships indicate that sulphide mineralization was deposited contemporaneously with the enclosing carbonate sediments and has been metamorphosed and deformed along with them. Similar conclusions were reached by Gauthier (1982) and Gauthier and Brown (1979, 1980) about the Quebec deposits, and Lea and Dill (1968), Solomon (1963), and Dill and DeLorraine (1978) about the Balmat-Edwards deposits.

Several workers, conducting independent studies in three separate areas have therefore arrived at similar conclusions as

to the stratiform nature and synsedimentary mode of formation.

The source of the metals is still largely speculative. Lead isotope data (Fletcher and Farquhar 1982; Farquhar and Fletcher 1980) indicates contained lead was originally mantle derived, suggesting a volcanic origin, but allowing for up to 300 Ma of sedimentary reworking. Although metavolcanics and amphibolites occur near most deposits, these are distal from recognized volcanic centres. Volcanic related hydrothermal activity has resulted in concentration of mineralization in southeastern Ontario (see 1A), but no direct link is seen with the carbonate-hosted zinc deposits.

The common association of the zinc deposits with siliceous zones in the marbles may be genetically significant. Unfortunately the origin of the siliceous zones has been obscured as a result of metamorphism and deformation. They may represent quartzite beds, chert horizons, silicified stromatolite beds, or alteration zones, each of which is suggests a different environment or mechanism of formation (see Plate 10, 11). The association of zinc orebodies with an anhydrite horizon at Balmat, which is generally interpreted to be a meta-evaporite, may be more definitive. Anhydrite is a common gangue mineral in the Balmat zinc ores and has also been reported to occur in the subsurface at the Renprior zinc deposit (Robertson, this paper). Its apparent absence near other documented occurrences may be deceptive; it may be absent as a result of dissolution due to surface weathering. This argument

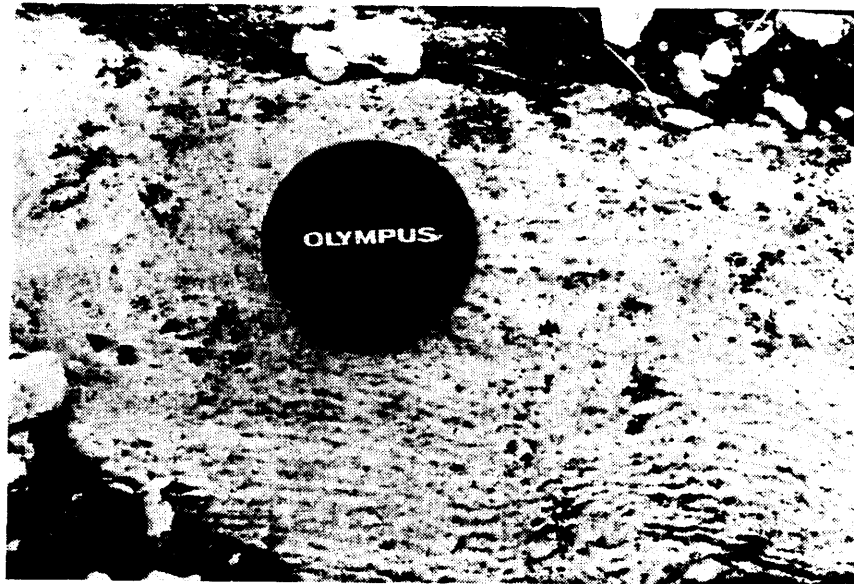


Plate 11: Laminated, siliceous rock at the Madoc talc mine that may be a metamorphosed stromatolite horizon.



Plate 12: Mineralized quartz vein in sheared gabbro at the former Cordova gold mine.

is made more compelling by the fact that anhydrite occurs only in the subsurface in the Balmat-Edwards area and at the Renprior deposit. The association with meta-evaporites suggests the sulfide deposits may have formed in a tidal mud-flat, or sabkha-type environment (Foose 1980; Renfro 1974). The tendency for association with dolomitic rather than calcitic marble is supportive of this interpretation. However it would be premature to conclude that this was the case. Comparisons with more widely recognized deposit types may assist in the understanding of localization of the Grenville zinc mineralization. For example, while terminology is not fully agreed upon in this field of sedimentary mineral deposits, these might be best considered as syngenetic, stratiform, carbonate-hosted zinc deposits; an increasingly recognized group of deposits in which synsedimentary hydrothermal exhalative activity is considered responsible for metal concentration (e.g. Morganti 1981; Krebs 1981; Gustafson and Williams 1981). In such areas as the Selwyn Basin, mineralization clearly related to basinal facies and structures is often closely associated with beds of barite. In the shale-hosted platform marginal type of lead-zinc deposit as defined by Morganti (1981) mineralization is simple, dominantly sphalerite and galena, with less than 5 percent pyrite, minor copper, and no association with major barite units. Deposits are localized in small sub-basins within base-of-slope facies adjacent to carbonate platforms. Faults along the platform margin are believed to

have served as conduits for hydrothermal discharge. Possible feeder vents such as these are either absent or have not been recognized in the Grenville deposits. Intense deformation of the rocks and their variable composition complicate recognition of associated alteration commonly accepted as evidence of such hydrothermal vents. For example, it is difficult to establish the presence of silicification in rocks which are commonly siliceous dolomites and have been subsequently metamorphosed to calc-silicate assemblages. Barite is noted to occur at Balmat but has not been recognized as a significant constituent at other deposits. However, analytical work by Papertzan and Kingston (1982) does show some barite concentrations in Grenville marbles in Ontario, and a stratiform barite-base deposit occurs in Lavant Township (mineral deposit description 7, this volume).

The Grenville carbonate-hosted deposits are not direct analogies of the 'shale-hosted' deposits, however the similarities are intriguing. Definition of primary sedimentary features in the Grenville Supergroup on both local and regional scales could assist in better definition of lithologic, stratigraphic, and particularly of structural and sedimentological settings favourable for zinc deposition. Generalized attempts at paleo reconstruction of the Central Metasedimentary Belt, such as on the basis of magmatic styles (i.e. Brown et al. 1975), are interesting but are not definitive. Additional work is necessary to establish more

useful guidelines to locations Grenville stratiform zinc deposits.

Exploration Techniques

In Ontario seven of the nine documented stratiform zinc deposits have been discovered by surface prospecting starting with discovery of zinc mineralization in surface outcrops at the Long Lake zinc mine, in 1897 (see Table 7). In New York State workmen quarrying for road-building materials accidentally uncovered part of the Edwards ore zone in 1903 (Lea and Dill 1968). Regular production began in 1915. Zinc mineralization had been noted as early as 1838 in surface outcrops in the Balmat area and in 1927 diamond drilling led to the discovery of the Balmat No. 2 orebody. Mining started in 1930 (Lea and (Lea and Dill 1968).

More recently, in 1981, the author located two new surface occurrences of disseminated sphalerite and pyrite in outcrop and in two boulders during geological mapping in the Long Lake area (Carter 1981). In Quebec, several new zinc occurrences are reported to have been discovered since 1977 as a result of surface prospecting in connection with geological mapping in the vicinity of previously known deposits (Gauthier and Brown 1979, 1980; Gauthier 1978). Sulpetro Minerals Ltd. has also recently found new, as yet undocumented, occurrences of zinc mineralization in Ontario using a combination of geochemical, geological, and surface prospecting techniques.

Table 7: Summary of lithological associations and discovery methods of documented stratiform zinc deposits in southeastern Ontario.

Deposit	Township	Host Rock	Associated Rock Types	Discovery Method	Date
Renprior	Admaston	siliceous dolomite	dolomite and calcite marble, metaclastics	surface prospecting	1922
Thirty Is. Lake	Bedford	calc-silicate and calcite marble	gabbro	surface prospecting	before 1947
Ardoch	Clarendon	calcite marble	dolomite, siliceous dolomite metaclastics	lake sediment and soil chemistry	1978
Wilkinson	Hinchinbrooke	dolomite marble	calcite marble, monzonite	surface prospecting	before 1947
Spry	Kaladar	siliceous dolomite	dolomite and calcite marble, metaclastics	surface prospecting	1952
Clyde River	Lanark	dolomite marble	calcite marble, gabbro	boulder train prospect, till geochemistry	1975
Long Lake area	Olden	calcite and dolomite marble	gabbro, calc-silicate, siliceous calcite, monzonite	surface prospecting	before 1947
Long Lake mine	Olden	siliceous layers in calcite marble	gabbro, monzonite	surface prospecting	1897
Slave Lake	Sheffield	calcite marble	granite, dolomite, marble, amphibole gneiss	surface prospecting	1915

In all three of these recent examples, 'zinc zap', a zinc indicator solution made by combining solutions of 3% potassium ferricyanide, 3% oxalic acid, and 0.5% diethylaniline, has been found to be an invaluable aid in identifying zinc sulfides in weathered outcrops. The importance of careful geological mapping must also be emphasized. In the case of the Renprior zinc deposit extensive exploration between 1922 and 1972 including trenching, geological mapping, geochemical and geophysical surveys, and approximately 6100 metres of diamond drilling in nearly 100 holes had resulted in delineation of only 16,000 short tons of mineralization grading 10.5 percent zinc (Carter et al. 1980; Robertson, this volume). Sulpetro Minerals Ltd. acquired the property in 1978 and guided by very careful mapping has been able to establish the presence of approximately 280,000 metric tons of 9 percent zinc in four zones.

Geochemical methods (soil, stream sediment surveys) have also proven to be effective at all scales of exploration both in Quebec and Ontario. Zinc has proven to be the best pathfinder, but lead and mercury were found to occur within the A and B soil horizons over zones of significant mineralization at the Long Lake mine (Brown 1976). At the Ardoch occurrence an anomalous content of Zn, Cu, As, Mo, and Ag in lake sediments attracted the attention of St. Joseph Explorations Ltd. Mineralization in bedrock was located following a program of geological mapping, and prospecting and trenching in the vicinity of a zinc anomaly located in the B soil horizon. The Clyde River prospect was

located as a result of glacial boulder train prospecting, geochemical sampling of the zinc content of basal tills, and diamond drilling. Litho-geochemical surveys have not proven to effective.

Geophysical techniques have not been successful in locating or delineating zones of zinc mineralization. Methods employed include vertical magnetics, induced polarization, spontaneous polarization, gravity, EM16, and tellurics (Brown 1976; Gauthier and Brown 1979).

In summary; 1) geophysical methods do not aid finding stratiform zinc deposits in marble; 2) geochemical methods, especially soil, stream, and glacial till sampling, are effective at all scales of exploration; 3) surface prospecting has historically and recently proven to be the most effective exploration method; and 4) careful geological mapping and interpretation is indispensable in the exploration for and delineation of zones of zinc mineralization.

Economic Potential: Stratiform zinc deposits are probably the most significant type of base metal mineralization in southeastern Ontario. Significant production has been obtained from the Long Lake mine; 94,631 short tons of ore averaging 11.6 percent zinc were mined and milled from March 1973 to December 31, 1974 (Ministry of Natural Resources, Toronto, Mineral Statistics Section). In New York, there has been continuous production from the zinc deposits in the Balmat-Edwards area since 1915. Production to 1979 totalled approximately 25

million tons of ore containing about 10 percent zinc and minor lead with an equal amount of reserves remaining (personal communication 1979, W.J. Cropper, St. Joe Zinc Company).

The past history of production, the large number of documented occurrences, and the favourable geology indicate there is a good probability that zinc deposits of economic significance will occur in Grenville Supergroup rocks in southeastern Ontario.

1C. Stratiform Cu-Sb-Ag-Hg-Barite Deposits

The Clyde Forks prospect (mineral deposit description 7, this volume) is the only deposit of this type in the area. It consists of a conformable lens of disseminated tetrahedrite, chalcopryrite, and pyrite with associated barite, and rare stibnite, arsenopyrite, chalcostibite, and getchellite contained within calcitic marble. Associated rock types include biotitic dolomite, amphibolitic and biotitic quartzo-feldspathic paragneisses, and an irregular mass of tourmaline-bearing pegmatite. Except for the pegmatite the rocks are stratified and are interpreted to represent a metamorphosed sequence of intercalated carbonate and siliceous clastic sedimentary rocks. Mineral Deposits description 7 is a detailed description of the deposit. Reference should also be made to Nikols (1972).

The conformable nature of the mineralized zone suggests that the deposit formed synchronously with the enclosing sedimentary rocks. Nikols (1972) proposed that the mineralization was precipitated from a series of hydrothermal

springs discharging into a subaqueous carbonate depositional environment. Similar sedimentary sequences are common throughout the Grenville Supergroup yet no other occurrences of a similar nature are documented. Consequently it is not possible to define the specific sedimentary environment favourable for localization, or provide geological guidelines for exploration.

Alternatively the Clyde Forks deposit may represent a metamorphosed stratiform vein correlative with stratibound quartz-dolomite vein networks of the 3B group. This is considered unlikely due to the lack of quartz in the mineralized zone but cannot be dismissed.

Diamond drilling of the Clyde Forks deposit has indicated the presence of approximately 60,000 tons of material grading 0.67 percent Cu, 0.37 percent Sb, 0.03 percent Hg, and 1.32 oz. Ag per ton in a lens approximately 400 feet long, 5.2 feet wide, with a down-dip extent of at least 600 feet (Northern Miner, April 2, 1970, Vol. 56, No. 2). Estimates of average barite content are not available. Soil and stream geochemical surveys completed by several companies have outlined copper, mercury, and zinc anomalies near the known mineralized zone. Most of these have never been examined. It seems reasonable to expect that other occurrences, possibly of more significant size and grade, may occur nearby. Available records also indicate that the main mineralized lens of the Clyde Forks deposit is open both along strike and down-dip.

1D. Stratiform quartz-magnetite ironstone

Quartz-magnetite ironstones are rare and are restricted to greenschist and lower amphibolite facies metamorphic terrain in southeastern Ontario, centred on the thickest accumulation of volcanic rocks in the area. The principal concentrations occur in the Belmont and Turriff volcanics, in Belmont and Limerick Townships respectively. Additional small occurrences occur in Tudor and Cashel Townships (see Table 8, Fig. 3).

The ironstones typically consist of narrow, parallel layers and discontinuous lenses of fine- to medium-grained magnetite a few mm. to cm. thick, alternating with layers of fine-grained cherty quartz. Pyrite, chlorite, amphibole, and epidote are common accessory minerals. Jasper, hematite, and specular hematite occur in some of the Belmont ironstones (see Belmont Township Ironstone Occurrences, Mineral Deposit description 8, this report). The ironstone units are closely associated with volcanic rocks at all the occurrences and are interbedded with mafic metavolcanic rocks at most of the occurrences. They also are intercalated with calcitic marble, at the Deer River Occurrence, with both mafic and felsic metavolcanics at the Limerick Township occurrences, and are gradational into rusty schist at the Cashel Township occurrence.

The Belmont Lake ironstone is the most extensive of the southeastern Ontario iron deposits. It is approximately 15 to 18 metres wide and has been traced along strike for about 400 metres (see Belmont Township Ironstone, this report). A sample

Table 8: List of copper-nickel deposits in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Host Rock</u>
Belmont Lake	Belmont	20	IV	mafic volcanic
Deer River	Belmont	25	III	calcitic marble
Round Lake	Belmont	25	VI	mafic volcanic
West Belmont Lake	Belmont	15	V	mafic volcanic
Cashel	Cashel	16	IX	rusty schist
Two Mile Lake	Limerick	14	VIII	mafic, felsic volcanics
Ormsby Junction	Limerick	28	VI	mafic, felsic volcanics
Molra River	Tudor	13	X	mafic volcanic

of this ironstone analysed by Miller and Knight (1913) contained 24.06 percent Fe, 0.024 percent S, and 0.126 percent P. Average iron contents of the other ironstone occurrences are also generally low.

The geological and mineralogical features of these southeastern Ontario ironstones are characteristic of oxide-facies Algoman-type iron-Formation as described by Gross (1965). Algoman-type iron-formation occurs in nearly all Early Precambrian belts of supracrustal rocks in the Canadian Shield, and is intimately associated with volcanic rocks. It typically consists of "interbands of ferruginous grey or jasper chert and hematite and magnetite" (Gross 1965, p.90). Single iron-formations may be up to a few kilometres in length and a few centimetres to a few hundred metres thick.

Gross (1967, p.84) noted the presence of oval-shaped rings of iron oxides that resemble metamorphosed granules and oolites in thin sections of the Belmont Lake ironstone unit. This is uncharacteristic of Algoman-type iron-formation and is more typical of Superior type. However, the other major features of Superior-type iron-formation are unlike the Belmont Lake deposit; association with quartzite and black shale, lateral continuity for up to hundreds of kilometres. Rather, the structures observed by Gross may simply represent local shallow water conditions favourable for formation of oolites and granular textures, or they may not be oolites.

No production has been attained from any of the documented ironstone units in southeastern Ontario. There appears to be little potential for discovery of economically significant deposits of this type in the area. Their principal value is as local stratigraphic marker horizons that may be useful in the search for other types of stratabound mineral deposits.

1E. Stratiform Magnesium

The only magnesium production in Canada comes from Chromasco Limited near the village of Haley Station north of Renfrew. The mine and processing plant have been in production since 1942 with a current annual capacity of approximately 10,000 to 12,000 tons of high-purity magnesium metal per year. The plant utilizes the Pidgeon process (Pidgeon 1944) to recover magnesium metal from dolomitic marble.

Dolomitic marble is mined from two open pits near the processing plant. It is very uniform in composition and is very pure. The range in composition of 13 analyses of dolomitic marble quoted by Pidgeon (1944) is 20.48 to 21.55 percent MgO, 30.85 to 31.95 percent CaO, 0.25 to 0.65 percent insoluble, 0.25 to 0.60 percent R_2O_3 , and 46.8 to 47.1 percent loss on ignition. As originally defined the marble deposit had an indicated length of 1070 metres and a width of 76 metres (Satterly 1945). A detailed description of the deposit is included in part 2 of this report (see Chromasco Magnesium Mine, Mineral Deposit description No. 9).

Dolomitic marbles of this type in the area appear to have formed in situ as a result of primary sedimentary processes or immediately succeeding diagenesis. Principal evidence are the sharp contacts and primary sedimentary structures such as regular lithologic laminations that are preserved in most of the dolomites. Cross-cutting zones of dolomite are known to occur but these are atypical and represent a different mode of formation from the bedded dolomites. In present-day sedimentary environments primary dolomites form in tropical, shallow-water, intertidal mud flats or sabkhas. By analogy Grenville bedded dolomites may represent a similar environment, or they may have formed under marine conditions not seen today.

The economic potential for increased magnesium production from Grenville marbles in southeastern Ontario appears to be limited primarily by market conditions and the high capital costs and operating expense of magnesium extraction. Dolomitic marble is very common in the Grenville Supergroup throughout southeastern Ontario. There appears to be no shortage of suitable raw materials even of the exceptional purity needed. Other economic deposits have not been defined but this appears to be due to lack of exploration for the reasons outlined above.

Extensive marble sampling programs completed by Storey and Vos (1981) and Papertzan and Kingston (1982a, 1982b) in southeastern Ontario revealed numerous occurrences of very pure dolomitic marbles. These publications contain nearly 3000 chemical analyses of Grenville marbles in the area and should be

useful guides to exploration.

2A. Copper-Nickel Deposits

Low-grade deposits of copper-nickel mineralization occur in several places in southeastern Ontario (see Table 9, Fig. 7). Mineralization is fairly consistent at all occurrences, consisting principally of pyrrhotite, chalcopyrite, pentlandite, and pyrite. The relative proportions of the sulphides vary but pyrrhotite is usually the most common, and pyrite is the least abundant. The sulphides form disseminated to-locally-massive pods or lenses within gabbroic host rocks. The principal concentrations are confined to several large, early, gabbroic intrusive complexes: the Thanet, Mountain Grove, Lingham Lake, and Raglan Hills intrusions.

The Raglan and Mountain Grove complexes have been metamorphosed to middle to upper amphibolite facies, substantially altering the original mineralogy and textures of the intrusive rocks. The predominant rock type in both intrusions is medium- to coarse-grained, massive to gneissic metagabbro composed of variable proportions of hornblende and plagioclase. Accessory minerals in the Raglan Hills complex include sphene, apatite, carbonate, zircon, quartz, olivine, and hypersthene (Hewitt 1954). Wolff (1982) reports accessory apatite, and pyrite in the Mountain Grove intrusion. Hornblende is common around the margins of the Raglan Hills complex and metapyroxenite and olivine metapyroxenite occur at scattered locations in the central part of the intrusion.

Table 9: List of copper nickel occurrences.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Host Rock</u>
Simmons	Glamorgan	1-5	VII	mafic gneiss
Crowe River	Lake	14-17	III	amphibolite
Macassa	Limerick	28,29	VI,VII	pyroxenite
Bonter	Marmora	27	V	ultramafic gabbro
McKnight	Olden	10	IV	gabbro
Sharbot Lake	Olden	10	VI	gabbro
Amerantium	Raglan	10	VI	gabbro
Genricks Lake	Raglan	17	VI	gabbro
Landolac	Raglan	4,5	II	pyroxenite
Raglan	Raglan	20	IV	anorthositic gabbro
Lingham Lake	Tudor	2	III	pyroxenite, peridotite

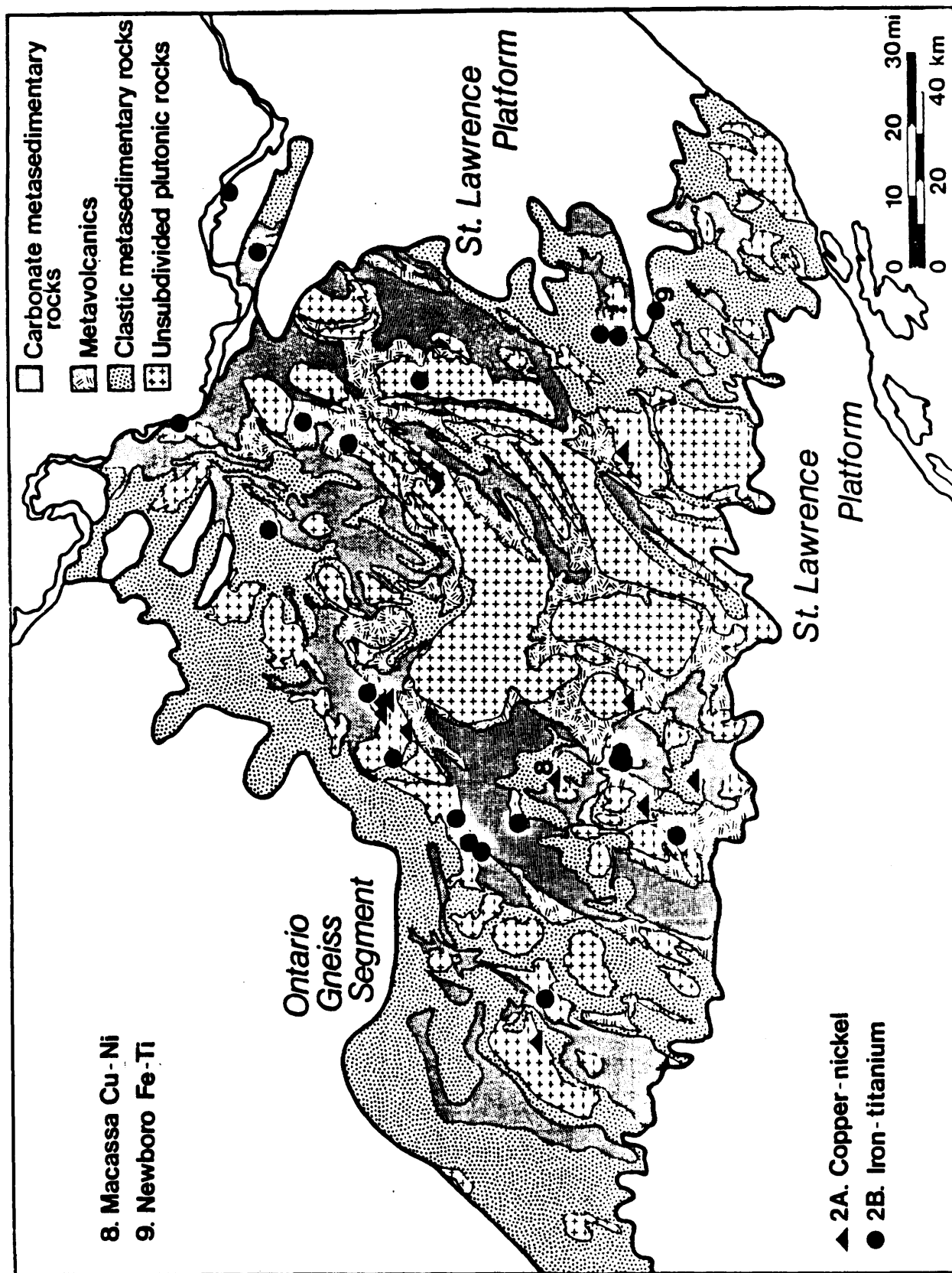


Figure 7: Distribution of copper-nickel and iron-titanium deposits in southeastern Ontario.

Anorthositic metagabbro occurs in both intrusions and Wolff (1982) reports quartz gabbro, monzonite, and syenite in the Mountain Grove complex. Textures are massive granoblastic to gneissic, with locally preserved primary sub-ophitic textures.

At the Sharbot Lake prospect, within the Mountain Grove intrusion, mineralization consists of a single sulphide-rich lens 228 metres long, 46 metres wide, and known to extend to a depth of 312 metres (Wolff 1982, p.66). One of the diamond drill holes completed by Sharbot Lake Mines within the zone intersected 5.5 metres containing 0.3 percent Ni, 0.3 percent Cu, and 0.14 percent Co. The mineralization is hosted by metagabbro. Four concentrations of copper-nickel mineralization are known to occur within the Raglan Hills metagabbro.. The Raglan prospect in the central part of the intrusion is the largest and best defined. Mineralization consists of a broad lens of disseminated pyrrhotite, chalcopyrite, and pyrite 155 metres long, 90 metres wide, with a thickness of 6 to 15 metres. It contains approximately 1 percent combined copper and nickel. The mineralization is hosted by anorthositic metagabbro, with a closely associated mass of metapyroxente. At the Landolac occurrence, located close to the southern margin of the intrusion, mineralization consists of an irregular zone of disseminated pyrrhotite, chalcopyrite, and rare pyrite. The sulphides are contained within an irregular mass of metapyroxenite surrounded by metagabbro. Poorly defined zones of disseminated sulphides hosted by metagabbro occur at the

Genricks Lake and Ameranium deposits.

The Thanet and Lingham Lake intrusive complexes have been most recently studied by Lumbers (1969). They are intruded into rocks of greenschist to lower amphibolite grade rocks, and have well developed contact aureoles, indicating emplacement occurred after the culmination of regional metamorphism according to Lumbers (1969). Primary igneous textures and intrusive relationships are generally well-preserved, although the mineralogy is usually substantially altered. Both intrusions have early mafic to ultramafic phases consisting of gabbro, metapyroxenite, and meta-peridotite, and late felsic to intermediate phases comprising of tonalite and quartz-bearing diorite. The phases are heterogeneous in composition and exhibit complex intrusive relationships. The mineralogy of the pyroxenite and peridotite has been largely altered to various proportions of serpentine, chlorite, talc, amphibole, carbonate, and Fe-Ti oxides. Textures of the various phases vary from massive aphytic to hypidiomorphic granular and foliated. The foliation is interpreted by Lumbers (1969) to be primary flow layering.

Mineralization at the Macassa (Mineral Deposit description 10) and Lingham Lake deposits, within the Thanet and Lingham Lake complexes respectively, consists of pyrrhotite, pentlandite, chalcopyrite, and pyrite, in order of abundance. At the Macassa deposit the sulphides occur disseminated within an apophysis of metapyroxenite, and within metapyroxenite and metaperidotite at

the Lingham Lake deposit. Diamond drilling at the Macassa deposit has indicated the presence of 3,894,000 short tons containing 0.825 percent nickel, 0.253 percent copper, and 0.054 percent cobalt (Financial Post Current Information Card, March 7, 1981), with trace amounts of gold and silver. The mineralized zone is 320 metres in length, and varies in width from 4 to 34 metres. The dimensions and grade of the Lingham Lake deposit are not well defined.

Three other occurrences of copper-nickel mineralization have been documented. At the Bonter occurrence mineralization consists of evenly disseminated pyrrhotite and chalcopyrite contained within a coarse-grained mass of ultramafic amphibolite. The amphibolite is exposed in a single outcrop 20 metres wide and 30 metres long in the middle of a swamp, and is intrusive into a sequence of intercalated sandstones and argillites that are metamorphosed to greenschist facies. Textures and mineralogy are similar to the Lingham Lake complex (Sangster 1970). The geological relationships of the Crowe River and Simmons occurrences are not well known. Mineralization at the Simmons deposit consists of disseminated pyrrhotite contained within mafic gneisses of probable intrusive origin. Mineralization at the Crowe River deposit is reported to consist of chalcopyrite and magnetite dispersed within shear zones in amphibolites and siliceous schists near masses and dikes of pyroxenite and gabbro. Some chalcopyrite mineralization reportedly occurs within asilicified zone in metagabbro.

Deposits of this type also occur outside Onatrio. In western Quebec, the Renzy Lake deposit, exhibits similar relationships. Sangster (1970), indicates that mineralization consists of disseminated pyrrhotite with pentlandite and chalcopyrite contained within a pyroxenite sill which cuts basement gneisses. Some production has been attained from this deposit.

Summary and Discussion

The geological relationships of the better-known copper-nickel deposits in southeastern Ontario are fairly consistent and several generalizations can be made. (1) They are hosted by intrusive rocks, usually within large igneous intrusive complexes; (2) mineralization consists of pyrrhotite, pentlandite, chalcopyrite, and minor pyrite; (3) cobalt is present in economically significant amounts, with only trace amounts of gold or silver; (4) mineralization is often preferentially associated with ultramafic phases of the intrusive host rocks.

The observed geological and textural relationships indicate sulphide mineralization formed contemporaneously with the enclosing igneous intrusive rocks, and has been metamorphosed and deformed together with them.

There is good possibility for copper-nickel mineralization of economic significance in southeastern Ontario. Limited production is recorded from one Quebec deposit (Renzy

Table 10: Deposits of Iron-titanium mineralization in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Host Rock</u>
Ashdad	Bagot	23	V	gabbro
Stufkos Lake	Bagot	28	VI	gabbro
Barryvale	Blithfield	13	I	gabbro
Boulter	Carlton	7	VI	syenite
Fraser Lake	Carlton	17	V	syenite
Cottson Lake	Dungannon	28	XIII	syenite
Bow Lake	Faraday	21	X,XI	syenite
Trent River	Faraday	7,8	A,B	syenite, nepheline gneiss
White Foot Lake	Faraday	?	?	syenite, nepheline gneiss
Fitzroy Harbour	Fitzroy	17	IX	gabbro
Pusey	Glamorgan	35	IV	gabbro
Grattan	Grattan	16,17 17,18	VIII,IX X	granite granite
Ottawa River	Horton	-	-	gabbro
Ricketts	Lake	16,17	II	gabbro
Lavant	Lavant	11	I	gabbro
Twin Lake	Methuen	8	III,IV	gabbro
Allen	N. Crosby	27	IV	gabbro
Crosby Lake	N. Crosby	24	V	gabbro
Newboro	N. Crosby	1	VI	anorthosite
Keller	Raglan	26	VII	gabbro
Newboro	S. Crosby	27	VI	anorthosite
Torbolton	Torbolton	6-8	VI,VII	gabbro
Hastings Road	Tudor	41,42, 54,55	E	gabbro
Orton	Tudor	56,57	W	gabbro
McMurray Lake	Wollaston	9,10	XV	gabbro
Umfraville	Wollaston	10,11	XVI	gabbro

Lake) and significant reserves of presently sub-economic grade have been outlined at the Maccassa body in Ontario. Intensive exploration has so far not focussed on these favourable environments which are known elsewhere in the area.

2B. Iron-Titanium Deposits

There are 26 documented occurrences of iron-titanium mineralization in Grenville rocks in southeastern Ontario (Table 10, Fig.7). All are hosted by intrusive rocks and can be grouped into two associations based on the composition of their host rocks; gabbroic and syenitic.

Seven deposits are hosted by alkalic intrusive rocks, all of which are confined within a northeast-trending belt of alkalic gneisses and intrusive rocks along the northwest margin of the Grenville Supergroup. Mineralization at the deposits consists essentially of magnetite. The gross TiO_2 content typically ranges from 1 to 3 percent; it probably occurs as sphene, which is a common accessory mineral. Ilmenite was not observed by the author but may also be present in significant amounts. Other common accessory minerals include plagioclase, hornblende, biotite, calcite, pyroxene, and pyrite.

In detail, the deposits exhibit diverse geological relationships. At the Boulter, Fraser Lake, Bow Lake, and Grattan deposits mineralization is hosted by discrete intrusions of syenitic composition. At the Bow Lake deposit mineralization consists of several small scattered pods of massive to disseminated magnetite of minor significance. At the other

deposits the mineralized zones consist of narrow parallel layers and lenses of disseminated to massive magnetite. The Grattan deposit (see Carter et al. 1980, p.98-102), is the largest of the alkalic deposits, with a mineralized zone which is nearly continuous over a length of about 2440 metres, and which varies in width from 4.6 to 10.4 metres. Diamond drilling has indicated the presence of about 9 million tons with an average iron content of 27.74 percent to a depth of 600 feet, within the main part of this zone. Samples of typical mineralization analysed by Carter et al. (1980) contained between 30.4 and 44.2 percent iron, 0.78 to 1.84 percent TiO_2 , and 0.14 to 1.30 percent P_2O_5 .

The Coltson Lake occurrence consists of a small lens of disseminated to massive magnetite only 3 metres long, and 0.3 metres wide within a syenite pegmatite dike. Calcite, biotite, and hornblende are common accessory minerals. The dike cuts nepheline gneisses which contain abundant disseminated magnetite.

The other deposits consist simply of large zones of disseminated magnetite contained within syenitic and nephelinitic gneisses, similar to the nepheline gneiss at the Coltson Lake occurrence. This type of occurrence is common within the alkalic intrusive belt and no attempt has been made to document all such deposits. The gneissic host rocks are believed to be metamorphosed intrusions.

The remaining nineteen Fe-Ti occurrences are hosted by gabbroic intrusions at scattered locations throughout the area (Figure 7). Mineralization consists of variable proportions of magnetite, ilmenite, and magnetite containing ilmenite lamellae. Common accessory minerals include hornblende, pyroxene, biotite, plagioclase, apatite, sphene and pyrite. The mineralization occurs most commonly as disseminated to massive lenses and layers parallel to the contacts of large intrusions, conformable with foliation or to rhythmic layering sometimes present in the host rocks. The titanium content of the mineralized zones is extremely variable, ranging from 1 to 15 percent in analyses reported in the literature. Mineralization may also occur as randomly scattered lenses and pods of disseminated to massive oxides, or as diffuse zones of disseminated oxides.

The Newboro prospect Mineral Deposit Description 11) is the best example of this type of deposit and is the largest Fe-Ti deposit in southeastern Ontario. Mineralization consists of two zones of well-layered, disseminated to massive ilmenite and ilmenomagnetite contained within a late intrusion of apparently unmetamorphosed anorthositic gabbro. Principal accessory minerals are plagioclase and pyroxene, with a minor amount of pyrite. Intensive exploration of the mineralized zones has indicated the presence of approximately 45 million gross tons of ore available for open-pit extraction, averaging 26.24 percent iron, and 6.60 percent TiO_2 . A detailed description of the

geology and economic features of the deposit is presented in description No. 11 of this report.

Summary and Discussion

The geological relationships of iron-titanium deposits in southeastern Ontario can be summarized as follows:

- (1) Deposits are hosted by intrusive rocks of either anorthositic to gabbroic or syenitic to granitic composition.
- (2) Mineralization consists principally of magnetite and sphene at alkalic-hosted deposits and magnetite; ilmenite, and ilmenomagnetite at anorthosite-gabbro hosted deposits.
- (3) Mineralized zones at the larger deposits consist of parallel lenses and layers conformable with foliation and layering in the host intrusions, and are oriented parallel to the contacts of the intrusion.
- (4) Titanium contents are generally higher in the gabbro and anorthosite related deposits, locally ranging up to 15 percent TiO_2 , with Fe-Ti ratios between 3:1 and 25:1. TiO_2 contents are lower and Fe-Ti ratios higher in the syenite-granite hosted deposits.

The gabbro-anorthosite hosted deposits have numerous counterparts in Canada and the rest of the world. Rose reports (1969, p.41) "Most of the titanium in the earth's crust is in gabbroic and anorthositic rocks in the ancient Precambrian Shield areas of the world.... The southeastern part of the Canadian Shield (known now as the Grenville structural province)

and its northeastern extension into the coast of Labrador (The Nain structural province) and western Newfoundland are particularly well noted for their tremendous development of anorthositic and gabbroic rocks and their associated titanium-rich occurrences." The Lac TiO mine deposit, north of Havre-St. Pierre in Quebec is one of the largest such deposits in the world. The main deposit (Gross 1967) forms a tabular mass 3600 feet long, 3400 feet wide, and up to 300 feet thick within an intrusion of anorthosite and gabbroic anorthosite. It is estimated to contain approximately 100 million tons of high-grade material averaging 32 percent TiO_2 and 36 percent Fe (Rose 1969; Gross 1967). Ore consists of coarse-grained massive ilmenite containing exsolved blades of hematite, with minor amounts of magnetite, pyrite, pyrrhotite, and chalcopyrite. Contacts of massive ore may be sharp, or gradational into disseminated ore which passes into anorthosite. Lower grade deposits consisting of disseminated magnetite and ilmenite occur at many other localities in the area; several billion tons of material grading upwards of 25 percent combined iron and titanium is estimated to occur in the Lac du Pin-Rouge area of Wexford Township (Rose 1969). Iron-titanium ore is mined from the Lac TiO deposit to produce high TiO_2 slag and pig iron. The titanium slag is valued by the pigment industry as an opaque whitener. Deposits hosted by syenitic and granitic rocks are not well documented. Gross (1967) has described several deposits in the Indian Head area of Newfoundland at which

mineralization consists mainly of magnetite in layers, bands, veinlets, and some disseminated zones in soda granite-gneiss. Representative samples from these deposits typically contain 3 to 5 percent TiO_2 with approximately 60 percent iron.

In northern Ontario disseminated to massive magnetite occurs in association with apatite in several zoned, circular, alkaline rock complexes. These have been examined as potential sources of niobium, columbium, and tantalum, and contain appreciable amounts of rare earths, titanium, zirconium, manganese, uranium, and thorium (Gross 1965, Sage).

Origin

The intimate association of both deposit types with igneous intrusive rocks leaves little doubt that they are magmatic in origin. The minerals of the ores and host rocks are mainly high temperature phases and relict igneous textures are locally preserved. The mechanism of formation and emplacement is considered to be a process of fractional crystallization, which can best explain the observed relationships. Rose 1969), and Gross (1967) in their reviews of iron and titanium deposits, and Krogh (1961) in his study of the Newboro deposit indicate that the oxide bodies at anorthosite hosted deposits were emplaced at a late stage in the cooling history of the intrusions. As discussed by Krogh (1961) and Gross (1967) the oxides probably separated from the silicate portion of the anorthositic magmas to form a late-crystallizing fluid in the deeper parts of the intrusive mass that was then injected into the upper levels when

they were rigid enough to fracture. A similar mechanism may account for the concentration of Fe-Ti oxides in the syenitic and granitic intrusions.

Economic Potential

The southeastern Ontario deposits are too low in titania contents are too low to compete effectively with the Quebec deposits as sources of TiO_2 . As a source of iron for normal blast furnace operation in the production of iron and steel even if they were larger, the titania present would make them unsuitable as sources of ore. Rose (1969) describes several techniques by which titaniferous ores can be successfully smelted. Consequently the ores might be used if need were great enough. The Newboro deposit has been briefly considered as a possible source of iron ore in the past (see Newboro Iron-Titanium Prospect, this report) and has the best potential for development. As these are targets easily identified by aeromagnetic methods it is not considered likely that other deposits of significant size remain to be discovered in southeastern Ontario.

3A. Contact Metasomatic Iron

Contact metasomatic iron deposits constitute the most common and widespread type of iron mineralization in southeastern Ontario. Nearly 50 occurrences of this type are documented within rocks of the Grenville Supergroup (see Table 11 and Fig. 8). Iron ore was produced from many of these deposits on a small scale in the late nineteenth and early

Table 11: List of documented contact metasomatic iron deposits in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Associated Rock Types</u>
Tory Hill	Anstruther	26,27	XV	granite, marble
Bluff Point	Bagot	16	X,XI	syenite, marble, amphibolite skarn
Calabogie	Bagot	16	VIII,IX	gabbro, marble, amphibolite skarn
Culhane	Bagot	21	VII	gabbro, marble, amphibolite skarn
Lerond	Bagot	23	IX	gabbro, marble
Martel	Bagot	13,14	X	syenite, amphibolite
Williams	Bagot	22	XI	gabbro, marble
Glendower	Bedford	6	II,III	gabbro, marble, skarn
Blairton	Belmont	7,8	I	gabbro, marble
Ledyard	Belmont	19	I	gabbro, marble
Pushing	Belmont	1,2	IV	skarn
Kennelly Lake	Brougham	7	X	granite, marble, amphibolite
Bow Lake	Faraday	21	X,XI	granite, amphibolite, marble, biotite schist
Carfrae	Faraday	3	XII	gabbro, marble, skarn
Tomahawk	Lake	20	IV	gabbro, amphibolite skarn
Wilbur	Lavant	4	XII,XIII	granite, marble, skarn
Paxton	Lutterworth	5	VI	amphibolite, marble
Dufferin	Madoc	18	I	granite, marble, skarn
Hobson, Nelson and Knob	Madoc	19	I	granite, marble
		18,19	II	granite, marble
Crowe Lake	Marmora	12	III	gabbro, marble
Maloney	Marmora	18	I	gabbro
Marmoraton	Marmora	4,5	V,VI	syenite, paragneiss, marble, skarn
Bessemer	Mayo	2,4,5	VI	tonalite, marble, skarn
		1	VII	tonalite, marble, skarn
Childs	Mayo	10,11	IX	tonalite, diorite, marble, skarn
Hamlyn	Mayo	8	VII	tonalite, skarn
Rankin	Mayo	10	IX	tonalite, diorite, marble, paragneiss
Stevens	Mayo	13	IX	tonalite, paragneiss, skarn
Swordfingal	Mayo	4-6	V	diorite, granite, marble
Minden	Minden	11	I	marble, gneiss
Harris	Olden	21	XI	granite, marble, greywacke
Skewgaw	Olden	17	XI	syenite, marble, greywacke
Lavant Station	Palmerston	27	XI	granite, marble
Robertsville	Palmerston	3,4	IX	diorite, marble
Howland	Snowdon	26	IV	gabbro, marble
Victoria	Snowdon	20	I	granite, marble
Bygrove	S. Sherbrooke	3	I	granite
Christie's Lake	S. Sherbrooke	18-20	III	skarn, marble
Silver Lake	S. Sherbrooke	16	IV	granite, marble, pyroxenite
Baker	Tudor	18	XVIII	gabbro, marble
Emily	Tudor	7	XIX	granodiorite, marble
Glanmire Lake	Tudor	26	XIV	gabbro, marble
Lee	Tudor	21	XVII,XVIII	granite, marble
St. Charles	Tudor	19	XI	gabbro, marble, skarn
Wadsworth Lake	Tudor	3	XIX	granodiorite, marble
Coe Hill	Wollaston	16,17	VIII	syenite, marble, amphibolite
Jenkins	Wollaston	18	VIII	syenite, pyroxenite-amphibolite
Snow Lake	Wollaston	NE of Snow Lake		gabbro, marble

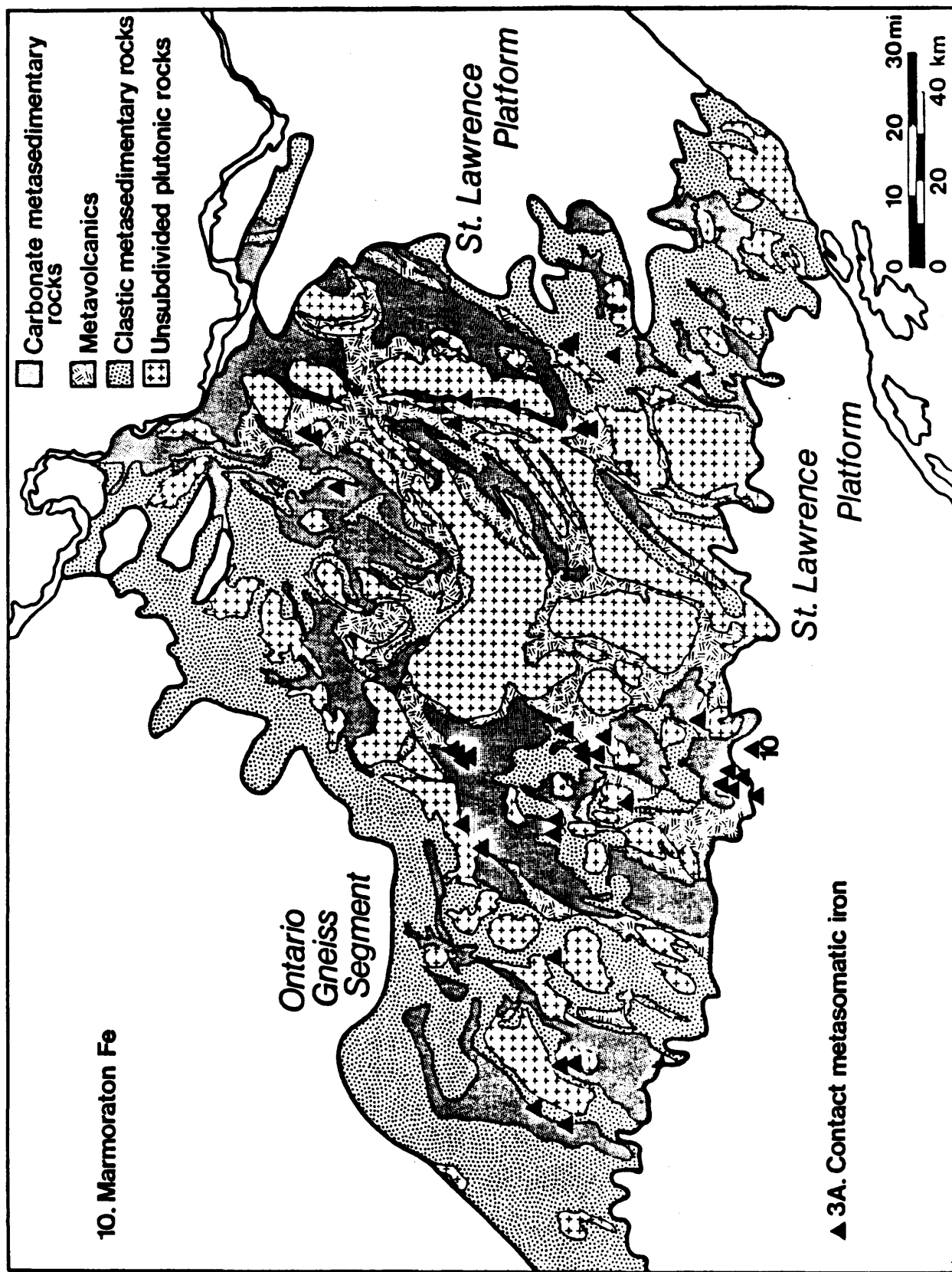


Figure 8: Distribution of contact metasomatic iron deposits in southeastern Ontario.

twentieth centuries, and significant production has been attained from the Marmoraton deposit near Marmora, and the Hilton deposit in Quebec, more recently. The documented occurrences in Ontario are all relatively small; probably only a few would be capable of producing more than one million tons of concentrate. Only one, the Calabogie deposit, has indicated reserves of greater than 20 million tons remaining. All contain less than one percent TiO_2 , and are not enriched in base or precious metals except for an anomalous, but minor, content of copper.

The deposits exhibit a close spatial relationship to intrusive rocks which vary from granitic to gabbroic in composition; there is apparently preferred association of mineralization with any one type. The deposits consist of tabular, concordant bodies of disseminated to massive magnetite contained in irregular skarn zones developed in Grenville marbles at, near, or within the margins of the intrusions. The skarn host rocks vary considerably in mineralogy at different deposits but generally consist of diopside, amphibole, and epidote, and may include garnet, calcite, dolomite, chlorite, talc, muscovite, biotite, pyrite, pyrrhotite, and chalcopyrite. Apatite is also a significant constituent at the Glendower deposit.

The Marmoraton deposit has been studied in detail by Park (1967) and described in general terms by Rose (1958), Gross (1967), and Sangster (1970). A detailed description No. 12) is

included with this report and the general characteristics are summarized here. The Marmoraton deposit consists of tabular, concordant lenses, layers, and irregular zones of disseminated to massive magnetite contained within a heterogeneous skarn rock developed within a sequence of marble and subordinate siliceous metaclastic rocks at the margin of a syenitic intrusion. The skarn is composed of variable proportions of diopside, epidote, amphibole, garnet, chlorite, talc, and calcite, with locally abundant pyrite and chalcopyrite. Crude layering in the skarn and mineralized zones is oriented parallel to the bedding in the sedimentary rocks. Gradational relationships and partially replaced beds indicate the skarn is largely derived from the bedded rocks, but some epidote-rich portions are related to the syenite. In Quebec the Hilton deposit, located between Shawville and Quyon in Bristol Township, occurs within the Mont Laurier Basin of the Central Metasedimentary Belt and is very similar to the Marmoraton deposit.

Discussion

In the literature, deposits of this type have been classified as pyrometasomatic, skarn, replacement, and contact metasomatic. Gross (1965) views the Marmoraton deposit as typical of those in Quebec and Ontario. Deposits on Texada Island in British Columbia resemble many similar deposits in that area. In British Columbia deposits are found in contact metamorphic aureoles developed adjacent to syenites, porphyries,

and felsic to mafic intrusive bodies into volcanic and sedimentary rocks. Beds of sedimentary carbonate rocks are commonly present and are usually the most favoured host rocks. Beds of tuff or greenstone present at some deposits may also be selectively altered and mineralized.

The deposits in southeastern Ontario have been variably affected varying degrees by regional metamorphism, with resultant recrystallization and deformation. At the Calabogie and Martel prospects in Bagot Township, the geological relationships are obscured as a result. Other magnetite occurrences, in high-grade metamorphic terrain, have not been classified. It is possible they may also be contact metasomatic deposits. These include the magnetite bodies at the contacts of silicate gneisses and marbles in high grade metamorphic terrain which have been described by Sangster (1970) as metamorphic metasomatic. The largest deposits are associated with amphibolite rocks.

Origin

It is clear that these deposits are genetically related to metamorphic and metasomatic effects at the margins of igneous intrusions where these cut on metasedimentary, especially carbonate, metasedimentary rocks. Similar conclusions were reached by Rose (1958), Hewitt and James (1955), Park (1966), and Giblin (1960). Characteristics of the deposits which support this hypothesis include: 1) the common spatial association with major intrusions, 2) association with and

apparent replacement of marble, 3) the high temperature mineral assemblage of the associated skarn rock, and 4) the lack of relict, primary sedimentary structures.

In details the origin of this type of iron mineralization in the area is not clear. Park (1966) has shown that the iron content of the Marmoraton deposit may have been derived from the adjacent syenite intrusion. He demonstrated a loss of iron in the syenite adjacent to the orebody approximately equal to that in the skarn zone. To account for this Park proposed that a process of 'modified deuteric release' was responsible. Ferromagnesian minerals in the syenite were broken down by infiltrating CO₂ and the liberated iron removed by exuding residual magmatic fluids to be deposited as magnetite in the metasediments near the contact.

Similar iron deposits on Vancouver Island studied by Sangster (1964) also indicate iron was derived from the adjacent intrusion. However, he suggested that the ultimate source of the iron was the underlying volcanic rocks.

Economic Potential

Significant production has been attained from the Marmoraton deposit in southeastern Ontario and the Hilton deposit in Quebec. The Marmoraton mine (Mineral Deposit description No. 12) was in operation from 1955 to 1978 and produced a total of 11,282,412 tons of iron concentrates from a total of 22,966,762 tons of ore with an average total iron content of 42.8 percent. Production figures from 1958 to 1976 for the Hilton mine are

very similar. Minor production has been attained from numerous other deposits in southeastern Ontario, most of which were worked in the late nineteenth century.

Their small size and current market structure means it is unlikely that any deposits of this type will become sources of iron ore in the near future. However, with their closeness to markets, good accessibility, and generally high grades they may be locally significant as long term sources of iron. Some of deposits may be able to supply the high-density aggregate for special concrete which is used to shield nuclea reactors. The Calabogie deposit, in Bagot Township, is the largest such deposit in the area. The Algoma Steel Company has estimated that the deposit contains 27.2 million tons of ore grading 22.28 percent Fe in an orebody 2,739 feet long and 145 feet wide, recoverable by open pit mining methods.

3B. Gold-quartz veins

Epigenetic gold-quartz vein deposits constitute by far the most important and most abundant type of gold deposit in the area. The author has identified 90 occurrences of this type in southeastern Ontario (Table 12, Fig. 9). Gold is the most economically significant metal in most of the deposits, although associated metals such as arsenic, antimony, copper, lead, and zinc are often present in greater amounts. Silver is usually present in only minor amounts, and gold/silver ratios are consistently greater than one.

Table 12: Gold deposits in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Host</u>	<u>Mineralogy</u>
Kennebec	Anglesea	7	V	maf.volc.	aspy
O'Donnell North	Anglesea	6	III	maf.volc.	men, aspy, gal, sph, cpy
O'Donnell South	Anglesea	8	II	maf.volc.	men, aspy, gal, sph, py
Ultimate Energy	Anglesea	6	IV	maf.volc.	?
-	Anglesea	7	III	maf.volc.	py, cpy
Big Dipper	Barrie	16	X	granite	py, tour
Cobalt-Frontenac	Barrie	13	I	maf.volc.	py, po, sph
Cook	Barrie	25	VI	?	?
Gough	Barrie	3,4	X	dolomite	py, asp, boul, sph
Hardie	Barrie	3	X	qtzite	py, cpy, tour, hem
Helena	Barrie	20	VI	dolomite	py, cpy, trem, act
International	Barrie	8	IX	dolomite	sph, boul, py, gal, cpy, jame
Kashwakamak	Barrie	14	VI	dolomite	cpy, tet, py, tour
Mazinaw	Barrie	12	VIII	dolomite	cpy, py, gal, sph
Mill	Barrie	36	II	dolomite	py, cpy, aspy, tet
Natto	Barrie	30-32	III, IV	marble	py, aspy
Ore Chimney	Barrie	35	I	maf.volc.	py, gal, sph, cpy
Pay Rock	Barrie	16	I	dolomite	?
Star	Barrie	24-26	IX, X	dolomite	py, cpy, act, trem, our, scheel
Cordova	Belmont	20	I	gabbro	py, po
Ledyard	Belmont	19	I	gabbro	py
Cashel	Cashel	20	I	maf.volc.	py, cpy, gal, tour
Cashel Copper	Cashel	31	I	grante	py, cpy, gal, po
Boerth	Clarendon	29	VIII	gwke	asp, tour
Cook	Clarendon	23	IX	marble	asp
Webber	Clarendon	28	IX	gwke	?
Bradford's Creek	Darling	23	V	dolomite	tet, cpy, py
Darling	Darling	23	IV	dolomite	tet, cpy, py
Green Lake	Darling	22	II	dolomite	tet, cpy, py
Barry	Elzevir	5	II	?	?
James	Elzevir	3	IV	volc.	aspy
Silver King	Elzevir	25	III, IV	granite	py, gal, born
Cobalt-Frontenac	Grimsthorpe	29	XVIII	maf.volc.	?
Gilmour	Grimsthorpe	30	XIX	maf.volc.	py
Palmotter	Grimsthorpe	-	-	?	gal
Robson	Grimsthorpe	29, 30	XX	?	gal
W. Black River	Grimsthorpe	29	X	biotite gneiss	?
Harvey	Harvey	5, 6	I	schist	?
Addington	Kaladar	24, 25	VI	maf.volc.qtzite	sph, tour, sch, mag, py, po, asp, cpy, gal

Table 12 (continued)

Ewing	Kaladar	20	IV	maf.volc.qtztite ?	
Stone	Kaladar	23	V	maf.volc.qtztite	py, cpy, po, asp, gal, sph
Dome	Kennebec	32	II	volc, marble	py, cpy, gal, chal
Emergy	Kennebec	31	II,III	volc, qtztite	py, asp, sph, gal
Gold Base	Kennebec	30	V	qtztite	py, cpy
Sopha-Miller	Lake	6-8	I	?	?
Begin	Lavant	5	VII	dolomite	cpy, tet, born, py
Joe Lake	Lavant	12	IV	dolomite	tet, cpy
Lavant	Lavant	5	VII	dolomite	tet, born, cpy
Lavant Creek	Lavant	12	V	dolomite	cpy, py
Lynx-Canada	Lavant	5	VII	dolomite	cpy, born
Nelson Lakes	Lavant	8	VII	dolomite	cpy
Robertson	Lavant			dolomite	py, po
Limerick Lake	Limerick	9	VII	?	?
McMurray	Limerick	1	I	rusty schist	py, asp
Bannockburn	Madoc	28	V	syenite	py
Empire	Madoc	1	VI	?	?
Fox	Madoc	18	V	?	?
Richardson	Madoc	18	V	?	cpy, gold, bran
Sophia	Madoc	14,15	X	maf.volc.	asp
St. Joe	Madoc	25	V	?	?
Webber	Madoc	29	V,VI	?	?
Ackerman	Marmora	6,7	VIII	granite	
Campbell-Blomfield	Marmora	6	VIII	granite	asp
Consolidated	Marmora	5	IX	granite	asp
Cook	Marmora	9	IX	granite	asp, py, cpy
Dean & Williams	Marmora	7	IX	granite	asp, py, cpy
Deloro	Marmora	9	VIII	granite	asp
Demars	Marmora	24	V	granite	asp
Getting Five-Acre	Marmora	10	IX	granite,diorite	asp
Gawley No. 1	Marmora	18	IX	marble	asp
Gawley No. 2	Marmora	9	IX	marble	asp
Gillen	Marmora	6	VIII	granite	-
Gladstone	Marmora	17	XI	granite	-

Table 12 (Continued)

Hawkeye	Marmora	10	VIII	granite	asp
Malone	Marmora	6	VIII	-	-
Neill	Marmora	14	X	granite	-
Pearce	Marmora	8	VIII	granite	asp
Rankin	Marmora	6	VIII	gabbro	-
Robinson	Marmora	17	IX	granite	py,asp,po
Sovereign	Marmora	16,17	XI	granite	py
Picamine	Palmerston	1,2	VIII,IX	gabbro	cpy
Morrow	Oso	15	II	qtzite	py
Craig	Tudor	4,5	III	gabbro	py, cpy
Glanmire	Tudor	26	XIII	granite	py, tour
Lingham Lake	Tudor	1	X	granite	asp, py
Molra River	Tudor	5	XIII	rhyolite	asp
Quinlan Lake	Tudor	2	II	volcanics	asp,py,tour
Sheppard	Tudor	12	II	granite	-
Snow Road	Tudor	11	XIII	maf,volc.	py
Tudor	Tudor	7	X	diorite	asp

The majority of the deposits exhibit a striking spatial association with a large pocket of low-grade metamorphic rocks north of Madoc (Figure 9). Most are hosted by greenschist facies rocks within the zone, others are confined to lower amphibolite facies rocks immediately to the northeast. A second, smaller group of deposits south of Renfrew, in Lavant and Darling Townships, occurs within another zone of greenschist facies rocks between the Addington granite and the Lavant gabbro (Figure 9).

The Madoc metamorphic low and its associated gold deposits is centred on the thickest accumulation of volcanic rocks in the Grenville Supergroup. Volcanic rocks are also a major component in the Lavant-Darling area. Although closely associated with metavolcanic rocks the deposits are hosted by a variety of lithologies, including mafic metavolcanics, dolomitic marbles, granitic and gabbroic intrusive rocks, and siliceous metaclastics. A large number of these deposits occur near the top of the Hermon Group, or near the base of the overlying Mayo Group. Others are closely associated with the contact between the Hermon Group and the unconformably overlying Flinton Group (Figure 10).

Two general types of mineralized veins are recognized.

1. Stratabound, quartz-dolomite vein networks in dolomitic marble.
2. Concordant to discordant quartz and quartz ankerite veins.

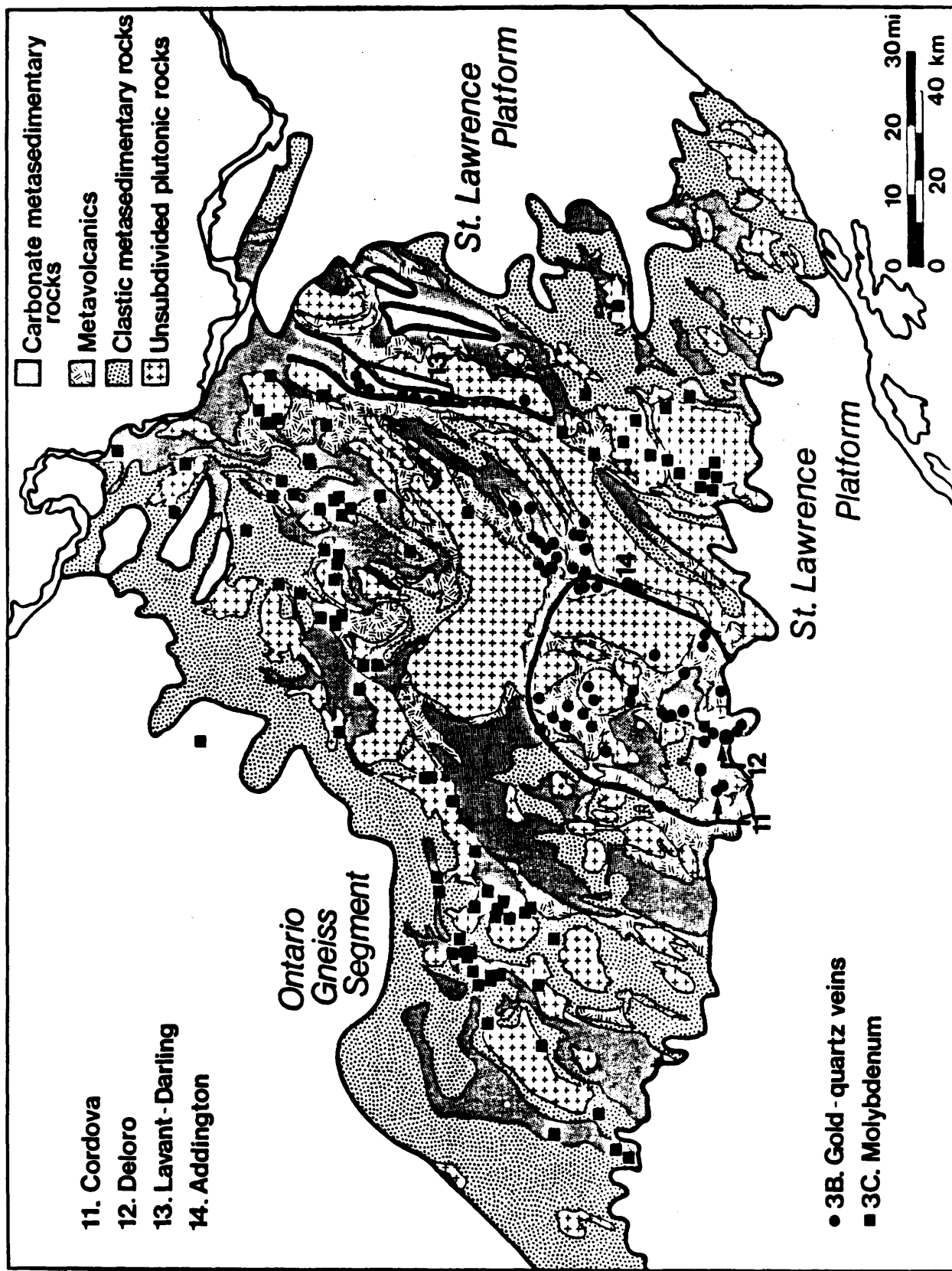


Figure 9: Distribution of gold-quartz vein deposits and molybdenum deposits in southeastern Ontario.

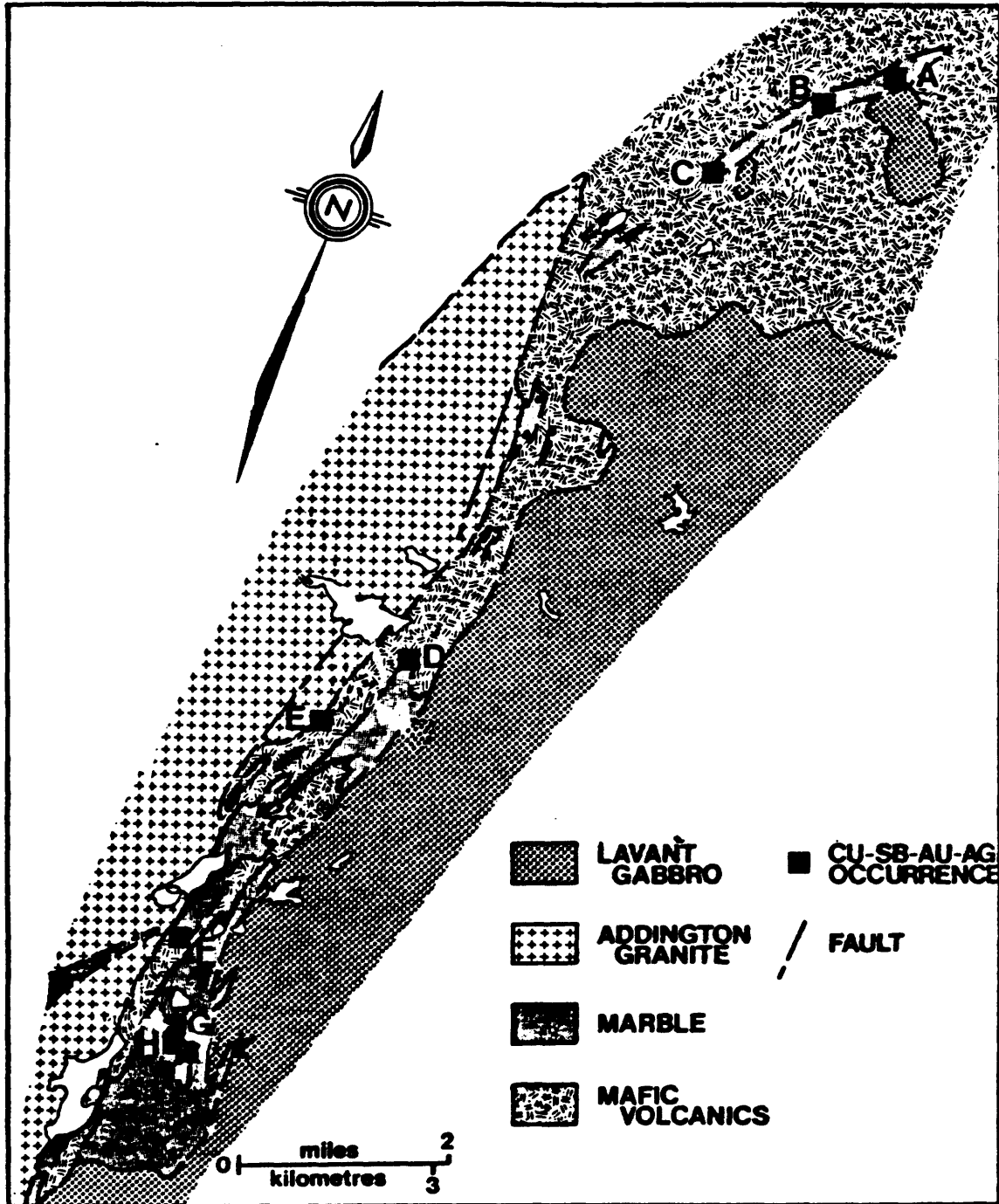


Figure 10: Geology of the Lavant-Darling area, showing location of Cu-Sb-Au-Ag vein occurrences.

1. Stratabound, quartz-dolomite vein networks

Deposits of the first type are generally small, with no past history of production. They consist of stratabound networks of narrow (<10 cm) quartz, quartz-dolomite, and dolomite veins, pods, and lenses confined to dolomitic marbles. Mineralization consists of erratically disseminated sulfides, including chalcopyrite, pyrite, tetrahedrite, bornite, boulangerite, jamesonite, sphalerite, galena, and rare arsenopyrite. There are two principal areas of concentration of this type of vein deposit; the Barrie and Clarendon Township area northeast of the Madoc "metamorphic low", and the Lavant-Darling area (Figure 9, 10).

The Lavant-Darling occurrences are the best-documented examples of this type in southeastern Ontario (see Carter 1981). Ten occurrences of Cu-Sb-Au-Ag mineralization form a series of stratabound vein zones within a narrow belt of intercalated mafic metavolcanics, dolomitic and calcitic marbles, and minor mudstone and felsic metavolcanics (Fig. 10). The sequence is bounded to the west by the Addington Granite, a concordant intrusive sheet of granite, and to the east by the Lavant Gabbro, a large, essentially concordant intermediate to basic intrusive complex.

Maximum presently exposed local accumulations of supracrustal rocks in the sequence do not exceed 1000 metres. Massive mafic flows of the Joe Lake Volcanics form the base of the sequence, grading upwards and laterally into a mixed

sequence of intercalated massive and rubbly mafic flows and dolomitic and calcitic marbles, with minor interbeds of mafic and felsic tuff, nudstone, and calcareous metaclastics. These are succeeded by a thick monotonous sequence of dolomitic and calcitic marble with minor metaclastics and metatuffs of the Lavant Marble Formation. Carter (1981) has tentatively correlated the Joe Lake Volcanics with either the Turriff or Tudor Formations of the Hermon Group, and the Lavant Marble with the Dungannon Formation of the Mayo Group.

All ten Cu-Sb-Au-Ag occurrences occur at approximately the same stratigraphic position in the sequence, over a strike length of about 20 km. All are hosted by dolomitic marble within the lower to middle portions of the Lavant Marble, stratigraphically above or equivalent to the upper part of the Joe Lake Volcanics. Mineralization consists of erratically dispersed grains and blebs of tetrahedrite, chalcopyrite, pyrite, and bornite contained in a complicated network of quartz-dolomite veins, pods, and lenses. The most significant associations and the apparent paragenetic sequence of follows:

1. Conformable layers and lenses of coarse-grained dolomite;
2. Quartz-dolomite lenses and cross-cutting veins; and
3. Cross-cutting quartz veins. Quartz pods and silicified breccia zones in the marble occur at some of the occurrences and are considered to be analogous to the quartz veins in mode of formation.

The dolomite layers and lenses are conformable with layering and foliation in the host marble and are gradational into isolated porphyroblasts of dolomite that displace the layering and foliation, suggesting a synmetamorphic origin. The dolomite layers and lenses are also apparently gradational, with increasing quartz content, into cross-cutting quartz veins. The quartz veins cut all other features in the marbles, have sharply defined contacts, and are relatively undeformed. Some veins contain euhedral, unstrained, zoned quartz crystals. All these relationships suggest late to post-metamorphic formation for the quartz veins.

Two suites of sulfide mineralization can be distinguished:

1) disseminated euhedral pyrite, and 2) anhedral chalcopyrite, tetrahedrite, bornite, and occasional pyrite. The euhedral pyrite is closely associated with the early dolomite layers and lenses, and is nearly absent from quartz veins. The chalcopyrite-tetrahedrite-bornite $\pm$ pyrite mineralization occurs either as dispersed intergranular grains within quartz and quartz-dolomite veins and to a lesser extent within dolomite layers and lenses, or as heavily disseminated grains within healed fractures in quartz veins or quartz-dolomite/dolomite layers, lenses, and veins. The relationships indicate pyrite was deposited during formation of layered dolomite lenses. Deposition of chalcopyrite-tetrahedrite-bornite $\pm$ pyrite started later during formation of dolomite layers and lenses, peaked during quartz vein formation, and concluded with deposition in

Chemical analyses of mineral separates reported by Carter (1981) indicate gold occurs in association with both pyrite and tetrahedrite. No visible gold was observed, either in hand specimen or in thin and polished thin sections of mineralized vein material.

There are abundant fluid inclusions trapped in quartz grains in the mineralized vein material. The vast majority contain simple aqueous solutions consisting of liquid water with a small gas bubble. Primary inclusions trapped during growth of the quartz grains, and secondary fluid inclusions trapped in later healed fractures are common. Sulphide mineralization is associated with both types of inclusions. In addition, carbon dioxide-rich primary fluid inclusions are fairly common in quartz grains associated with early dolomite layers and lenses. This suggests an evolution or change in fluid composition from carbon dioxide-rich to aqueous during the course of vein formation and mineralization.

Heating/freezing studies of the fluid inclusions were completed by Carter (1981). Freezing studies of the aqueous fluid inclusions indicate they have salinities ranging from 5 to 25 weight percent equivalent NaCl, with a modal peak at 15 percent. NaCl is the principal dissolved species, but some of the fluid inclusions have final or initial melting points below the H₂O-NaCl eutectic, indicating the presence of other dissolved salts. Mineralogic and theoretical considerations

indicate that the fluid inclusion brines probably also contain significant but subordinate amounts of Ca^{++} , Mg^{++} , K^+ , and dissolved quartz and carbonate. Phase homogenization temperatures determined by heating the fluid inclusions range from 105°C to 215°C , with a mode of 140°C , which represents the minimum temperature for formation of the veins and associated mineralization.

2. Concordant to discordant quartz and quartz-ankerite vein deposits

Quartz and quartz-ankerite vein deposits of this type are much more widespread and numerous than the first type. Significant production has been attained from several deposits of this type, principally from the Cordova and Deloro deposits.

Veins at deposits of this type have several modes of occurrence. They may 1) occupy shear zones in gabbroic, granitic, and syenitic intrusions and in mafic volcanic rocks; 2) occur within cross-cutting fractures in marble and siliceous metaclastic rocks; 3) form concordant veins within marbles; and 4) form concordant to locally discordant lenses along the basal unconformity of the Flinton Group. Mineralization is variable and erratic. Pyrite and arsenopyrite are the most common sulfides at most of the deposits, with locally abundant galena, sphalerite, chalcopyrite, pyrrhotite, and tetrahedrite. Tourmaline and actinolite are locally abundant accessory minerals. Native gold has been reported to occur at some deposits but has not been observed by the author. Brief

descriptions of deposits and groups of deposits representative of the four subtypes are presented below.

1) The Cordova and nearby Ledyard gold deposits are the best examples of the first type (see Cordova Gold Mine, Mineral Deposit description No. 13). Gold-bearing quartz-feldspar-ankerite veins are contained in shear zones within the northwest margin of the Cordova Gabbro, a large elliptical mafic intrusive complex. Mineralization consists of sparsely disseminated pyrite and minor pyrrhotite. Analytical results obtained by the author, and production records reported by Satterly (1943) indicate most of the gold at the deposit is probably contained in the pyrite. The mineralogy and dressing methods of the Cordova deposit is discussed briefly by Springer (1982). The shear zones vary from 30 cm to 50 metres in width and at the Cordova deposit (see Plate 12) enclose mineralized zones up to 12 metres in width. The zones occur throughout the intrusion but are most abundant in the northern and eastern parts of the pluton. Attitudes of the shear zones are variable. However, the main mineralized zones at both the Cordova and Ledyard deposits strike east-west and dip moderately to steeply to the south. Within the shear zones the gabbro host, which normally is composed principally of medium- to coarse-grained plagioclase and amphibole, is altered to an aphanitic to fine-grained, strongly foliated mass of biotite, chlorite, and vein minerals. Thomas and Cherry (1981) give more descriptions of the veins at Cordova. Springer (1982) has

calculated the attitude of the ore bodies in the shear zones from published and unpublished data, and drawn tentative structural conclusions.

At the Craig deposit a shear zone striking in a southeasterly direction and dipping steeply to the southwest cuts basalts of the Tudor Formation within the contact aureole of the Lingham Lake intrusive complex (Lumbers 1969). The shear zone encloses a fairly well defined vein of white to locally rusty quartz, varying from about 50 cm to nearly 2 metres in width, which has been traced for a distance of about 300 metres. The quartz encloses layers and lenses of sheared basalt and in places separates to form an echelon veins. The vein quartz is locally sheared and Lumbers (1969) reports slickensides on the wallrocks locally. Pyrite, chalcopyrite, and rare pyrrhotite are sparsely disseminated within the vein. Representative chip samples of quartz vein material collected by the author for assay purposes gave the following results: 0.12 oz. Au per ton, trace silver, 565 ppm Cu; and 0.28 oz. Au per ton, 0.26 oz. Ag per ton, and 152 ppm Cu.

Chemical analyses of representative chip samples of typical basalt and sheared basalt devoid of vein material are presented in Table 13. Corresponding analyses of gabbro and sheared gabbro from the Ledyard deposit are also presented. At both deposits there has been a minor loss of SiO_2 , major loss of Na_2O , and significant addition of K_2O and volatiles, principally CO_2 from the sheared rocks relative to their unaltered equivalents.

A distinctive group of gold-arsenic deposits, including the past-producing Deloro, Sovereign, Cook, and Dean Williams deposits, occurs west of Madoc, near the village of Deloro. The deposits are associated with the Deloro Pluton, a large granitic intrusion (Figure 11). The pluton is typically composed of massive, medium-grained perthitic granite. This is bounded by a complex, heterogeneous zone of gabbroic, dioritic, syenitic, and granitic rock along the western margin of the pluton, adjacent to the contact with a thick succession of calcitic and dolomitic marbles. The relationships between the rocks in the contact zone are complex; contacts between diorite, syenite, and gabbro vary from gradational to sharp, the mafic rocks are often contained as angular blocks within syenite. The granite appears to be intrusive into the other three rock types in the contact zone; it usually has sharp contacts with and contains xenoliths of all three. Locally the granite is gradational into quartz-poor and mafic-rich phases which may represent a transitional phase with the syenite and diorite. All the rocks in the contact zone are extensively altered, especially near the gold-arsenic deposits. Replacement by iron carbonate is common, and masses of diopside-mica schist occur within the contact zone. The increased mafic content and decreased quartz content of the contact zone rocks relative to the typical perthitic granite of the pluton may also be a result of alteration. Alternatively these rocks may represent an early more mafic

phase of the intrusion. At the Sovereign deposit, peripheral to a system of quartz veins, perthitic granite is gradational into sericitized granite in which the feldspar is altered to a fine-grained mass of sericite, leaving the quartz grains intact (Fig. 12).

All the documented gold deposits of this sub-group occur within the highly altered rocks in the western margin of the Deloro pluton. The gold mineralization is confined to quartz veins contained within shear zones or fractures in highly altered syenite and diorite, often localized at the contacts between these two rock types. The shear zones observed by the author vary from a few cm up to 3 metres in width and generally strike north-south, parallel to the margin of the pluton, and dip moderately to the west. Within the shear zones the host rock is converted to a light grey, carbonate and arsenopyrite-bearing mica schist. Irregular lenses and discontinuous veins of white to glassy quartz and coarse-grained, brown-weathering carbonate occur within the sheared rock. Arsenopyrite is locally abundant, often occurring as massive blebs and lenses in the vein material. Assays of selected representative samples from outcrops and mine dumps give the following results: 0.28 oz. Au per ton, 1.77 percent As; 0.01 oz. Au per ton, 3.71 percent As; 0.15 oz. Au per ton, 10.5 percent As; 0.03 oz. Au per ton, 4.65 percent As; and trace Au with 54 ppm As. All samples contain only trace amounts of silver.

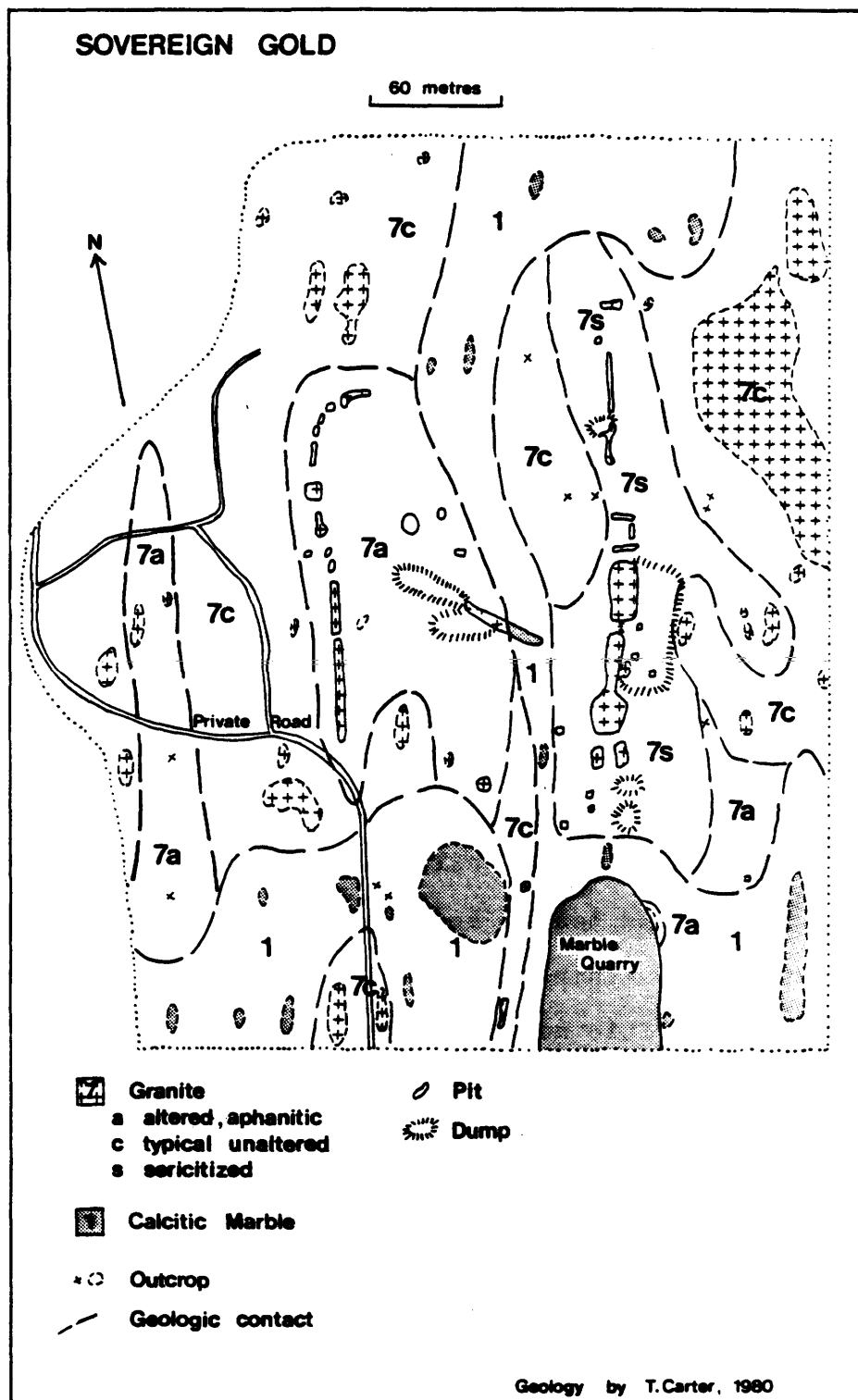


Figure 12: Geology of the Sovereign gold deposit.

Available records indicate that the veins mined at the former Deloro mine were 30 to 300 metres long, 30 cm to 1.5 metres wide, dipping westerly at 20 to 50 degrees, containing up to 10 percent arsenopyrite. The veins were mined to a maximum depth of 150 metres, in the Gatling shaft.

2) The Boerth deposit in Clarendon Township is the best example of discordant, cross-cutting quartz veins. The Boerth veins are hosted by a unit of light grey, fine-grained, thinly bedded, pelitic metasandstones, siltstones, and mudstones (Figure 13). The host unit is about 100 metres wide in the vicinity of the mineralized veins and is bounded by calcitic marble, within an alternating sequence of metaclastics and marble, northeast of the Madoc metamorphic low. Pits and trenches expose four moderately to steeply dipping quartz veins, varying from 30 metres to 60 metres in length, that cut the metaclastic host rocks nearby at right angles to the bedding. The veins pinch out within the metaclastic unit and do not extend into the calcitic marbles. The veins vary from 10 to 50 cm in width, and pinch and swell rapidly along their strike length. Quartz within the veins is often rusty and badly fractured, and encloses sparsely disseminated pyrite, arsenopyrite, and tourmaline. Representative chip samples collected from each of the veins by the author contained: 1.42 oz. Au per ton, 0.14 oz. Ag per ton, 14 ppm As; 0.01 oz. Au per ton, trace Ag, 2500 ppm As; 1.96 oz. Au per ton, trace Ag, 1400 ppm As; and 0.26 oz. Au per ton, trace Ag, and 1420 ppm As.

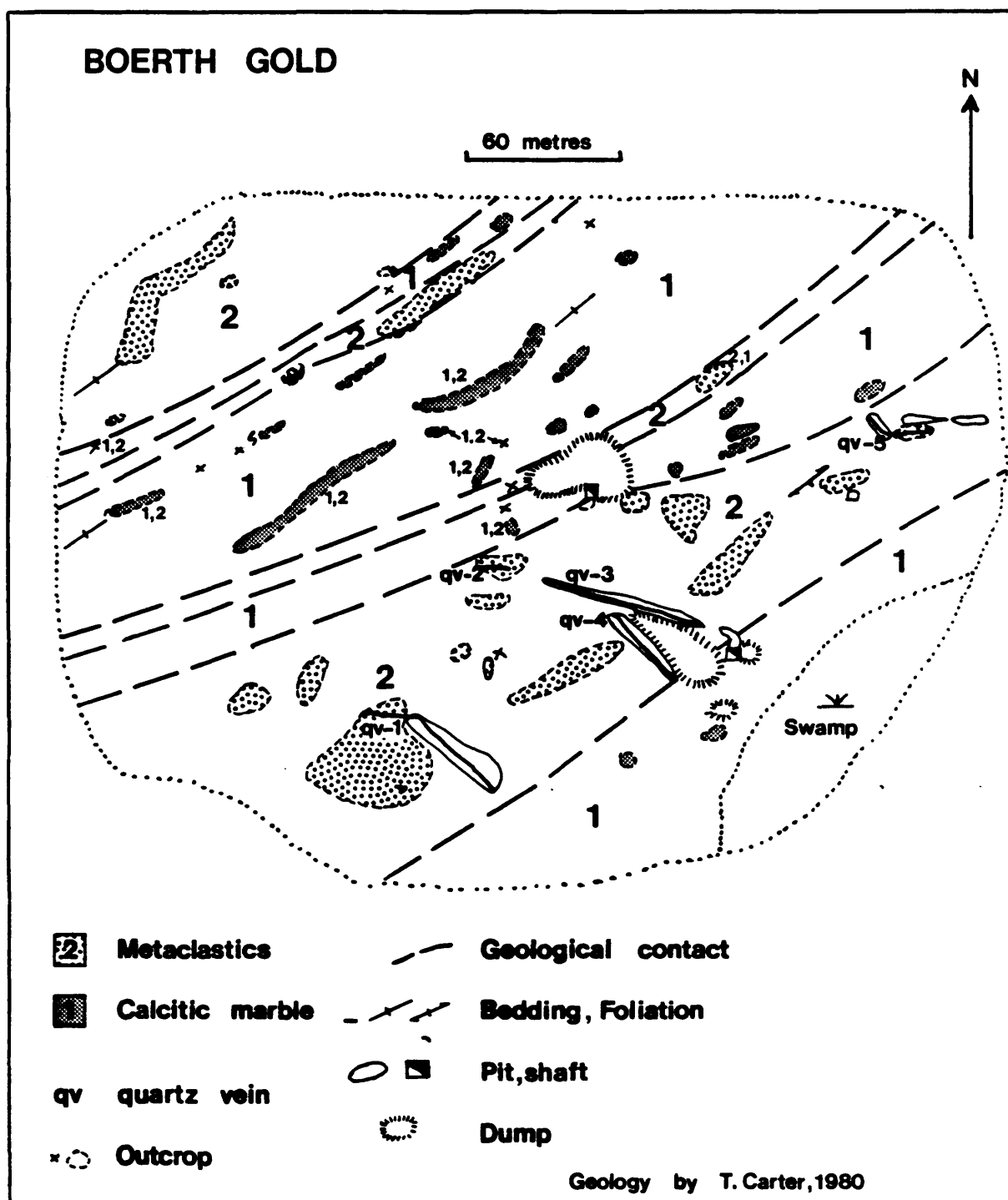


Figure 13: Geology of the Boerth gold deposit.

3) The Gough and Star deposits in Barrie Township exhibit relationships typical of the concordant, marble-hosted veins. The Star veins are hosted by massive to layered, grey to pink dolomitic marble, immediately south of and stratigraphically above a major sequence of andesitic flows and pyroclastics. Narrow beds of dacitic pyroclastics are intercalated with the marbles. Subordinate quartz, calcite, tremolite, and actinolite occur in the marble. Pits and trenches expose a series of northeast-trending quartz-actinolite veins that are concordant with the layering and foliation in the marbles. The veins consist of narrow, irregular masses of quartz and coarse actinolite that pinch and swell rapidly along their strike length. Individual veins are usually only 10-30 cm wide and often form parallel en echelon veins. Meen (1944) reports 11 parallel veins over a width of 3 1/2 metres in one trench. Disseminated pyrite and tourmaline are contained in the veins; pyrite also occurs in narrow parallel fractures in the marble wall rocks. Meen (1944) also reports chalcopyrite, scheelite, and rare bismuthinite in the veins. Three representative chip samples of mineralized veins collected by the author contained trace amounts of silver with 0.18 oz. Au per ton, 0.04 oz. Au per ton, and trace gold.

At the Gough deposit mineralized veins are hosted by light grey, massive to layered, dolomitic marble immediately southeast of a unit of massive, staurolite schist, within a sequence of intercalated marble and metaclastic rocks. A series of shallow

pits and trenches expose narrow lenses and discontinuous veins of quartz containing locally abundant calcite and sparsely disseminated pyrite, sphalerite, boulangierite, and arsenopyrite. Individual veins vary from 2 to 30 cm in width. A network of parallel, en echelon veins 2 to 15 cm wide occurring at erratic intervals over a width of 70 cm are exposed in the largest pit. The veins are concordant with layering and foliation in the host marbles. Two representative chip samples collected by the author from mineralized veins contained only trace amounts of gold, in addition to 0.40 oz. Ag per ton, 540 ppm As, 2430 ppm Sb, 36 ppm Cu, 8960 ppm Pb, and 315 ppm Zn; and trace Ag, 6600 ppm As, 300 ppm Sb, 330 ppm Cu, 350 ppm Pb, and 3950 ppm Zn.

4) The Addington and Ore Chimney deposits are the best examples of mineralized quartz veins associated with Flinton Group rocks. A detailed description of the Addington deposit is included with this report (see Addington Gold Mine, Mineral Deposit description No. 14). Both deposits are principally hosted by amphibolitic mafic volcanic rocks at or near the basal contact of Flinton Group quartzites and conglomerates. The Flinton Group rocks are interpreted to lie unconformably on the volcanic rocks (Moore and Thompson 1972, 1980) and are confined within a tight, isoclinally folded synform. At the Ore Chimney deposit, the geological relationships of the mineralized zone cannot be observed on surface. A shaft was sunk on the vein to a depth of 170 metres between 1902 and 1909 and a

considerable amount of underground exploration and development was completed by a diverse group of companies at intervals between 1902 and the present. Available records of the underground exploration results on file at the Geoscience Data Centre, Ontario Geological Survey indicate that disseminated chalcopyrite, pyrite, pyrrhotite, galena, sphalerite, and tetrahedrite occur within a narrow quartz vein hosted by schistose mafic volcanic rocks. The vein is reported to widen from about 50 cm near the surface to 1.2 metres at the 500 foot level of the shaft. Gold content is reported to increase with depth and silver values decrease. It has been estimated that 11,000 short tons of material grading 0.20 oz. Au per ton and 5.64 oz. Ag per ton is present between the depths of 30 metres and 170 metres. The predominant rock type on the dumps by the shaft is schistose amphibolitic to biotitic mafic volcanic rocks containing quartz vein material. Ankerite and dolomite are associated with the quartz, and disseminated grains; blebs, and scattered veinlets of galena, sphalerite, pyrite, pyrrhotite, and sphalerite occur in the vein material. A representative chip sample of dump material collected by the author contained 0.07 oz. Au per ton, 3.17 oz. Ag per ton, 1260 ppm Cu, 9600 ppm Pb, 1.63 percent Zn, 132 ppm As, and 134 ppm Sb.

At the Addington deposit mineralization is contained within a vein zone which has been traced almost continuously over a length of about 1700 metres. Lenses and stringers of quartz are irregularly distributed within biotitic schist representing a

shear zone along the contact between Flinton Group quartzite and conglomerate and amphibolitic mafic volcanic rocks of the Hermon Group. Subordinate carbonate, biotite, tourmaline, scheelite, magnetite, and ilmenite occur within the quartz lenses and stringers, along with disseminated pyrite, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, and galena. Native gold is also reported to be present (Bell 1949). Diamond drilling and underground exploration has outlined four orebodies within the vein zone that are gradational into sub-ore grade material both along strike and down dip. The orebodies form pipe-shaped lenses with vertical dimensions exceeding lateral dimensions, varying in width from less than 2 metres to nearly 15 metres in places. Gold values range from trace to nearly 1 oz. Au per ton over comparable widths. Recent brief descriptions of the structure and mineralogy are given by Springer (1982); mapping near the vein zone has been conducted by Dillon and Barron (1983).

Origin

These Grenville gold-quartz vein deposits have features in common with deposits such as the Dickenson, Dome, and Campbell-Red Lake lode gold mines in northern Ontario. There is currently a lack of consensus on the mode of formation of lode gold deposits but structural controls on localization are widely recognized. Study of Grenville gold-quartz vein mineralization may aid in interpretation of the genesis of these deposits.

Several features of the southeastern Ontario gold deposits are considered to be significant in determining an origin for the veins.

1. The principal veins are generally concordant with foliation and lithological contacts in the host rocks. Although cross-cutting veins representing later phases of vein formation occur within many of the concordant vein zones, there is, for example, a complete gradation from concordant dolomite, quartz-dolomite lenses to cross-cutting quartz veins at the Lavant-Darling deposits. Cross-cutting veins only rarely (i.e. Boerth) form the principal vein structure.

2. Sulphide mineralogy in the veins is broadly reflective of the host rock composition, arsenopyrite is more abundant in veins related to volcanic and intrusive rocks, antimony sulphides are more common in carbonate-hosted veins. The gangue mineralogy of carbonate-hosted veins (i.e. quartz-dolomite, quartz-tremolite) is consistent with the metamorphic mineralogy of the host rocks.

3. The veins are spatially related to low metamorphic grade rocks, and to areas of concentration of volcanic rocks. Veins are also often located proximal to large intrusions, or even hosted by intrusive rocks.

4. Localization of the larger, more economically significant veins is structurally controlled. These are principally confined to shear zones in relatively competent rock types, or adjacent to lithologic contacts.

In the author's opinion, formation of the stratabound Lavant-Darling vein occurrences can be used as model of the origin of all gold-quartz vein deposits in southeastern Ontario. Detailed studies completed by Carter (1981) indicate that vein formation and mineralization at the deposits probably occurred during retrograde metamorphism. Evidence cited includes the concordance of early mineralized dolomite and quartz-dolomite vein material with foliation and layering in the host rocks; and the close correlation between vein mineralogy (quartz, dolomite) and stable metamorphic mineral assemblages of the host dolomitic marble (quartz, dolomite). Metamorphic fluids are believed to have been responsible for vein formation. Contained metals were probably derived by remobilization of pre-existing concentrations of metallic sulfides in the host rocks. Evidence for this includes: 1) the stratabound, localized occurrence of the mineralized zones, and 2) the association of mineralized veins with a layer of stratiform pyrite at the Joe Lake occurrence. Fluid inclusion compositions of vein quartz indicate the mineralizing fluid was initially CO₂-rich and evolved into an aqueous brine of variable salinity; with 5-25 weight percent equivalent NaCl, in which NaCl was the principal dissolved constituent. Phase homogenization temperatures of the aqueous fluid inclusions define 140°C as the minimum temperature of vein formation and mineralization. The maximum is dependent on the peak metamorphic conditions reached in the area. Work completed by

Ewert (1977) in dolomitic marbles a few kilometres to the east indicate metamorphism peaked at approximately 400°C at estimated pressures of 3 to 5 Kb. The lower pressure estimate seems more likely, based on calcite-dolomite geothermometry and sphalerite geobarometry respectively. Consequently, vein formation and mineralization in the Lavant-Darling area must have occurred between 140°C and 400°C, at pressures of 3 Kb or less.

Geologic relationships of the other gold-quartz vein deposits in the area are consistent with a metamorphic origin. In particular the concordance of regional foliation and vein structures; correlation between deposit distribution and areas of low metamorphic grade; and consistency of vein mineralogy with host rock metamorphic mineral assemblages in carbonate-hosted veins. Shear zones provided dilatant zones favourable for localization of veins and associated mineralization. Many of the shear zones occur along lithological contacts and may have formed as a result of ductility contrasts. The origin of other shear zones, such as those in the Cordova gabbro, are uncertain. Veins in carbonate rocks are less well developed, probably as result of a similar ductility difference, their ability to dissipate stress by plastic flow rather than brittle fracture.

The observed geological relationships may indicate the origin of the metals. There is sufficient quartz in all the local rock types to provide a source for the veins. Sangster (1971) proposes that the veins and their contained metals were

mobilized locally from the host rocks during metamorphism into dilatant zones, such as shear zones. As the principal evidence he cites "the fact that the elemental content of the veins in both volcanic and carbonate hosts is compatible with their host rocks." (Sangster 1971, p.252). Other than an apparent preferential concentration of arsenic in volcanic and intrusion-hosted veins, and antimony in carbonate-hosted veins, the author could not confirm this close relationship. Carbonate rocks in southeastern Ontario generally have very low concentrations of metals, especially gold (Storey and Vos 1981); Papertzian and Kingston 1982a, 1982b), consequently they are considered to be unlikely source rocks. It is considered more likely that metals were derived from volcanic rocks which generally occur near most deposits, or from stratabound metal-bearing pyritic deposits (1A group) known to occur at the top of the volcanic succession. Supporting evidence includes the correlation between distribution of the veins and major volcanic successions, as noted above and previously, and the apparent localization of the vein deposits at certain stratigraphic levels, principally in the middle and upper parts of the Hermon Group, and in the lower portion of overlying members of the Mayo Group. The Cordova and Deloro groups of deposits also occur at this stratigraphic position as both host plutons have intruded the supracrustal sequence at the contact of the Hermon and Mayo Groups, on opposite sides of a major synform or basinal structure. Consequently the metals may have

been mobilized by the intrusions from the underlying volcanic rocks or associated stratabound mineral deposits. A more definitive identification of the source of the metals cannot be attempted without additional detailed geological studies and isotopic and trace element studies.

Fluid inclusion studies of the Lavant-Darling deposits (Carter 1981) indicate that both CO₂-bearing and saline aqueous fluids were responsible for mineralization and vein formation. NaCl was the principal dissolved salt. Aqueous fluid inclusions were observed by the author in thin sections of vein quartz from other deposits in the area. Cubic daughter crystals, probably halite, within aqueous fluid inclusions were observed in thin sections of vein quartz from the Deloro deposits. These observations suggest that aqueous brines were at least partly responsible for transportation and deposition of vein mineralization at other gold-quartz vein deposits in the area. This is also supported by the available data on alteration of the host rocks adjacent to veins (see Table 13) which indicates an addition of volatiles, including both CO₂ and H₂O.

Economic Potential

Production of greater than 1000 oz. of gold has been attained from three discordant quartz and quartz-ankerite vein deposits in southeastern Ontario; the Cordova, Deloro, and Gatling Five Acre mines (see Table). Significant amounts of silver were produced from the Cordova mine. Production of minor

Table 13. Chemical analyses illustrating alteration of host rocks near selected gold-quartz vein deposits.

<u>Craig</u> 1 - sheared basalt 2 - typical basalt														
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	CO ₂	S	LOI
1	42.0	1.47	12.10	1.20	9.80	0.14	7.54	9.50	0.79	3.53	0.10	7.83	0.38	9.10
2	47.2	1.58	13.80	2.60	10.50	0.20	8.77	10.40	2.46	0.40	0.12	0.11	0.06	0.80
1-2	-5.2	-0.11	-1.70	-1.40	-0.70	-0.06	-1.23	-0.90	-1.67	+3.13	-0.02	+7.72	+0.32	+8.30
<u>Ledyard</u> 1 - sheared gabbro 2 - typical gabbro														
1	40.0	1.5	13.10	2.55	6.80	0.16	9.17	9.37	0.34	2.09	0.12	9.84	0.01	13.50
2	46.0	0.92	17.10	3.48	5.59	0.12	9.24	8.76	2.42	0.26	0.09	0.57	0.02	3.50
1-2	-6.0	+0.23	-4.00	-0.93	+1.21	+0.04	-0.07	+0.61	-2.08	+1.83	+0.03	+9.27	-0.01	+10.0
<u>Sovereign</u> 1 - sericitized granite 2 - typical granite														
1	71.2	0.64	13.60	1.50	2.75	0.05	0.44	1.71	1.07	3.73	0.01	1.43	0.14	3.00
2	74.8	0.39	13.40	1.64	0.65	0.01	0.18	0.86	3.79	4.36	0.04	0.12	0.01	0.50
1-2	-3.6	+0.25	+0.20	-0.14	+2.10	+0.04	+0.26	+0.85	-2.72	-0.63	-0.03	+1.31	+0.13	+2.50

amounts of gold and silver is documented from eleven other deposits in the area (Carter 19..). Except for some production from the Cordova mine in 1939-1940, and the Sophia mine in 1940-1941, all the ore mined in the area was extracted in the late nineteenth and early twentieth centuries. No significant production has been attained from stratabound quartz-dolomite vein occurrences.

Significant tonnages of gold-bearing material both in bedrock and in surface dumps and tailings ponds are documented. At the Cordova mine it is estimated that remaining underground reserves total approximately 44,000 tons grading between 0.104 and 0.175 oz. Au per ton, with 50,000 tons probable and 100,000 tons possible ore (Cominco Ltd. company files; Satterly 1943). Approximately 21,700 tons of tailings and development ore and 0.175 oz. Au per ton, with 50,000 tons probable and 100,000 tons possible ore (Cominco Ltd. company files; Satterly 1943). Approximately 21,700 tons of tailings and development ore averaging 0.17 oz. Au per ton are estimated to be present in surface dumps (H.G. Harper, unpublished report for Orvana Mines Ltd., 1965). More recently Lasir Gold Inc. has estimated the ore dumps to contain 15,000 to 20,000 tons of broken rock averaging 0.06 oz. Au per ton, and has outlined 1000 tons of tailings estimated to contain an average of 0.33 oz. Au per ton (Walter Hood, Lasir Gold Inc., personal communication, 1982).

At the Addington deposit, in Kaladar Township, reserves are estimated to total 176,000 to 256,000 tons grading 0.15 to 0.16

oz. Au per ton, with 103,000 possible tons grading 0.08 oz. Au per ton (L.V. Bell, unpublished geological report for Addington Mines Ltd., 1949; Cominco Ltd. company files). The deposit is being evaluated by E.B. Exploration Inc. under an option agreement with the owner, Cominco Ltd. at the time of writing (1982).

At the Deloro deposit, on the east side of the Moira River opposite the former mill-site, is a large tailings pond estimated to contain 100,000 dry tons of ferric arsenate mud and silt. The average metal content of six sediment samples collected from the surface of the pond by Carter (1981b) is 5540 ppm Cu, 1300 ppm Ni, 104 ppm Pb, 153 ppm Zn, 1550 ppm Co, 4.65 percent As, 1030 ppm Sb, 0.83 oz. Ag per ton, and trace amounts of gold. The tailings pond is the waste from a custom mill that operated at the site subsequent to closure of the gold mine, treating various types of ore, principally from the Cobalt area of Ontario. Tailings from the gold mining and milling operation were not located by the author.

No reserve figures are available for other gold deposits in southeastern Ontario. However, gold assays of up to 1.96 oz. Au per ton have been obtained from samples taken by the author from surface exposures and dumps.

Re-evaluation of known gold deposits in southeastern Ontario and exploration for additional mineralization appears to be warranted at current high prices. Exploration should be directed to discordant quartz and quartz-ankerite vein deposits

in consideration of their past history of production, and should be confined to areas of greenschist to lower amphibolite facies metamorphism, close to major accumulations of volcanic rocks. Vein systems occupying major zones of structural displacement, i.e. shear zones, are considered to have the best potential of hosting mineralized bodies of economic size and grade. The basal contact of the Flinton Group, especially where it is in sheared contact with Hermon Group metavolcanics, and shear zones in the Cordova gabbro are recommended targets for exploration.

3C. Metamorphic-Metasomatic Molybdenum Deposits

Over 100 documented deposits of molybdenum mineralization occur in Grenville rocks in southeastern Ontario (see Table 14, Fig. 9). The deposits are very different from the more widely-recognized porphyry-type deposits. According to Karvinen (1973) similar deposits occur elsewhere in the world, but they are uncommon. At Matasvaara, Finland, and at Knaben, Norway, molybdenite occurs in gneisses, and in the Jordan River area of south-central British Columbia molybdenite occurs within sillimanite grade rocks.

In the southeastern Ontario deposits mineralization consists of very erratically dispersed coarse flakes of molybdenite, commonly in association with pyrite and pyrrhotite. Some of the deposits are enriched in uranium. The deposits are generally small, are locally high-grade (up to 1 percent MoS_2), and are erratically distributed over a wide

Table 14: List of documented molybdenum deposits in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Host</u>	<u>Associated Rock Type</u>
Gorman	Admaston	9	IX	pyroxenite	marble, pegmatite, paragneiss
Kiley	Admaston	8	XIII	pegmatite	paragneiss, marble
LaFleur's Lake	Admaston	12,13	XII	-	syenite gneiss, marble
Anstruther	Anstruther	24,25	XIV	-	marble, gneissic granite
Bagot Molybdenite	Bagot	29	IV	pegmatite	granite, marble, paragneiss
Belongers Corners	Bagot	30	IV	pyroxenite	marble, pegmatite, paragneiss
Blinkies Mountain	Bagot	29	I	amphibolite	marble, pegmatite, biotite gneiss
Buckhorn	Bagot	28	IV	pyroxenite	marble, granite
Culhane	Bagot	28	XII	pyroxenite	-
Hond Lake	Bagot	26	IV	pyroxenite	marble, pegmatite
Hunter	Bagot	15	X	pegmatite	marble
Morin	Bagot	25	IV	pyroxenite	-
Stones Lake	Bagot	11	V	pegmatite	granite gneiss, hornblende gneiss
Zenith	Bagot	27,28	IV	pyroxenite	pegmatite, granite, biotite gneiss, marble
Quilty	Blithfield	29	I	pyroxenite	marble, pegmatite
Cole	Bromley	24	V	pyroxenite	marble, pegmatite, paragneiss
Box	Brougham	18	I	pyroxenite	marble, pegmatite
Charron	Brougham	15	XI	pegmatite	marble, paragneiss
Guiney	Brougham	8	XII	pegmatite	marble, pegmatite
Hunt	Brougham	8,9	XI	pyroxenite	marble, granite, paragneiss
Maloney	Brougham	13,14	XIII,XIV	-	marble, paragneiss
Ross-O'Brien	Brougham	16,17,18	XI,XII	amphibolite	marble, granite, paragneiss
Sunset	Brougham	36	XIV	pyroxenite	marble, paragneiss
Brotton	Burns	13	II	pegmatite	paragneiss
Brough Lake	Cardiff	14	X	pegmatite	biotite-hornblende gneiss
Dixon & Hunter	Cardiff	27	XI	pegmatite	biotite paragneiss
Dickson-Riddel	Cardiff	18	XIV*	paragneiss	-
Evans	Cardiff	11	X	pyroxenite	granite, marble, gneiss
Joiner	Cardiff	3	XX	-	paragneiss, marble, pegmatite
Lot 7, Con. IX	Cardiff	7	IX	pegmatite	-
Matthews-McMahon	Cardiff	12	XI	pyroxenite	pegmatite, gneiss
Mooney	Cardiff	18	IX	pegmatite	hornblende gneiss
Orr-Kidd	Cardiff	11	V	pegmatite	gneiss
Powell & Anderson	Cardiff	9	VI	pegmatite	granitic gneiss
Bronson	Dungannon	25	XIII,XIV	-	-
Stoughton	Dungannon	5	XVI	-	pegmatite, marble, gneiss
Keller	Faraday	21	A	pyroxenite	gabbro, marble, paragneiss
British	Glamorgan	32	V	pyroxenite?	pegmatite, gabbro, nepheline syenite
Little Glamour	Glamorgan	34	XIII	pegmatite	quartzite gneiss

Table 14 (Continued)

Simmonds	Glamorgan	1-5	VII	-	gneiss, pegmatite, granite
Wren	Gattan	11	XI	pegmatite	paragneiss
Legree	Griffith	33,34	IV	-	pegmatite
Lepine	Griffith	19	VII	pyroxenite	pegmatite, marble
Spain	Griffith	31	IV	pyroxenite	marble, paragneiss
Harcourt	Harcourt	2,3,4	I	pyroxenite	-
Baptiste Lake	Herschel	30,31	V,VI	pyroxenite	marble, pegmatite, granite
Williams	Herschel	27,28	IV	-	-
Clow	Hinchinbrooke	22	III	pegmatite	granite gneiss
Drader	Hinchinbrooke	18	X	pegmatite	granite gneiss
Godfrey	Hinchinbrooke	4	II	pegmatite	paragneiss
Sillis	Hinchinbrooke	26	VIII	pegmatite	granite gneiss
Marisette	Kaladar	13	II	pegmatite	granite gneiss
Horscroft	Laxton	5	XI	pyroxenite	marble, granitic gneiss
Denna Lake	Lutterworth	7	X	quartz vein	hornblende-scapolite gneiss
Hopkins	Lutterworth	7,8	II	quartz vein	gneiss
Lutterworth	Lutterworth	23	V	-	granite gneiss, marble
Bruceston	Lyndoch	33	V	pyroxenite	marble
Jamieson	Lyndoch	5,6	VIII	pyroxenite	marble, amphibolite, granite
Lyndoch	Lyndoch	4	VIII	pegmatite	marble, granitic gneiss
McCoy	Lyndoch	34	II	pegmatite	marble, paragneiss
Mining Mountain	Lyndoch	7	VIII	-	granite, marble, pegmatite, paragneiss
Wolfe Fire Tower	Lyndoch	4	XIV	granitic gneiss	paragneiss, amphibolite
Wilson	Matawatchan	3	VI	pyroxenite	pegmatite
Burnstown	McNab	19	IV	pegmatite	paragneiss, granite
Kring	Miller	5	NE Range	pegmatite	gneiss
Shannon	Miller	5	SW Range	pegmatite	gneiss
Affenby	Monmouth	10,12	XV	pyroxenite	-
American					
Molybdenites	Monmouth	32	XV,XVI	pyroxenite	biotite paragneiss
Anderson	Monmouth	12	XI	-	-
Dwyer	Monmouth	32	XVII	pyroxenite	granite, marble
Georgia Lake	Monmouth	11	XV	pegmatite	marble, hornblende gneiss
Gibson	Monmouth	13	XIII	hbde gneiss	pegmatite
Johnston	Monmouth	17	XV	hbde gneiss	pegmatite
Lillico	Monmouth	14,15	XII	pyroxenite	pegmatite, granite, hbde gneiss
MacDougall	Monmouth	31	XVI	marble	pegmatite
Madill	Monmouth	10	XIV	-	-
York River	Monteagle	6	I	quartz vein	-
Merkley	N. Crosby	14	V	pyroxenite	marble, granite

Avery	Olden	24	IX	marble	granite
Gray	Olden	19	IV	greywacke	marble
MacDonnell	Olden	7	VI	marble	granite-syenite
Smith	Olden	6	VI	hbde gneiss	granite, marble
Varettes	Olden	2	VII	pyroxenite	-
Corak	Oso	15	II	-	-
Craigmont	Raglan	6	XVIII	alkalic dike	granite
Liedtke	Raglan	27	IX,X	pegmatite	marble, paragneiss, pyroxenite
Elliot	Ross	7	IX	marble	-
Rose	Ross	22	II	pegmatite	marble, paragneiss
Felhaber	Sebastopol	14,15	II	pegmatite	paragneiss
Opeongo Road	Sebastopol	36-38	Range C	pegmatite	marble, gneiss
Burns	Sheffield	4	XV	-	-
Calvert	Sheffield	9,10	XII	pyroxenite	-
Chisholm	Sheffield	5	XIV	pyroxenite	marble, granite
Dwyer	Sheffield	8	XV	marble	-
Kellar	Sheffield	12	XIII	pegmatite	marble, gneiss
O'Berkerk	Sheffield	10,11	XIII	-	marble, gneiss
Spratt	Sheffield	8	XV	-	marble, gneiss
Wager	Sheffield	15	XVI	pyroxenite	marble, gneiss
Adair	Sommerville	3	A	-	marble, mica schist

area. They invariably occur within moderate to high-grade metamorphic rocks (amphibolite to granulite facies) of the Grenville Supergroup, spatially removed from gold-quartz vein deposits which are preferentially concentrated within low-grade metamorphic rocks. Their distribution is very similar to that of uranium deposits in the area (see Fig. 14). Deposits are preferentially localized within sequences of intercalated marbles and siliceous sedimentary gneisses, usually in close association with the marbles. Many of the deposits also occur within or near the margins of large granitic plutons, or intrusions of granite pegmatite.

Three distinct sub-types, as previously described by Karvinen (1973), are recognized.

1. Stratabound deposits hosted by lenses of pyroxenite skarn.
2. Deposits hosted by pegmatite dikes or sills.
3. Stratiform deposits hosted by layers of amphibole gneiss.

1. Mineralization at the skarn-hosted deposits consists of erratically dispersed coarse flakes of molybdenite contained within a dark green, massive, coarse-grained skarn comprising diopside, and scapolite and/or plagioclase. Accessory minerals may include calcite, apatite, sphene, microcline, tremolite-actinolite, muscovite, biotite, quartz, pyrite, and pyrrhotite. The pyrite and pyrrhotite locally form massive lenses within and gradational into the skarn. According to

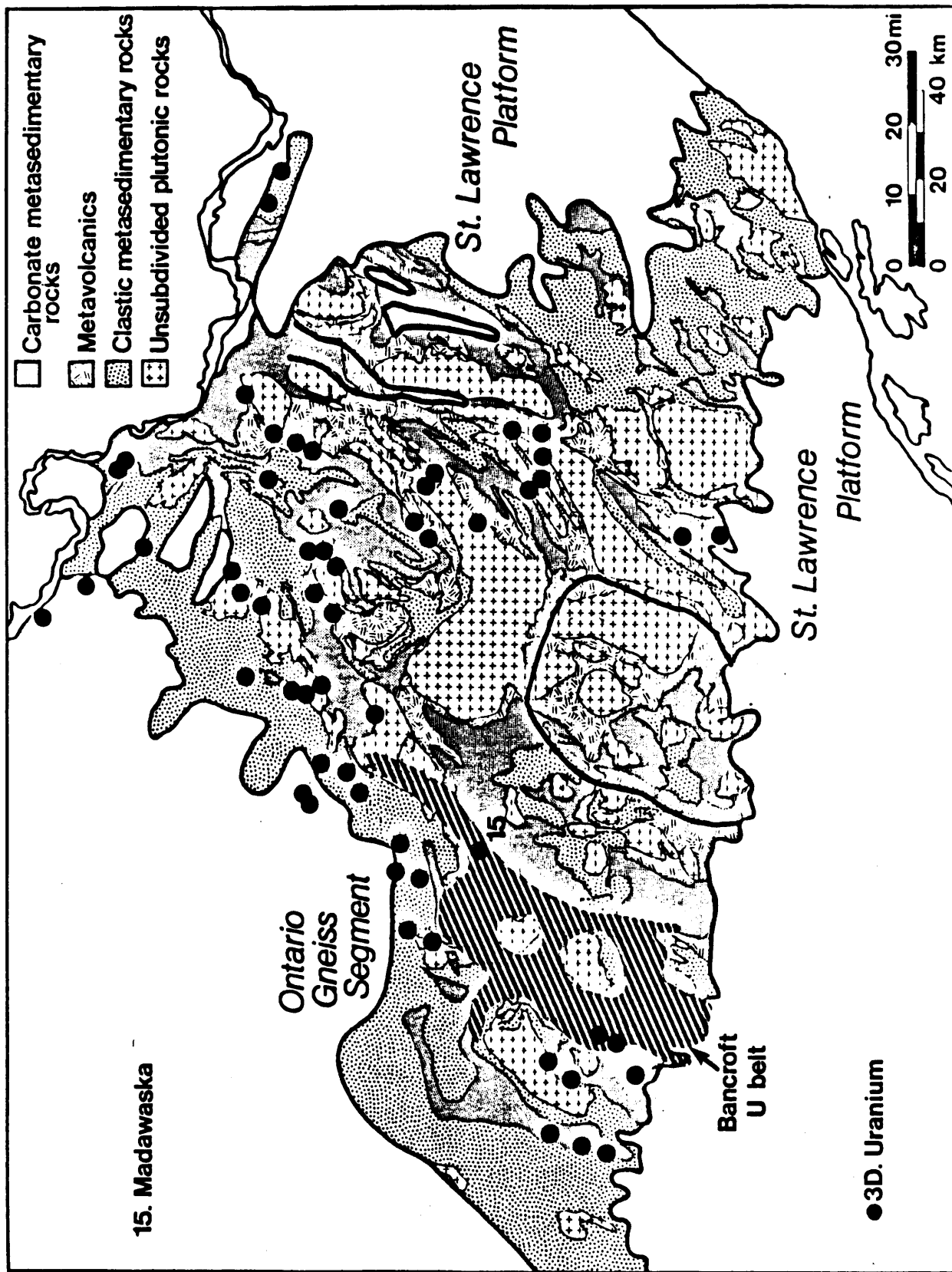


Figure 14: Distribution of uranium deposits in southeastern Ontario.

Karvinen (1973) in scapolite-rich skarns molybdenite is preferentially concentrated in the sulfide-rich lenses and occurs as sparsely scattered flakes in sulfide-poor parts of the skarn. In feldspar-rich skarns molybdenite is normally more abundant in the diopside-rich portions.

The skarns form stratabound lenses within sequences of intercalated marbles and siliceous paragneisses, often occurring as conformable bodies along a marble-paragneiss contact. The marbles in contact with the mineralized skarns are calcitic, with minor amounts of dolomite, muscovite, quartz, biotite, phlogopite, and albite. The paragneisses include granitic gneisses, hedenbergite gneisses, quartzite gneisses, and biotite and hornblende gneisses. Pegmatite dikes and sills are present at some deposits, and in some cases, such as the Hunt (see Hunt Molybdenum Mine, Mineral Deposit description No. 15), and Matthews-McMahon deposits, the skarn zones occur at the contacts between pegmatite dikes or sills with marble or paragneiss.

In detail the geological relationships of the mineralized skarn bodies are much more complex. For example, at the American Molybdenite deposit, described by Vokes (1963), the principal rock type is a coarse-grained pyroxene-albite rock consisting of light green, subhedral to euhedral diopside grains set in a matrix of white albite. Irregular patches and vein-like segregations of coarser albite and diopside occur within this rock, and are gradational into it. Crystal aggregates of a darker green pyroxene occur within the lighter

green diopside. Light green euhedral apatite crystals occur randomly scattered throughout the rock, and sphene is another accessory mineral. Vein-like segregations of coarse pyroxene, albite, and grey to white calcite were also noted by Vokes (1963). Within the mass of the pyroxene-albite skarn are numerous inclusions of a fine- to medium-grained, rusty-weathering gneiss. The gneiss is composed mainly of plagioclase and light green pyroxene, with accessory biotite, pyrite, pyrrhotite, and rare quartz. There are no exposures of marble in the immediate vicinity of the deposit.

Rock types exposed in the vicinity of the Hunt deposit include calcitic and dolomitic marble, pegmatite, biotite gneiss, amphibole gneiss, and pyroxenite skarn. The skarn is a massive, coarse-grained, dark green rock that consists essentially of diopside and minor scapolite, tremolite, and microcline, and locally abundant pyrite and pyrrhotite. The skarn forms narrow lenses and layers within the marble near or at the contact with the pegmatite. At some deposits molybdenite

Molybdenite mineralization at the skarn-hosted deposits generally consists of erratically dispersed coarse flakes. At some deposits molybdenite and pyrrhotite are confined within pyrite veins within the skarn, as at the Harcourt deposit, or within vuggy sulfide-rich zones.

2. Late pegmatite dikes and sills are common within the moderate to high-grade metamorphic terrain in southeastern Ontario. Some of these dikes and sills host concentrations of

molybdenum mineralization. The mineralized pegmatites usually occur within successions of intercalated marbles, amphibole paragneiss, biotite paragneiss, and granitic gneiss. The pegmatites consist mainly of massive intergrowths of quartz and feldspar, with subordinate hornblende, pyroxene, pyrite, and pyrrhotite, and are often mineralogically similar to the rocks they intrude. This is well illustrated at the Spain deposit (Mineral Deposit description No. 16) where the dikes are remarkably similar to the gneisses they intrude except for a higher content of microcline, quartz, and iron sulfides. As noted by Karvinen (1973), dikes which intrude the mineralized gneiss at the deposit are mineralized; similar pegmatite dikes in surrounding unmineralized gneiss are unmineralized.

Molybdenite occurs randomly distributed as coarse flakes within the mineralized pegmatite. At some other pegmatite-hosted deposits, such as the Kellar deposit in Sheffield Township and the Liedtke prospect in Raglan Township, the molybdenite is confined to fractures and forms veins and stringers within the pegmatites.

3. The deposits hosted by amphibole gneiss are very similar to the skarn-hosted deposits. Although described here as amphibole gneisses the principal primary mafic mineral in these gneisses, is hedenbergite (Karvinen 1973). Karvinen has identified primary and secondary mineral assemblages in the gneisses. The primary assemblage consists of hedenbergite, scapolite, minor sphene, apatite, iron sulfides, and rare

quartz. This has been replaced in whole or in part by an assemblage of microcline, plagioclase, hornblende, calcite, quartz, and biotite at most of the deposits. Scapolite-rich gneiss is only locally preserved; the scapolite is largely replaced by plagioclase of albite or oligoclase composition.

The plagioclase in turn is largely replaced by microcline, especially at the Ross-O'Brien deposit. Hornblende commonly occurs as rims on hedenbergite grains.

The gneisses normally occur as conformable layers within mixed sequences of carbonate and siliceous clastic metasedimentary gneisses, usually along marble-paragneiss contacts. The rocks are normally medium-grained, homogeneous, and have a good foliation, and locally exhibit gneissic layering. Molybdenite occurs as coarse flakes that are commonly concentrated in coarse-grained pegmatitic portions of the gneisses which contain more quartz and microcline, and generally lack a directional fabric. At the Joiner deposit in Cardiff Township and the Spain deposit in Griffith Township these pegmatite phases form narrow, irregular veins and cross-cutting dikes. At the Ross-O'Brien deposit they form narrow lenses parallel to the foliation of the gneisses. Bodies of pyroxenite skarn are associated with the amphibole gneisses at all deposits, and pegmatite dikes and sills are not uncommon.

The marble at the deposits is calcitic, with minor amounts of dolomite, diopside, mica, graphite, and quartz. The adjacent

paragneisses include granitic, hornblende, and diopside gneisses.

Origin

As a result of an intensive study of molybdenum deposits in the Grenville Province in both southeastern Ontario and southwestern Quebec, Karvinen (1973) has proposed that all the deposits have a common origin related to sedimentation and metamorphism. The molybdenum is envisaged as originally being concentrated in sediments probably organic shales.

Rusty-weathering schists which are common in low-grade metamorphic rocks in the Grenville Province are possible equivalents of organic shales, and contain minor amounts (5-20 ppm) of molybdenum (Lumbers 1969). Karvinen proposes that during regional metamorphism molybdenum was selectively leached from molybdenum-rich sediments by chloride-rich metamorphic hydrothermal fluids and deposited in skarns and hedenbergite gneisses along carbonate-metaclastic contacts. Further mobilization of molybdenum occurred during a late period of metasomatism, with redeposition into pegmatite dikes, sills, and lenses.

Several significant features of the deposits appear to suggest the origin proposed by Karvinen, including:

- 1) All molybdenum mineralization is hosted by skarns, gneisses and pegmatites of metamorphic-metasomatic origin.

- 2) Mineralization is preferentially associated with mixed sequences of carbonate and siliceous clastic sedimentary rocks.
- 3) All the deposits are confined to rocks which have been regionally metamorphosed under intermediate to high-grade conditions; no molybdenum mineralization occurs in greenschist facies rocks in southeastern Ontario, even within units that are mineralized in high-grade terrain.

The significance of the spatial relationship between the deposits and igneous intrusions is uncertain. The intrusions were, for the most part, emplaced before the culmination of regional metamorphism. As the host rocks are massive it seems , that the molybdenum deposits formed after the culmination of of regional metamorphism. Consequently, in their present form at least, the deposits are genetically unrelated to the intrusions. The spatial relationship may be simply fortuitous, due to the large number of intrusions in the area. Alternatively the intrusions may have been the initial source of metals, with regional metamorphism causing remobilization of the molybdenum and redeposition along favourable lithologic contacts.

Economic Potential

The skarn and gneiss-hosted deposits form lenticular bodies that range from less than one metre to 25 to 30 metres thick (Harcourt prospect, Joiner prospect), and a few metres to a few hundred metres long (Hunt mine). The mineralized pegmatites are normally much smaller. Average metal contents of the deposits range up to 1.5 percent MoS_2 , but the molybdenite is very erratically distributed, making accurate grade assessment difficult.

Limited production usually consisting of a few tens or hundreds of pounds of hand-picked flake, has been attained from many deposits, in operations conducted in the early 1900's. Production of 96,660 lb. of 95% MoS_2 obtained from about 9100 tons of ore is documented from the Hunt mine in Brougham Township, between 1915 and 1918, making it the largest producer in the area. Production of more than 10,000 lb. of MoS_2 is also recorded from the Spain and Zenith deposits.

The known deposits are small relative to porphyry-type deposits. They contain insignificant amounts of molybdenum and must be considered to have low potential for development.

3D. Uranium Deposits

Uranium mineralization in the Grenville Province in southeastern Ontario has been described by numerous workers including Ellsworth (1922), Freeman (1936), Hewitt (1967), Long et al. (1962), Robinson and Hewitt (1958), Rowe (1952), Satterly (1945, 1957), Steacy et al. (1973), Thomson (1943), Bright

(1977, 1979), Gordon et al. (1981), and Masson and Gordon (1979, 1980, 1981). Numerous university theses have been written on this subject and large amounts of development and exploration work have been completed by mining companies. The author has not conducted field studies of uranium deposits in the area consequently cannot contribute original observations.

Information present here is summarized from the sources quoted above, with principal reference to Masson and Gordon (1981) and Gordon et al. (1981). Over 350 uranium deposits occur in the area; the reader is referred to Gordon et al. (1981) for a complete list and geological summary of the deposits.

Geology

Concentrations of uranium mineralization are abundant and widespread and constitute the single most common type of metallic mineralization in the area (see Fig. 14). Uranium mineralization normally consists principally of disseminated uraninite and uranothorite, with minor to locally abundant allanite, thorite, thorianite, and columbates of titanium and tantalum. The mineralization is hosted by several rock types including zoned and unzoned pegmatites, sulphide-rich siliceous marbles, calc-silicate skarns, and calcite and pyroxene veins (Masson and Gordon 1981). All these types of uranium deposits are confined to areas of moderate to high amphibolite-granulite)

metamorphic grade. There is one deposit of different type hosted by quartzose sandstone and dolomite of the Lower Ordovician March Formation, in March Township. Most significant concentrations of uranium mineralization in the area and are described in some detail below. The reader is referred to Masson and Gordon (1981) for more detailed descriptions of the other deposit types.

Unzoned pegmatites cut all other Precambrian rocks in the area and were emplaced during the waning phases of regional metamorphism (Lumbers 1981), probably as a result of local anatexis melting. The pegmatites are granitic to syenitic in composition, and consist principally of quartz, microcline, microperthite, and soda plagioclase, with variable amounts of biotite, muscovite, hornblende, magnetite, pyrite, pyroxene, allanite, and zircon (Masson and Gordon 1981). They occur as long narrow dikes or sills up to 1 km in length and up to 50 metres in width. Mineralization is usually concentrated in sheared, fractured portions of the pegmatites, often in altered zones near the contacts with the country rocks, with associated silicification, hematization, and albitization. Mineralization is principally disseminated uranothorite and uraninite, usually in association with abundant magnetite (Masson and Gordon 1981).

Significant production of uranium was obtained from the Madawaska, Canadian Dyno, Bicroft, and Greyhawk mines. All four deposits represent complex unzoned pegmatites and are described in general terms below. The Madawaska mine is described in

detail by R. Alexander (Madawaska Uranium Mine, Mineral Deposit description, No. 17, this report).

The Madawaska mine deposit occurs within the Faraday metagabbro complex, an elliptical pluton which has intruded a northeast-trending sequence of amphibolite, paragneiss, and minor marble. Gneissic granite and syenite form northeast-trending belts north of the mine. Complex, unzoned pegmatite dikes and sills of syenitic to granitic composition intrude the metagabbro and associated rock types. The pegmatites are generally conformable with foliation in the country rocks, and are only locally cross-cutting. The distribution of the pegmatites defines the limbs of an overturned synform and a less well defined antiform. There are also subsidiary zones of pegmatite dikes and veins between the limbs of the two fold structures.

All of the ore at the Madawaska mine occurs within pegmatite. Ore shoots are randomly located within the pegmatite bodies and are gradational into the surrounding pegmatite. In the larger pegmatites the mineralized zones frequently form lenticular zones along and oriented parallel to the contacts of the pegmatite, or are medially located. Better grade ore shoots are usually distinguished by increased amounts of hematite, and increased frequency of magnetite, mafic crystals and xenoliths of metagabbro. Ore shoots typically vary from 50 to 350 feet in length, 5 to 250 feet wide, and 50 to 300 feet high. Grades are irregular.

The mineralized pegmatites are composed of pink to red feldspars (microcline, microcline perthite, albite), pyroxene, amphiboles, and quartz. Accessory minerals include magnetite, zircon, sphene, apatite, tourmaline, hematite, calcite, anhydrite, pyrite, marcasite, and uranium minerals. The main uranium minerals are uraninite, uranothorite, thorite, allanite, and secondary uranophane. The pegmatites are fractured or jointed and locally are brecciated. Quartz fractured by shattering radioactivity is often observed in rich ore-bearing sections.

The Greyhawk mine deposit occurs adjacent to and is very similar to the Madawaska deposit. Metagabbro is intruded by granitic pegmatite dikes which may vary from 0.3 to 18.3 metres in width. The larger pegmatite bodies are sills which are conformable with foliation in the metagabbro. Ore shoots average about 30 metres in length by 1.8 metres wide, and occur in association with magnetite, hematite, and pyroxene-rich zones in pegmatite, enrichments in contact zones of pegmatites, and in breccia zones in metagabbro. Principal radioactive minerals present are uraninite, uranothorite, allanite, and rare pyrochlore and betafite. Accessory minerals present include sphene, zircon, apatite, and pyrite.

The Canadian Dyno mine deposit occurs within a sequence of amphibolite, pyroxene amphibolite, biotite-diopside-scapolite granulite, and minor garnet-sillimanite paragneiss and marble along the eastern flank of the Cheddar granitic pluton. The

metasedimentary paragneiss sequence is intruded by and partially replaced by syenite gneiss. All the rocks are intruded by north-trending leucogranite pegmatite dikes.

Five contiguous mineralized zones, A to E, occur at the deposit. Each consists of numerous lenticular branching dikes of leucogranite and pegmatitic leucogranite. Mineralization consists of uraninite, uranothorite, uranophane, allanite, and rare cyrtolite and thorite, with accessory sphene and zircon. The mineralization is preferentially associated with zones of abundant magnetite and hematite within the pegmatites. Within the B zone ore shoots average 65 feet long and 6.5 feet wide.

The Biccroft, or Centre Lake, deposit occurs within a band of syenitized paragneiss and amphibolite which is overlain by marble and underlain by the Centre Lake leucogranite sheet of the Cardiff batholith. The paragneisses include biotite paragneiss, amphibolite, scapolite-biotite gneiss, granet-sillimanite-biotite paragneiss, and narrow bands of siliceous marble. En echelon radioactive pegmatite dikes up to 80 feet wide and 400 feet long form a mineralized zone 3000 feet long and extending to a depth of 1500 feet within the paragneiss succession. Ore shoots of variable width and up to 200 feet long occur within the dikes, in association with mafic-rich (pyroxene) syenitic and granitic pegmatite. Uraninite and uranothorite are the principal radioactive minerals, with accessory allanite, zircon, sphene, apatite, fluorite, pyrite, pyrrhotite, and molybdenite.

Economic Potential

Significant production of uranium was achieved from the Bicroft, Canadian Dyno, Greyhawk, and Faraday mines between 1956 and 1964. A total of 11,102,056 pounds of U_3O_8 were produced from 6,188,852 tons of ore during this period (see Table 15, Gordon et al. 1981). In 1976 production resumed at the Faraday mine, operated by Madawaska Mines Limited, and continued to July 1982. During this period Madawaska Mines Ltd. recovered 3,336,666 pounds of U_3O_8 from 2,152,548 tons of ore milled for a recovered grade of 0.078 percent U_3O_8 , or 1.55 pounds U_3O_8 per ton. Total production from uranium mines in southeastern Ontario thus amounts to 14,438,722 pounds of U_3O_8 from 8,341,400 short tons of ore. There is no current production from uranium mines in the area.

Mineralized zones of significant dimensions have been outlined at several of the other uranium deposits in the area, in Anstruther, Burleigh, Cardiff, Cavendish, Faraday, and Monmouth Townships. Reserve calculations have been made by several companies based on diamond drilling and underground exploration programs. These are summarized in Table 15, and range from about 30,000 tons to over 2,000,000 tons, with grades ranging from about 0.7 to 4 pounds of U_3O_8 per ton. At current price levels and market conditions all of these deposits are probably uneconomic. The Madawaska mine is a compelling example as it was forced to close in July of 1982 with remaining proven

Table 15: Inventory of mineral reserves in the proven, probable, and possible categories at uranium deposits in southeastern Ontario. Summarized from data in Gordon et al. (1981). Grades are expressed as pounds of U_3O_8 per ton.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Reserves</u>
Farcroft	Anstruther	23-28	II,III	1200 tons/vertical foot, 1.54 lb/ton
Newkirk-B Group	Anstruther	14-18	I,II	406,000 tons, 1.77 lb/ton
	Burleigh	26	VIII,IX	
Pole Star	Burleigh	23-25	XI,XII	406,112 tons, 1.768 lb/ton
Bicroft	Cardiff	27,28	XI	?
Canadian Dyno	Cardiff	12	VII-IX	500,000 tons, 1.3 lb/ton
Croft	Cardiff	32	XV	979,810 tons, 1.20 lb/ton, in 3 zones
Halo	Cardiff	4,5	XVIII	472,000 tons, 2.24 lb/ton
Kenmac Chibougamau	Cardiff	6-8	XIV	200,000 tons, 4 lb/ton
Covendish	Cavendish	14	VII	435,624 tons, 1.92 lb/ton
Greyhawk	Faraday	9-11	XII	200,000 tons, 1.3 lb/ton
Madawaska	Faraday	16,17	II	863,181 tons, 3 lb/ton
Amalgamated				
Rare Earth #1	Monmouth	20	VIII	216,660 tons, 2.2 lb/ton
Amalgamated				
Rare Earth #2	Monmouth	17-21	V,VI	292,444 tons, 1.9 lb/ton
				56,720 tons, 2.4 lb/ton
Empire B	Monmouth	33-35	X-XII	2,179,166 tons, 0.726 lb/ton
Northern Nuclear	Monmouth	5-8	VI,VII	2,000,000 tons, low-grade fluorite
				200,000 tons, 0.9 lb/ton

and probably reserves of over 800,000 tons of ore averaging 3 pounds of U_3O_8 per ton (see Alexander, this report).

Although not exploitable at present, in the long term it is considered probable that one or more of these deposits may be profitably mined for uranium. It can also be reasonably expected that deposits of similar size and grade remain to be discovered.

Origin: There are several important regional associations of uranium mineralization in the area that may be of genetic significance.

- 1) All uranium deposits are restricted to areas of relatively high (amphibolite-granulite) regional metamorphic grade.
- 2) Significant concentrations of uranium mineralization do not occur in the Ontario Gneiss Segment.
- 3) Most of the deposits are spatially related to a northeast-trending belt of alkalic gneisses and intrusive rocks in the northwestern part of the area. This belt parallels the contact of the Grenville Supergroup with the underlying Ontario Gneiss Segment.
- 4) In the Glamorgan-Anstruther-Cardiff area, southwest of Bancroft, uranium deposits are preferentially localized within certain stratigraphic units along the margins of large gneiss domes and igneous plutons (Bright 1977, 1979).
- 5) Many uranium deposits are localized within zones of intense regional deformation, often near the flanks of large gneiss domes or igneous plutons (Masson and Gordon 1981). Bright (1977) has noted that many of the deposits in the Bancroft area

occur within major northeast-trending zones of faulting, shearing, and cataclasis:

The geologic associations of uranium mineralization in the area strongly support an epigenetic origin closely related to high grade regional metamorphism and intense structural deformation. According to Masson and Gordon (1981, p.14), "The spatial relationship of unzoned pegmatites and most zoned pegmatites to areas of high-grade regional metamorphism rather than to intrusive granites suggests an anatectic origin.... The age of the pegmatites precludes a genetic connection to the intrusive granites. According to Fyson et al (1979) the pegmatites are about 230 m.y. younger than most of the intrusive granites which have been dated at 1250 m.y." Uranium may have been locally remobilized from previously existing concentrations or leached in trace amounts from the country rocks by metamorphic fluids or anatectic melts during high-grade regional metamorphism. The observations of Masson and Gordon (1981) suggest the former process is more likely. For example, pegmatites intruding pyritic rocks at the Card occurrence contain pyrite, and where they intrude biotite gneisses at the Barr Feldspar Quarry they contain biotite. Good examples of uranium enrichment by this process are the pegmatite dikes intersecting the mineralized zones at the Spain and Zenith U-Mo deposits. The pegmatites contain uranium and molybdenum minerals only where they cut pre-existing mineralized skarns and gneisses. Faults and shear zones would have provided favourable

structural sites for localization. Subsequent brecciation and shearing provided channelways for additional uranium deposition from late-stage hydrothermal fluids (Masson and Gordon 1981).

Masson and Gordon (1981) proposed several possible sources of uranium mineralization in the area:

1) Late Precambrian metaclastic rocks comprising the basal unit of the Grenville Supergroup immediately above the contact with the Ontario Gneiss Segment. The Grenville Supergroup is interpreted by Lumbers (1980) to rest unconformably on the underlying gneisses of the Ontario Gneiss Segment. Consequently erosion of these Middle Precambrian rocks probably contributed a major portion of the basal clastic sequence of the Grenville Supergroup. Synchronous erosion and concentration of uranium may also have occurred.

2) Alkalic intrusive rocks and gneisses. Masson and Gordon (1981) perceive the principal role of alkalic rocks as providing mobilizers for the uranium. Alkalic rocks are also commonly enriched in radioactive and REE elements, consequently significant amounts of uranium may also have been leached from these rocks.

3) Quartz-monzonite intrusive rocks.

3E. Post-Ordovician Ba-F-Sr-Pb Veins

A large number of late fissure vein deposits occur in southeastern Ontario and southwestern Quebec. The veins occupy late, cross-cutting, vertical to nearly vertical faults and fractures which parallel the strike of northwest-trending

post-Ordovician faults of the Ottawa-Bonnechere graben system, to which they are probably genetically related. Veins cut and are preferentially hosted by both Grenville marbles and Ordovician limestone near the Grenville/Paleozoic contact (see Fig. 15). Some veins are also hosted by Grenville metaclastics, metavolcanics, and intrusive rocks. Coarse-grained, white to pink calcite is the principal vein mineral at most of the deposits, with extremely variable proportions of associated barite, fluorite, galena, and locally abundant sphalerite and celestite. According to Sangster (1970) and Sangster and Bourne (1982), the three most common associations are calcite-fluorite-barite, calcite-barite-galena, and calcite-celestite. This is generally consistent with observations by the author and a survey of the literature (see Table 16, Plate 13, 14).

Calcite-fluorite-barite veins. The following description is taken largely from Guillet (1964). Almost all the fluorite-bearing veins of this type in southeastern Ontario occur in the Madoc area. The fluorite and associated barite and calcite occurs in fractures and fissures within or associated with the Moira Lake fault. The fault is a northwest-trending, nearly vertical fracture zone that defines the Grenville-Paleozoic contact in the vicinity of the town of Madoc. The main fault has been traced for about 5 1/2 km and is evident on air photos for a further 6 1/2 km to the southeast. The principal fluorite deposits occur within this fault, but

Table 16: List of late calcite fissure vein deposits in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Vein Mineralogy</u>
Crosier	Bedford	19	VIII	calcite-galena
Murphy-Hickey	Bedford	17	VI	calcite-galena
Murphy, James	Bedford	14	V	calcite-galena-barite
Murphy, John	Bedford	13	V	calcite-barite-galena
Murphy, Leo	Bedford	12	IV	calcite-galena
Patterson	Bedford	21	VIII	calcite-galena
Robinson	Bedford	19	VII	calcite-galena-sphalerite
Trumble	Cashel	29	IV	calcite-galena-barite
Campbell	Fitzroy	NW extension	VI	calcite-galena
Kingdon Mine	Fitzroy	22-24	VI	calcite-galena-sphalerite
Stanton	Fitzroy	20	VII	calcite-galena
Flaherty	Galway	18	IX	calcite-galena
Union Creek	Galway	20	A	calcite-galena
Blakely	Huntingdon	10	XII	calcite-fluorite-barite-sphalerite
Coe	Huntingdon	10	XIII	calcite-fluorite-barite
Herrington South	Huntingdon	2	XII	calcite-fluorite
Howard	Huntingdon	14	XI	calcite-fluorite-barite
Johnston	Huntingdon	14	XI	calcite-fluorite-barite
Jones	Huntingdon	15	IX	calcite-fluorite
Keene	Huntingdon	9	XIV	calcite-fluorite-barite
Kilpatrick	Huntingdon	9	XIV	calcite-fluorite
North Reynolds	Huntingdon	8	XIV	calcite-fluorite-barite
Noyes	Huntingdon	13	XII	calcite-fluorite-barite
Palmaeer	Huntingdon	18	VIII	calcite-fluorite-barite
Perry	Huntingdon	11	XIII	calcite-fluorite-barite-celestite
Perry Lake	Huntingdon	11	XIII	calcite-fluorite-barite-celestite
Rogers	Huntingdon	10	XIV	calcite-fluorite-barite-celestite
South Reynolds	Huntingdon	7	XIII	calcite-fluorite-barite
Williams	Huntingdon	1	XI	calcite-fluorite-barite
Wright	Huntingdon	15	XI	calcite-fluorite
Woodruffe	Kingston	16, 17	IV	calcite-barite
		15, 16	V	
Donahue	Lake	10	XI	calcite-galena
Katherine	Lake	7	XI	calcite-galena
Crysler	Limerick	1, 2	II	calcite-galena
Frontenac	Loughborough	15, 16, 17	IX	calcite-galena
Bailey	Madoc	1	IV	calcite-fluorite-barite
Hill	Madoc	1	V	calcite-fluorite-barite
Hollandia	Madoc	A	VI	calcite-galena
Lee Junior	Madoc	2	III	calcite-fluorite-barite
Lee Senior	Madoc	1	I	calcite-fluorite-barite
McBeath	Madoc	3	III	calcite-fluorite-barite
McIlroy	Madoc	2	IV	calcite-fluorite-barite
Miller	Madoc	4	I	calcite-fluorite
Plain	Madoc	9	I	fluorite-barite
Pondon	Madoc	3	I	calcite-fluorite
Rooks	Madoc	6	I	calcite-fluorite
Stewart	Madoc	2	I	fluorite-barite
Wallbridge	Madoc	1, 2	I	calcite-fluorite-barite
William Reynolds	Madoc	5	I	calcite-fluorite-barite
McNab	McNab	9	XI	calcite-galena
Methuen	Methuen	2	I	calcite-galena
Crawford	Oso	25	I	calcite-barite-fluorite
Marshall	Palmerston	4	VII	calcite
Carleton Place	Ramsay	5	IV	calcite-galena
Lynch	Ramsay	4, 8	IV	calcite-galena
Ramsay	Ramsay	3	VI, VII	calcite-galena
Long Point	Rear of Leeds			
	& Lansdowne	2-4, 6	VIII	calcite-galena
Crown King	Somerville	1	VII	barite-galena
Victoria	Somerville	2	V	barite-galena
Blackburn	Tudor	11	II	calcite-galena
Murphy	Tudor	30-32	Hastings Rd. E.	calcite-galena
Ramsay	Tudor	11, 12	Hastings Rd. E.	calcite-galena
Roberts	Tudor	4, 5	B	calcite-galena
Stewart	Tudor	1, 2	A	calcite-galena
Wright	Tudor	11, 12	Hastings Rd. W.	calcite-galena



Plate 13: Steeply dipping calcite vein containing barite and galena cutting metagreywacke at the Hollandia lead deposit in Madoc Township



Plate 14: Calcite-fluorite-sphalerite vein material filling matrix in brecciated limestone, at the Blakely fluorite occurrence near the village of Madoc

several smaller deposits to the west, the Lee-Miller group occupy subsidiary, parallel fractures.

The fluorite-barite-calcite zones are lenticular bodies occupying cavities apparently caused by lateral movement along an undulating fault surface. Principal evidence of the direction of movement includes lateral displacement of rock units by 8 up to 30 metres, and the predominance of horizontal striations on the fault surface. The mineralized bodies occur either as connected lenses, disconnected en echelon lenses, or isolated occurrences. Individual lenses are up to 6 metres wide, but average 3 metres wide and 100 metres long.

Host rocks, in order of importance, include marble, granite, Paleozoic limestone, and andesite. The Paleozoic (Black River Group) host is a light grey, medium- to thick-bedded limestone of Ordovician age. At the Howard deposit the basal member of the succession consists of about 12 metres of calcareous sandstone, arkoses, conglomerate, and shale, resting unconformably on crystalline Grenville rocks. Thicknesses of the Black River Group along the Moira Lake fault range from about 42 to 60 metres.

Vein material consists principally of fluorite, calcite, and barite, in order of abundance, with minor amounts of celestite, quartz, marcasite, pyrite, and sphalerite. Fluorite content is reported by Guillet (1964) to average between 50 and 75 percent, calcite perhaps 25 percent, and barite 15 percent. Sphalerite is abundant at the Blakely deposit. Brecciated wall

rock fragments are also common within the veins. The fluorite is green, colourless, amber, and less commonly purple or smoky, and commonly occurs as cubic and octahedral crystals. The veins are vuggy and exhibit crustiform, rimming, and comb structures. Banding, especially of fluorite, calcite, and barite, is common. Bands of pure fluorite up to 1/2 metre thick and 26 metres long occur at the Bailey deposit.

Calcite-barite-galena veins: Calcite-barite-galena veins are more common and occur over a much wider area, from the Kingdon deposit between Renfrew and Ottawa, in the northeast, to the Crown King and Victoria prospects in Somerville Township, in the southwest. Calcite is the principal vein mineral, accompanied by either or both barite and galena. Sphalerite is locally common, and marcasite, pyrite, and chalcopyrite occur locally in minor amounts. The Hollandia prospect is one of the more significant deposits of this type in the area and is described in detail Mineral Deposit Description No. 18, this report) in part 2 of this report.

Calcite-celestite veins: Calcite-celestite deposits in the area are not listed in Table 16. They occur principally in the Kingston-Sharbot Lake and Ottawa Valley areas and consist of a few veins similar to the above except for the abundance of celestite.

Economic Potential

Significant production has been attained from the Kingdon lead mine, in Fitzroy Township, and from several of the fluorite

veins in Madoc and Huntingdon Township. Fluorite was produced intermittently between 1905 and 1961. Production was attained from 21 deposits in the Madoc area, and amounted to approximately 122,000 tons (see Guillet 1964). All but a few small shipments were of metallurgical grade.

The Rogers mine was the most productive fluorite mine in southeastern Ontario, producing over 40,000 tons of ore, principally between 1943 and 1951. The mine was worked from four shafts, to depths of 123 feet (#1), 87 feet (#2), 120 feet (#3), and 240 feet (#4). The fluorite-bearing vein has an average width of 55 feet over a length of 365 feet on the 240 foot level. The vein has been largely mined out above the 240 foot level, but continues for an unknown distance below this level. A drill hole near the number 4 shaft indicated a vein width of 6 feet at a vertical depth of 360 feet.

According to Guillet (1964), the Madoc vein deposits average 3 to 6 feet wide, with a maximum width of 18 feet, over lengths of several hundred feet. The vein material averages 60 percent fluorite and can be hand-cobbed to metallurgical grade. The presence of significant amounts of barite is a quality constraint and rendered most of the Madoc fluorite production unsuitable for acid production. The narrow, discontinuous nature of the veins has been a drawback for major exploration and development of the deposits. Water influxes in excess of 2000 gallons per minute were encountered in the lower levels of several of the Madoc mines, especially those north of Moira

Lake which led to abandonment of many of the mines at shallow levels. These factors, taken together, are considerable constraints on the economic potential of the Madoc fluorite deposits. Nevertheless, diamond drilling has indicated widths of vein material of up to 7 feet over a length of at least 300 feet between the Keene and Kilpatrick deposits in Huntingdon Township. The Johnston deposit is indicated to extend 300 feet southeast of the present workings over similar widths. Significant quantities of fluorite probably also remain to be found in unexplored parts of the Moira Lake fault. The veins therefore remain as potential sources of fluorite if market conditions improve and if an efficient beneficiation technique to produce acid-grade material from the Madoc ore is developed.

Production of lead ore from the Kingdon mine, between 1915 and 1931, totalled 905,000 tons, with an average recovered grade of 3.32 percent lead and minor zinc; not 8.5 percent lead as reported by Sangster and Bourne (1982). A total of 76,821,409 pounds of lead concentrates and 857,312 pounds of zinc concentrates were produced from the ore, and 60,074,077 pounds of pig lead were smelted from these concentrates. The ore was mined from a galena and minor sphalerite-bearing calcite vein averaging 1.5 metres in width, which was traced over a length of 823 metres, and to a depth of 396 metres.

Significant amounts of lead mineralization have also been indicated at the Frontenac prospect in Loughborough Township, and the Hollandia prospect, in Madoc Township. At the Frontenac

deposit a calcite vein has been traced for a distance of about 300 metres. Bulk sampling over a length of 135 metres and an average width of 3.5 metres, indicated an average grade of 4.2 percent Pb, 0.30 percent Zn, 0.22 oz. Ag per ton, and trace gold. The Hollandia vein has been traced over a strike length of about 175 metres with an average width of about 1.2 metres. A total of 2,653,365 pounds of lead were produced from an undisclosed quantity of ore, between 1903 and 1916; high-grade ore grading between 1 and 12 percent lead was mined from the upper 6 to 12 metres. Silver is associated with the galena in the ore, and minor amounts of barite occur. Diamond drilling indicates that the vein continues to a depth of at least 60 metres.

Although the known lead deposits are small, with low average grades, numerous deposits probably lie concealed beneath surficial drift. These must be considered to be potential sources of lead if efficient prospecting techniques to discover them can be devised.

Origin

Formation of late veins of all three types can be attributed to a single mechanism. A low temperature of formation is suggested by the general lack of wall rock alteration and absence of chilled margins in the vein material. This is confirmed by studies of fluid inclusions in fluorite from some of the Madoc deposits (McCartney 1964), which suggest minimum filling temperatures of 122°C to 132°C. Wilson (1929),

Sangster (1970), and Sangster and Bourne (1982) have proposed that the mineralization was emplaced by circulating meteoric water, based on the lack of known post-Ordovician intrusive activity in the area, and the low temperature of deposition. However, this process does not explain the close spatial relationship of the deposits to the Paleozoic/Grenville unconformity. The simple mineralogy of these deposits, open space filling textures, low temperature of deposition, and their geological setting and location near an intracratonic basin margin resemble the Mississippi Valley type of deposits. For these, various researchers (i.e. Heyl 1968; Snyder and Gerdemann 1968) have proposed that the Mississippi Valley type of deposits formed by the release of metal-bearing connate brines from Paleozoic source rocks during diagenesis and subsequent movement of the fluid through permeable horizons to the site of deposition. In southeastern Ontario permeable sandstones along the basal unconformity of the Paleozoic succession may have acted as aquifers for metal-bearing brines moving up-dip from central portions of the Paleozoic basins. The fractures and faults in the marbles and Paleozoic limestones on the margins of the basins provided depositional sites.

4. Hematite

Several small concentrations of hematite mineralization occur in the area (Table 17, Fig. 15), restricted in distribution to the eastern and southern margins of the exposed

Table 17: Hematite deposits in southeastern Ontario.

<u>Deposit</u>	<u>Township</u>	<u>Lot</u>	<u>Con.</u>	<u>Geology</u>
Delta	Bastard	23-25	X	Dissemination in Potsdam sandstone
Plum Hollow	Bastard	13	IX	Uncertain
Bayne Farm	Bathurst	23	II	Vein in marble
Dalhousie Lake	Dalhousie	11	XII	Uncertain
Playfair	Dalhousie	1	IV	Vein in marble
Fahey	Darling	26	II	Vein in marble
White Lake	Darling	23	II	Veins in marble
Brennan	Madoc	7	VI	Vein in marble
Miller	Madoc	3	I	Vein in Black River limestone
Wallbridge	Madoc	12	V	Uncertain
McNab	McNab	6,7	XIII,XIV	Vein in Paleozoic limestone
Smith-Hambley	Portland	5	XIII	Veins in marble
Dog Lake	Storrington	20	X	Dissemination in Potsdam sandstone

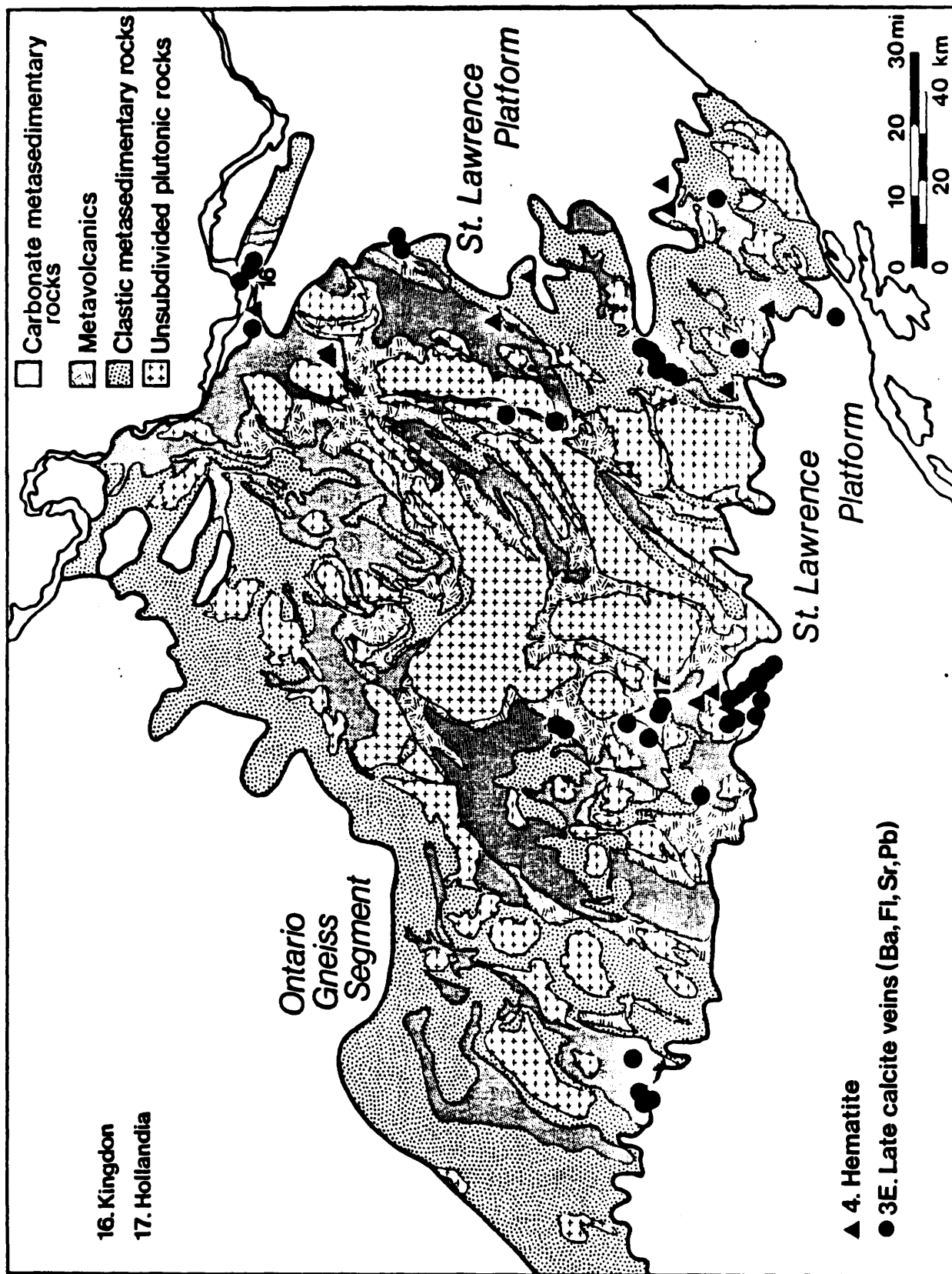


Figure 15: Distribution of post-Ordovician vein deposits and hematite deposits in southeastern Ontario.

area of the Grenville Supergroup, close to the unconformity with the overlying Paleozoic sequence. Mineralization has two modes of occurrence; 1) disseminated to massive hematite contained within Potsdam sandstone at the base of the Paleozoic succession, or 2) hematite confined to fractures in Grenville marbles and Paleozoic limestone.

The Dog Lake (Mineral Deposit Description No. 19, this report) and Delta prospects are the best examples of the first type. Mineralization is contained within flat-lying Potsdam sandstone unconformably overlying marble and granite. The sandstones are composed principally of well-sorted, well-rounded quartz grains and a few scattered pebbles of quartzite, cemented by carbonate or silica. A basal layer of conglomerate about a half metre thick occurs at the Delta prospect. Mineralization consists of disseminated hematite replacing the carbonate cement in porous portions of the sandstone, gradational into irregular lenses of hard, massive, dark grey hematite. Specular hematite, calcite, and siderite are mixed with the massive hematite at the Delta prospect. Hematite also occupies narrow veins at the Delta prospect.

The Fahey (Mineral Deposit Description No. 20, this report), White Lake, and McNab prospects illustrate the relationships of the second type. At the Fahey and White Lake prospects disseminated to massive hematite is contained within vertical fractures and breccia zones in dolomitic marble. There is widespread silicification of the marble associated with the

mineralization at the White Lake occurrence. The main Fahey vein is reported to be about 5 metres wide (Frechette 1910) and can be traced for nearly 100 metres. A selected sample collected by Carter et al. (1980) contained 63.6 percent Fe, 0.04 percent TiO_2 , 0.32 percent P_2O_5 , 0.01 percent V, and 0.01 percent S. At the McNab prospect mineralization is reported to "consist of hematite, or hematite and calcite, filling fractures, joint fractures, joint planes and fault fissures either in Beekmantown dolomite just above its contact with the Bristol limestone phase of the Grenville series, or in the Bristol limestone itself.... Those on Lot 6, Con. XIV, occur chiefly in two veins having an en echelon relationship to one another. One of these veins, that in pit 4, evidently occupies a fault fissure, for the vein walls are striated and slickensided at an angle of about 20 degrees from the vertical" (Wilson 1924, p.113).

The mode of formation of these deposits is not certain. It is likely, however, that they have formed as a result of percolation of iron-rich meteoric water into fractures and porous zones with subsequent deposition of iron as hematite.

Only minor production of hematite has taken place from these deposits, principally in the late nineteenth century. Approximately 12-15,000 tons of hematite are reported to have been produced from the McNab prospect between 1868 and 1874, and about 11,000 tons were produced from the Playfair deposit between 1866 and 1871.

The documented deposits have very limited extents and probably have little or no potential as potential sources of iron ore. They may have significant potential as sources of high purity hematite for use in the pigment or electronics industry.

DISCUSSION

Metallic mineral deposits are integral components of the geologic history of southeastern Ontario. The interpreted relationships between mineralization and regional geologic events are summarized in Table 18, and relationships of stratabound and stratiform mineralization to the composite stratigraphic section of the Late Precambrian supracrustal sequence are illustrated in Fig. 16.

Processes favourable for the concentration and deposition of metallic mineralization were apparently not active during sedimentation, plutonic activity, and metamorphism associated with formation and consolidation of the basement gneiss complex, at least in that portion exposed in the study area. Subsequent to consolidation and uplift of the basement complex, erosion of clastic detritus from the craton occurred, with subsequent deposition as basal sandstones of the Grenville Supergroup. These basal sandstones may have been enriched in uranium derived from the basement complex, and may have acted as source rocks for subsequent formation of metamorphic concentrations of uranium.

Table 18: Relationship between geologic events and deposition of metallic mineralization.

<u>Time (Ma B.P.)</u>	<u>Geologic Event</u>	<u>Mineralization</u>
	Rifting, faulting - Ottawa-Bonnechere graben	calcite fissure veins
500-600	Erosion, weathering, deposition of Paleozoic rocks	hematite
1000	Emplacement of Westport pluton	
1050	Emplacement of pegmatite Metamorphism	uranium, molybdenum molybdenum, gold-quartz
1050-1080	Consolidation of Grenville Supergroup. Erosion, deposition of Flinton Group Metamorphism	pyritic shales
1100-1250	Emplacement of varied suite of plutonic rocks Deposition of carbonate, associated clastic sediments of Mayo Group	copper-nickel, iron-titanium, iron skarn, uranium?, molybdenum? Zinc, Cu-Sb-Ag-Hg-barite, magnesium
1300	Deposition of volcanic rocks, associated clastic sediments of Hermon Group Erosion of clastic detritus from basement gneiss, deposition of basal clastics of Grenville Supergroup	pyritic sulfides, ironstone uranium?
1400-1500	Intrusion of anorthosite suite plutonic rocks of the Algonquin Batholith, metamorphism, consolidation	
1700-1800?	Deposition of clastic sediments	

THE GRENVILLE SUPERGROUP

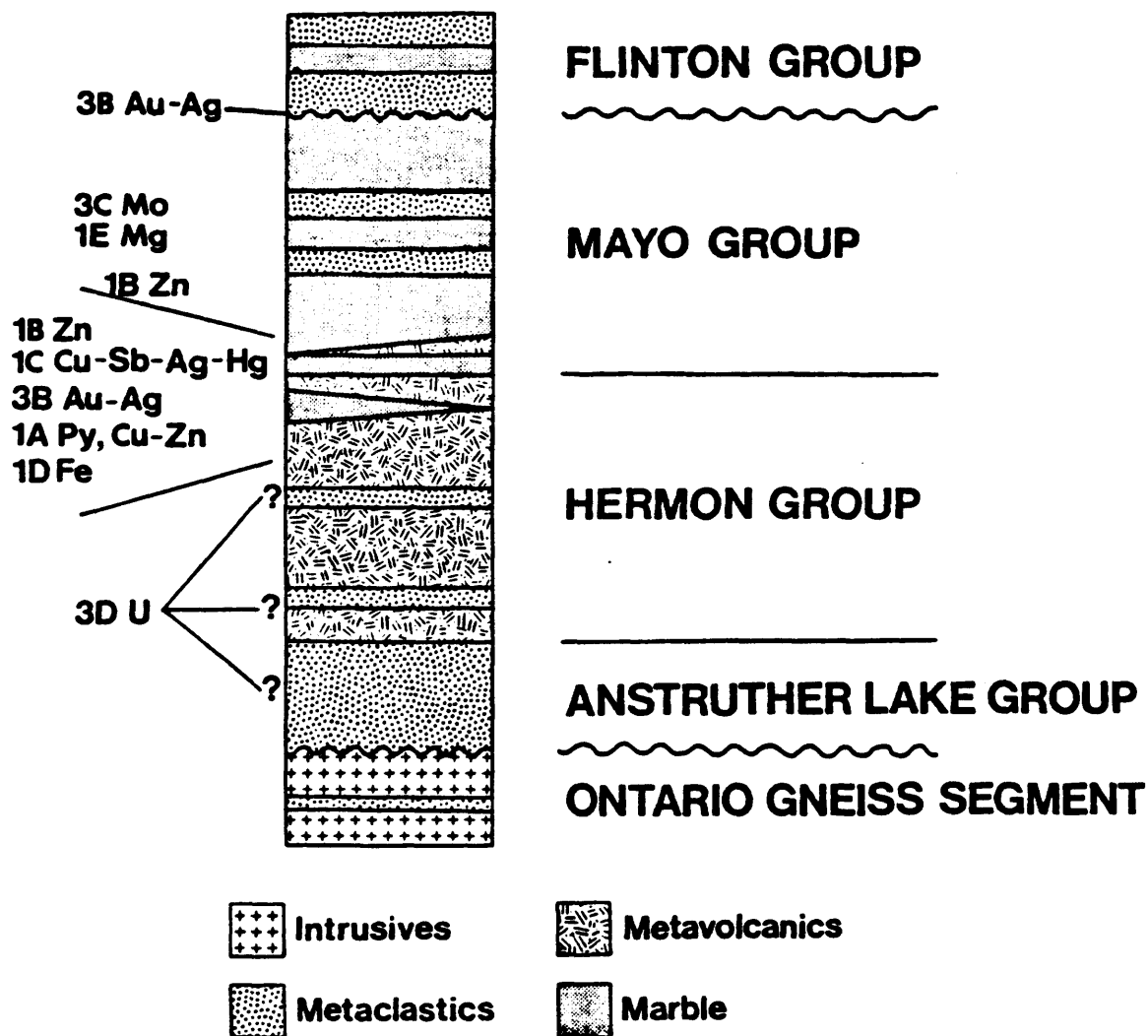


Figure 16: Interpreted stratigraphic associations of metallic mineral deposits within the Grenville Supergroup in southeastern Ontario.

Coeval or subsequent deposition of a thick sequence of volcanic rocks occurred in an island arc complex founded on oceanic crust adjacent to the continental margin. Pyritic sulfides and quartz-magnetite ironstones formed as integral parts of the volcanic succession, principally at the top of and lateral to the Tudor Formation. As noted by Sangster and Bourne (1982), the New Calumet Zn-Pb-Ag deposit in southwestern Ontario is probably the best example of clearly volcanogenic exhalative activity in the area. Deposition of carbonate and related clastic sediments of the Mayo Group occurred synchronously with and subsequent to deposition of the upper parts of the volcanic succession, possibly in a shallow back-arc basin. Concentrations of zinc, Cu-Sb-Ag-Hg-barite, and magnesium carbonates formed in the carbonate depositional environment. Deposition of some of the zinc deposits was closely associated with evaporite horizons and possible stromatolites.

A varied suite of plutonic rocks invaded the Grenville Supergroup, part of a protracted period of magmatism that culminated in regional metamorphism of the intrusive and supracrustal rocks. Segregations of copper-nickel sulfides formed in association with ultramafic phases of the gabbroic intrusions. Concentrations of iron-titanium oxides formed in anorthositic phases. Contact metasomatic iron deposits formed in carbonate rocks along the contacts of intrusions of all compositions, especially early plutons of the biotite-diorite suite.

A period of consolidation and uplift of the Grenville Supergroup and associated plutonic rocks probably followed. Deposition of the Flinton Group was accompanied by formation of pyritic shales, some of which are enriched in base and precious metals. A major regional metamorphic event after deposition of the Flinton Group resulted in formation of pegmatite dikes and calc-silicate skarns in high-grade areas, accompanied by formation of concentrations of uranium and molybdenum. In areas affected only by low-grade metamorphism quartz-carbonate veins carrying concentrations of gold, minor silver, and associated base metals were formed.

Consolidation and uplift of the Precambrian rocks was followed by deposition of Paleozoic platformal sedimentary rocks. Weathering of the Precambrian rocks liberated hematite which was concentrated within basal sandstones of the Paleozoic sequence and within fractures and fissures in the overlying carbonates by later ground water movement. Finally, a post-Ordovician episode of block-faulting associated with the Ottawa-Bennechere graben affected the area, resulting in fracturing and faulting of the Paleozoic rocks.

Calcite-barite-fluorite-celestite-galena veins akin to Mississippi Valley-type deposits formed within these structural zones on the up-dip margins of the Paleozoic sedimentary basins.

SUMMARY AND CONCLUSIONS

Several distinct types of metallic mineral deposits can be distinguished in rocks of the Grenville Province in southeastern

Ontario. These include stratiform zinc in carbonate rocks; stratabound pyritic (+ base metal) sulfides in volcanic and sedimentary hosts; gold-quartz veins; quartz-magnetite ironstone; copper-nickel and iron-titanium concentrations in intrusive rocks; iron skarns; molybdenum in skarns and pegmatites; uranium and thorium in pegmatites, veins, and calc-silicate gneisses; hematite veins; magnesium in dolomitic marble; and barite-fluorite-celestite-galena in calcite fissure veins.

Four genetic processes were responsible for deposition of the observed suites of mineralization:

- 1) Syngenetic processes related to volcanism and sedimentation
- 2) Epigenetic processes related to diagenesis regional metamorphism, and igneous intrusive activity
- 3) Magmatic processes related to igneous intrusion, and
- 4) Supergene processes.

These four processes provide a basis for a simple genetic classification of metallic mineral deposits in the area, and for relating metallogenesis to geologic events.

Many of the deposits are correlatives of deposit types which elsewhere are major producers. Sedimentary exhalative lead-zinc (stratiform zinc?), lode gold (gold-quartz vein), volcanogenic, exhalative copper-zinc-silver (stratabound pyritic sulfides), Mississippi Valley-type lead-zinc (post-Ordovician fissure veins), contact metasomatic iron, and magmatic copper-nickel and iron-titanium deposits are recognized. There

are several other less widely recognized types of local significance, the most important being pegmatite-hosted uranium deposits. Significant production has been attained from the Marmoraton contact metasomatic iron deposit, the Kingdon fissure vein lead deposit, the Cordova and Deloro gold deposits, the Long Lake stratiform zinc deposit, the Chromasco magnesium deposit, and the Madawaska (Faraday) uranium deposit. Minor production has been attained from numerous other deposits. The only current producer is the Chromasco magnesium mine, north of Renfrew.

The similarity of many of the deposits to major deposit types, favourable geology, and past history of production indicates the area has significant unrealized potential. The favourable geographic location should facilitate and lower the costs of exploration. Stratiform zinc, pyritic base and precious metals, and gold-quartz vein deposits are judged to have the best current potential. Exploration techniques and guidelines applicable to sedimentary exhalative, volcanogenic exhalative, and lode gold deposits should be utilized. Development of specific guidelines is dependent on further study. Uranium deposits in the area are economically attractive at higher price levels.

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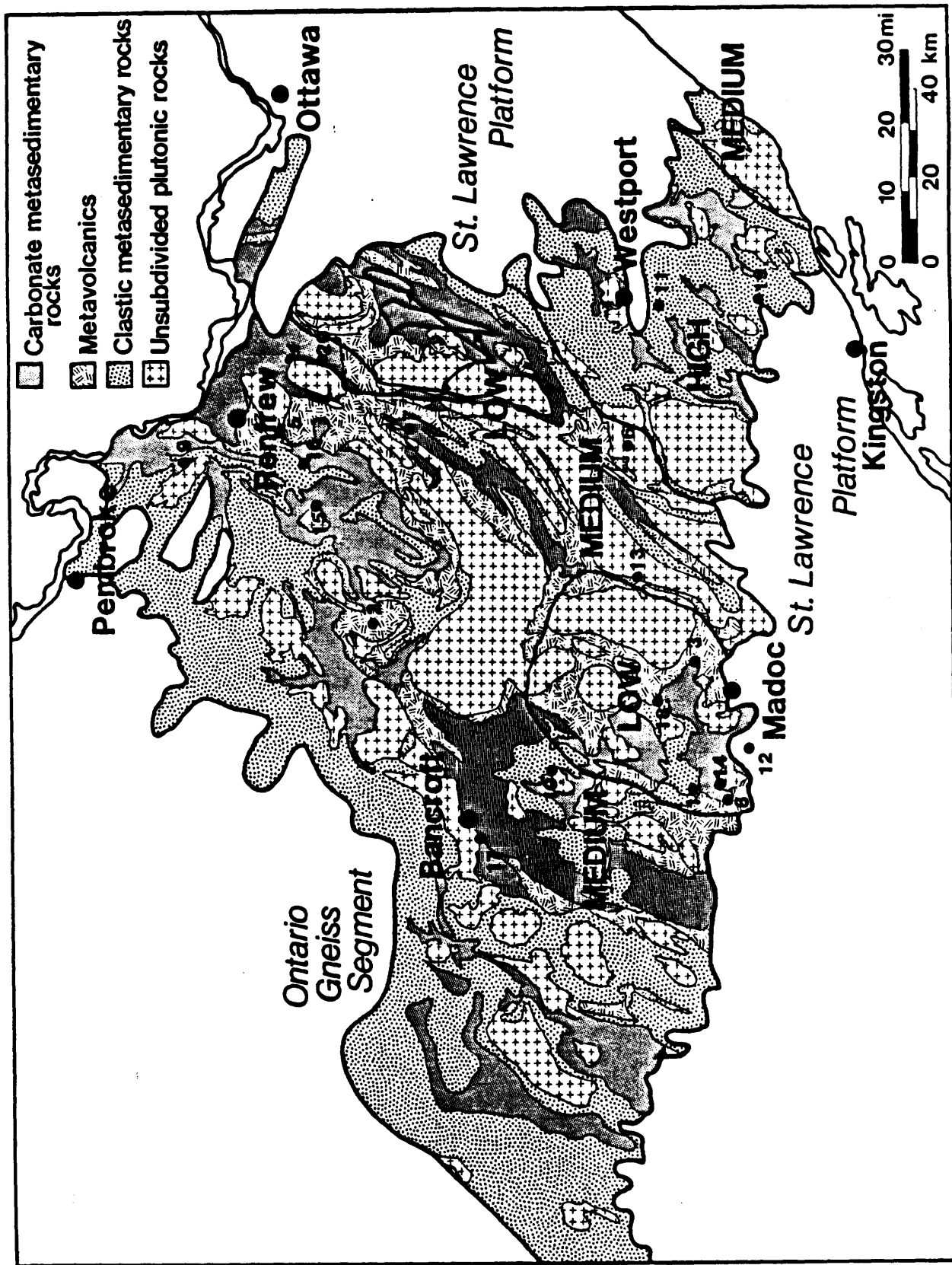


Figure 17: Location of deposits described in detail; number 4, Wilcox Cu-Zn not in area shown.

II. DESCRIPTIONS OF MINERAL DEPOSITS

SIMON COPPER-ZINC PROSPECT

Location and Access:

The Simon copper-zinc deposit is located about 8 km north of the village of Denbigh (Figure 18) on the eastern slope of a large hill. There are two mineralized zones at the deposit, termed the north and south prospect, connected by an overgrown dirt road. The south prospect is the main copper-zinc deposit and lies near the south boundary of the east half of lot 1, Range B, Lyndoch Township, in NTS quadrant 31F/3, at UTM co-ordinates 5008560N, 318370E. The north prospect occurs about 300 metres to the north at UTM coordinates 5008780N, 318500E. The deposit may be reached by driving along the State Falls road from Highway 41 till it terminates, a distance of 5.2 km, and from the point north along a dirt lumber road for about 2 km to the opposite side of a low sandy hill. From this point the deposit is accessible by foot, about 900 metres at a bearing of 250°.

Economic Features

The main copper-zinc deposit, the south prospect, consists of disseminated chalcopyrite, pyrrhotite, and minor pyrite and sphalerite contained in a conformable lens averaging about 3 metres thick, 180 metres long, and continuous to a depth of at least 107 metres as indicated by

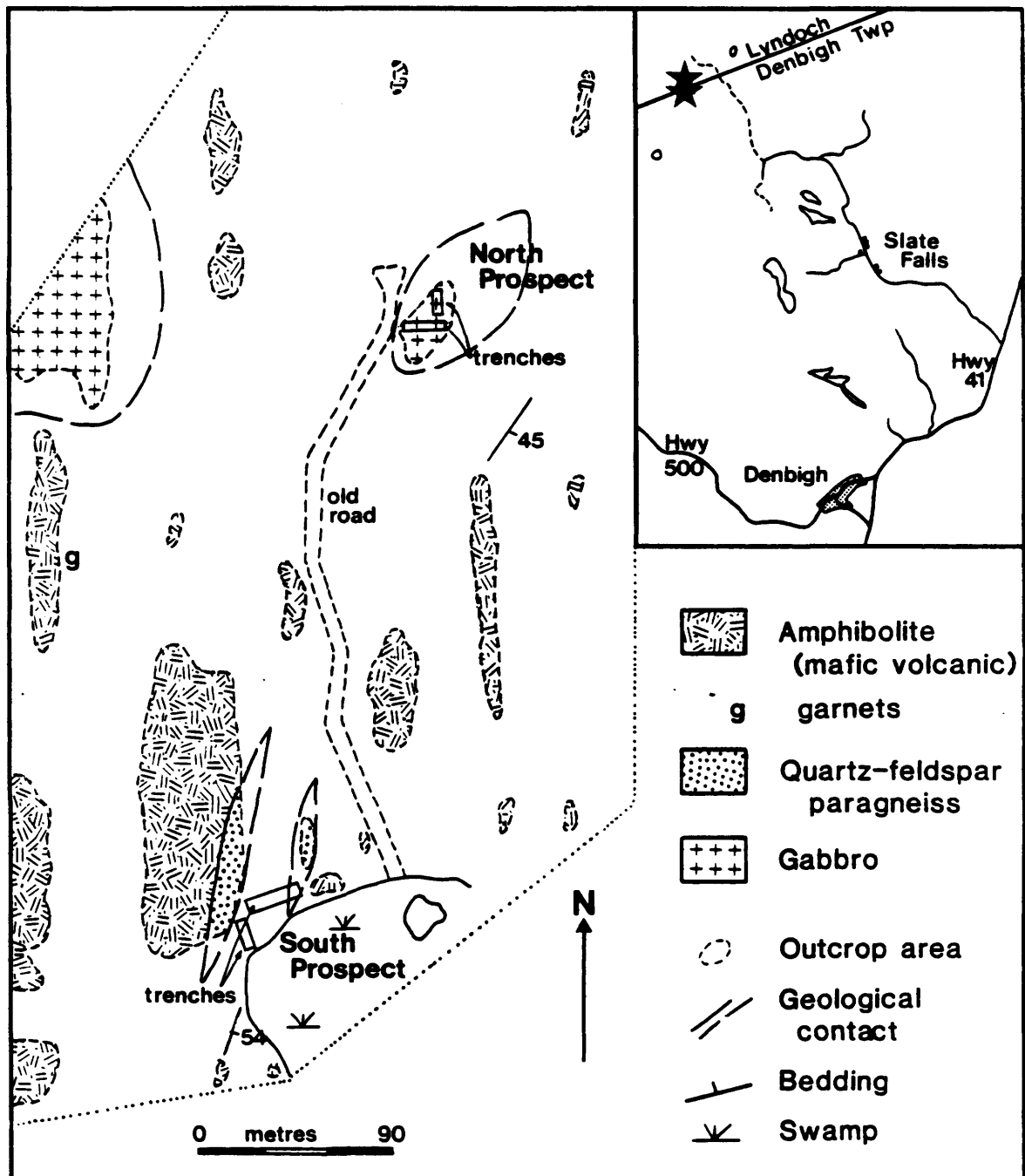


Figure 18: Geology of the Simon copper-zinc prospect, Lyndoch and Denbigh Townships, Ontario. Geology by T. Carter 1977.

diamond drilling. This lens is reported to contain 253,000 tons of 1.09 percent Cu (Young-Davidson Mines, Report to Shareholders, 1966).

There are two narrow trenches up to a meter deep and 15 and 30 metres long respectively on the prospect. Samples collected by the author from these trenches contained from 0.16 to 3.5 percent Cu, and 0.04 to 3.4 percent Zn (see Table 1).

Mineralization at the north prospect consists of minor chalcopyrite and pyrrhotite disseminated within a lens of massive magnetite 0.3 to 1 metre thick and 5 metres long (Cochrane, 1964). There are two trenches up to 1 metre deep and 13 metres and 21 metres long respectively. A sample collected from one of these trenches by the author contained 2240 ppm copper (Table 19).

Geology

The Simon Cu-Zn prospect occurs within a wide belt of amphibolite gneiss with minor intercalated marble and quartzite extending from Denbigh Township northwards into Lyndoch Township. The rocks strike north and dip moderately to the east and have been folded such that the Simon prospect lies on the western edge of a large conical fold with many associated minor folds, all plunging at 40 to 60 degrees to the east (Cochrane 1964).

TABLE 19: Partial chemical analyses
Simon Cu-Zn prospect (in ppm unless indicated)

	<u>Cu-11-5</u>	<u>Cu-11-7</u>	<u>Cu-11-8</u>	<u>Cu-11-9</u>	<u>Cu-11-13</u>
Cu	1560	3.5%	2.82%	5540	2240
Zn	420	1550	0.89%	3.4%	-
Pb	32	10	20	<10	-
Cd	-	-	-	106	-
Au	-	-	90 ppb	-	-
Ag	-	-	4	-	-
Fe(total)					64.3%
TiO ₂					0.80%
P ₂ O ₅					0.36%

Cu-11-5 to Cu-11-9 collected from south prospect
 Cu-11-13 from north prospect

The southern prospect occurs within amphibolite gneisses which contain scattered thin interlayers of quartz-feldspar paragneiss. The quartz-feldspar paragneiss is very abundant in the vicinity of the mineralized zone and hosts some of the mineralization, but amphibolite is the principal host rock. Pegmatite dikes were intersected during diamond drilling and are intrusive into the other rock types, including the mineralized zone. The mineralized zone at the northern prospect is poorly exposed but appears to lie within a small body of gabbro that has intruded the gneisses.

Amphibolite is the most common rock type in the vicinity of the Simon prospect and forms a black, fine-to-medium grained (0.1 - 1.0 mm), well-layered, foliated rock composed essentially of hornblende and plagioclase with locally abundant garnet, biotite, and quartz. Accessory minerals include sphene, epidote, apatite, chlorite, carbonate, pyrite, pyrrhotite, and magnetite. The quartz-feldspar paragneiss is a white rock composed essentially of fine-grained quartz and plagioclase with minor biotite. The gabbro forms a black, foliated rock similar in appearance to the amphibolite and is composed of a coarse-grained (2 mm) aggregate of plagioclase, hornblende, and relict pyroxene. According to Cochrane (1964) the pyroxene is largely replaced by amphibole, epidote, chlorite and carbonate who reports that the rocks

close to the mineralized core at the south prospect have been altered, resulting in a noticeable bleaching of the amphibolite host. The alteration zone is described as "narrow but distinct" and consists of "the development of chlorite, biotite, sericite, and sphene; the disappearance of chlorite as an alteration product of hornblende; variation in the anorthite content of plagioclase; and a slight increase in the iron content of the hornblende in the altered rocks" (Cochrane 1964, p.64).

The author has interpreted the amphibolite gneiss and quartz-feldspar paragneiss to be volcanic in origin. Evans (1964) and Hewitt (1953) have interpreted these rocks to be sedimentary in origin.

Mineralization at the southern prospect consists of disseminated chalcopyrite, pyrrhotite, pyrite, and sphalerite hosted by amphibolite and to a lesser extent by quartz-feldspar paragneiss. The sulphides are confined to a conformable, lens-shaped body that strikes north and dips moderately (45 degrees) to the east. At the surface the mineralization forms a crumbly gossan of limonite and scattered sulphides. Assays are listed in Table 19.

Petrology: Two thin sections of quartz-feldspar paragneiss (Cu-11-1,3) and one thin section of amphibolite (Cu-11-4) were examined by the author (see Table 20). Twenty sections of representative rock types were examined by Cochrane (1964).

The amphibolite gneiss is composed of a granoblastic intergrowth of hornblende, plagioclase, quartz, and minor biotite, chlorite, carbonate, sericite, and opaque minerals. The hornblende forms large subhedral laths with a preferred orientation and contains small inclusions of quartz. It is often partially altered to light green-brown chlorite and epidote. Biotite forms small laths and blebs usually associated with hornblende. Plagioclase (An₂₀ to An₃₇) forms equidimensional laths that may be partly altered to carbonate and sericite. The quartz-feldspar paragneiss is texturally similar to the amphibolite and is composed of quartz, plagioclase, and minor hornblende, biotite, muscovite, and chlorite.

The average composition of mineralized sections from the south prospect examined by Cochrane (1964) is 30 percent pyrrhotite, 20 percent chalcopyrite, 5 percent pyrite, 2 percent sphalerite, and the remainder a mixture of hornblende, quartz, and plagioclase. The pyrrhotite occurs

Table 20: Modal composition, in percent, of thin sections of amphibolite (Cu-11-4) and quartz-feldspar paragneiss (Cu-11-1,3) from the south prospect of Simon Cu-Zn deposit.

	<u>Cu-11-1</u>	<u>Cu-11-3</u>	<u>Cu-11-4</u>
quartz	60-65	45-50	30
plagioclase	20-25	40	20
hornblende	10-15		35-40
opaques			5
biotite	2-3	5	2
tremolite			
chlorite	1		2- 3
sericite	2	5 -10	1
carbonate			2

as coarse (1-3 mm) subhedral grains and grain aggregates. Chalcopyrite occurs as fine veinlets and blebs interstitial to silicate minerals or within pyrrhotite. Pyrite occurs as broken skeletal crystals while sphalerite most commonly occurs as blebs within chalcopyrite and pyrrhotite.

Sections from the northern prospect contained, on average, 60 percent magnetite, 20 percent chalcopyrite, 5 percent pyrrhotite, and trace sphalerite and marcasite (Cochrane 1964). Magnetite occurs interstitial to a silicate gangue. Chalcopyrite forms small blebs and veins in the magnetite and pyrrhotite is disseminated within magnetite. Marcasite occurs as colloform spheres.

History of development:

pre 1953: Small pit on north prospect, operator unknown (Hewitt, 1954).

1956: Trenching, 6 diamond drill holes totalling 328 meters on the north prospect, by Eugene Simon (Evans, 1964).

Six diamond drill holes totalling 352 metres by Malcolm Property Denbigh (Diamond drill file 10, Lyndoch Twp., Assessment Files Research Office, Ont. Geol. Survey, Toronto).

1961: Mineralization at south prospect discovered by Harvey Simon. Electromagnetic and geologic surveys with 13 diamond drill holes totalling 763 metres completed by Noranda Exploration Ltd (Cochrane, 1964).

1965: Geophysical work and 1160 metres (3807 feet) of diamond drilling completed by Young-Davidson Mines Ltd. (Canadian Mines Handbook 1968-1969, Northern Miner Press, Toronto, p.350).

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- Cochrane (1964)
- Evans (1964, p.35-36)
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- Shklanka (1969, p.226-227)

CANADIAN SULPHUR ORE COMPANY AND BLAKELY PYRITE MINES
(PAST PRODUCERS)

by

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Location and Access

The Canadian Sulphur Ore property is situated on the north half of lot 9, Concession X of Madoc Township, in Hastings County. The approximate UTM coordinates are 4937250 m N, 307500 m E on NTS sheet 31C/11.

The property is accessible from Hunt Club Road, (5.6 km east of the Highway 62 junction on Highway 7), 4.8 km north of Highway 7 and just south of a white farm house and gravel pit on the west side of the road. From Hunt Club Road the mine workings are located approximately 0.4 km to the west, first through a hay field and then up a moderately steep wooded hill. The old mining road leading to the property is no longer passable by vehicle; however, remnants of the old road bed can be followed on foot (Figure 19 *inset*).

The Blakely Pyrite Mine is also accessible from the Hunt Club Road, 6.4 km north of Highway 7, 100 m north of a white wooden farm house situated on the east side of the

road. From Hunt Club Road the property is located approximately 75 m to the east. The Blakely Pyrite Mine is located on lot 11, Concession XI of Madoc Township, UTM coordinates being 4938500 m N, 308000 m E on NTS sheet 31C/11 (Figure 19 inset).

Economic Geology

Canadian Sulphur Ore Company Property

Fraleck (1907) reported that pyrite mineralization is capped by a gossan zone which outcrops in an area 170 m long by 70 m wide, trends in a general east-west direction and dips steeply south. It ranges in depth from 0.5 m to 10 m and is fragmental in places, with some large subangular massive pyrite fragments supported in a chiefly quartz limonite matrix. Surface exposure of the gossan zone has since been largely covered with mine waste.

Massive to siliceous banded pyrite mineralization occurs within an east-west trending rusty schist zone, hosted by intermediate metavolcanics. The massive pyrite mineralization, averaging 46-49 percent sulphur, occurs as lenticular bodies within the rusty schist ranging from approximately 1 m to 9 m in width and 20 m in length. Locally these lenses are brecciated and cemented with aggregates of quartz, calcite and secondary pyrite. In the massive lenses the pyrite is fine to medium grained and occurs as a mosaic of equant grains with minor disseminated quartz grains.

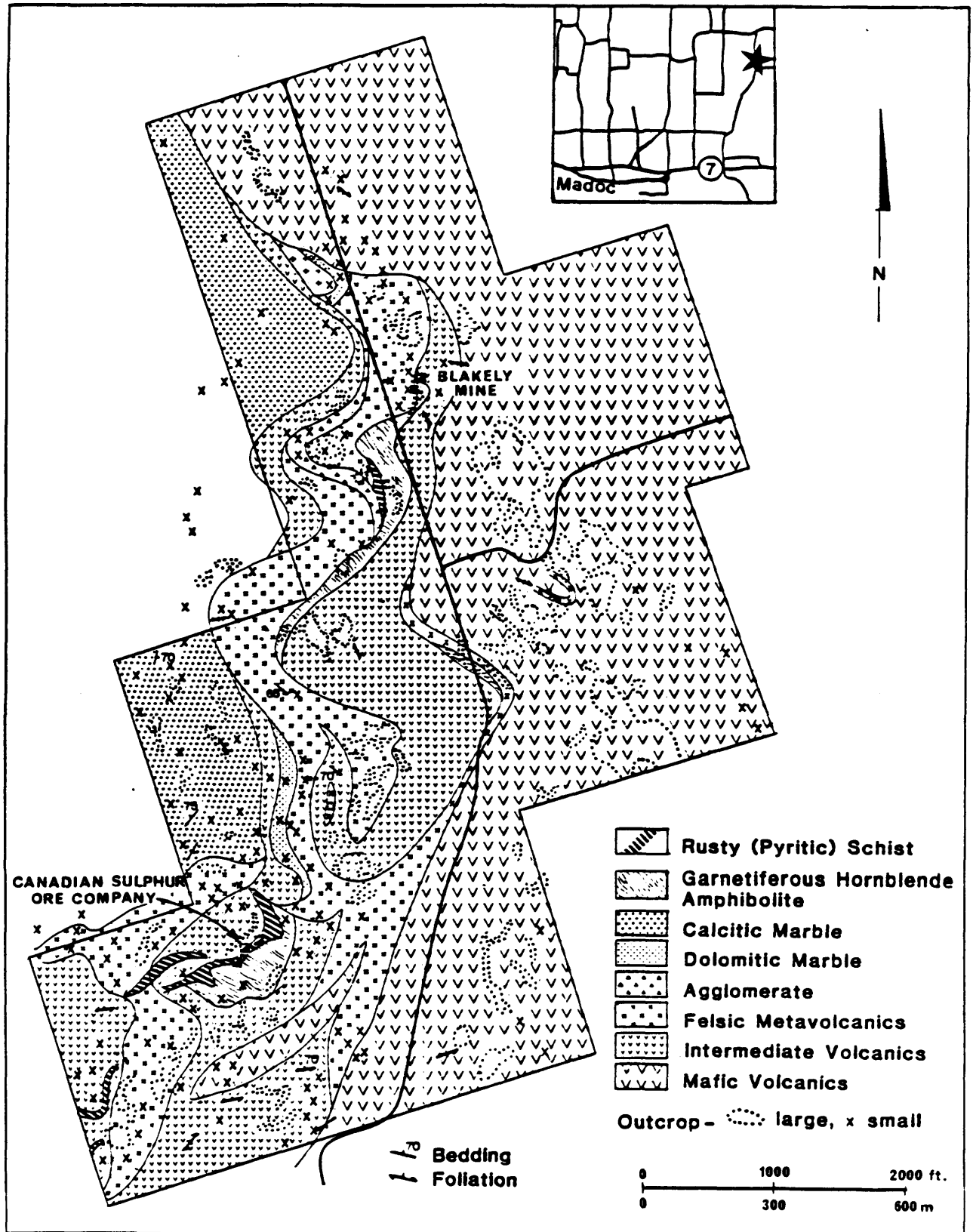


Figure 19: The geology around Canadian Sulphur and Blakely pyrite mines (Verschuren 1982).

Banded siliceous pyrite constitutes the lower grade ore averaging up to 35 percent sulphur (Miller and Knight 1914). The exact physical dimensions of these zones are unknown. Like the massive pyrite lenses, they are hosted by the rusty schist unit (Figure 19). The zones are composed of disseminated grains and bands of pyrite supported in a mosaic of quartz, with minor amounts of sericite and graphite. These zones commonly grade into almost pure granular quartz.

No other sulphide mineralization is apparent; however, Miller and Knight described pyrrhotite and minor chalcopryite in pits No. 3 and No. 4. These authors report that the deposit is for the most part virtually free of copper, nickel, gold, lead and arsenic. Minor copper and trace nickel and gold are associated with the rusty schist zone where pyrrhotite and minor chalcopryirte replace pyrite as the predominant sulphide. Good samples of massive pyrite can be found in waste dumps. Massive pyrite was mined primarily from pits No. 3 and No. 4 and shaft No. 3. Massive ore was also mined from shaft No. 2 (Figure 20, 21)

BLAKELY PYRITE MINE

Several massive pyrite lenses, up to 5 m wide and 16 m long, occur in rusty schists at the contact between felsic metavolcanics and garnetiferous hornblende amphibolite. The grade of the massive lenses was reportedly high (Fraleck

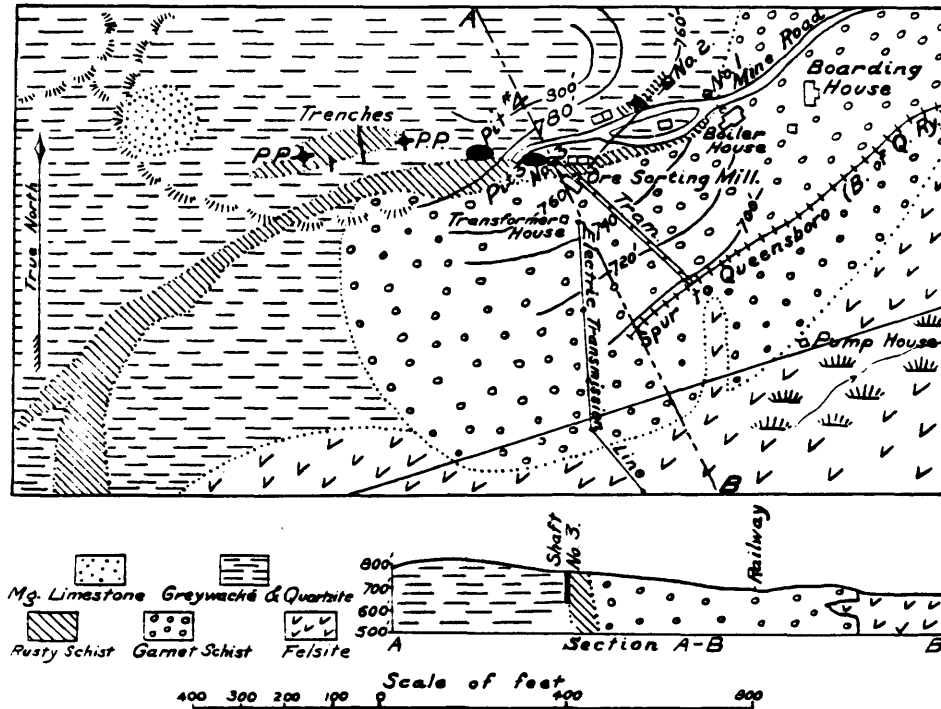


Figure 20: Geology and Location of mine workings at Canadian Sulphur Ore Company Mine, Miller and Knight 1913.

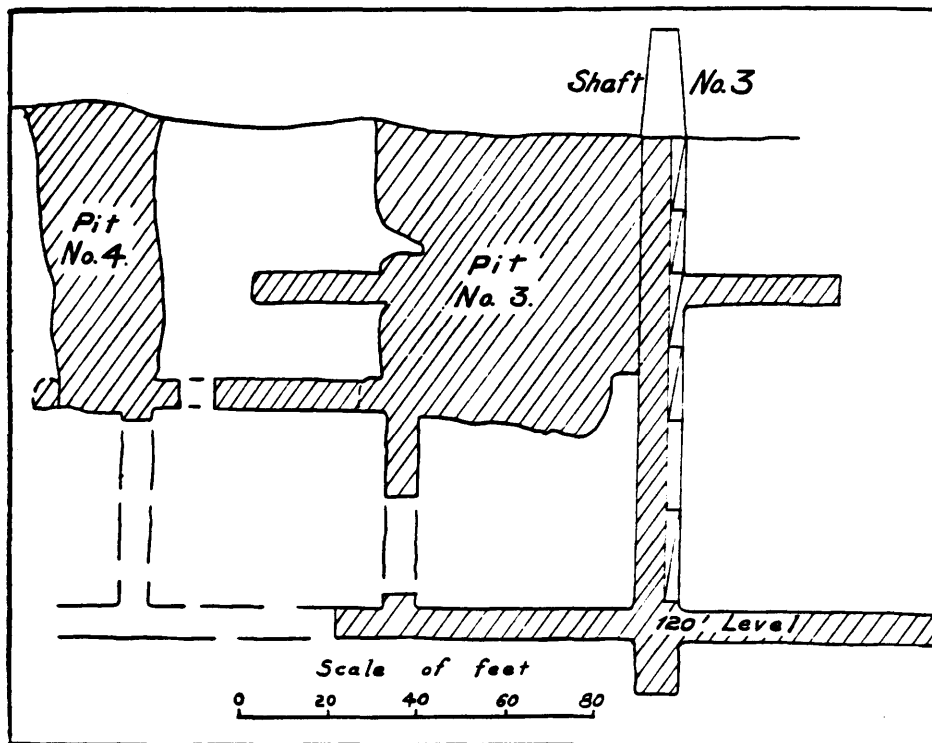


Figure 21: Cross-section of Pits No. 3 and 4 and Shaft No. 3 at Canadian Sulphur Mine, Miller and Knight 1913.

1907), probably in excess of 40 percent sulphur.

Disseminated and banded pyrite zones, grading approximately 35 percent sulphur, were also mined. Sphalerite, jamesonite (geochronite?), chalcopyrite, gold and arsenopyrite mineralization are associated with massive and banded siliceous pyrite. A prospect pit located approximately 70 m south of the open pit exposes banded pyrite and sphalerite with significant amounts of jamesonite. The jamesonite predominantly occurs at the hinges of macro-folds. A selected highly mineralized sample collected by the author assayed 1.3 oz/t silver, .03 oz/t gold, .34 percent antimony, 8.96 percent zinc, and .205 percent arsenic.

Diamond drilling conducted by Syngenore Exploration Limited in the late 1960's also confirmed substantial silver, gold, antimony, copper, and zinc values across minimum widths. One such intersection gave upon assay 297.1 oz Ag/t, 0.46 oz Au/t, 2.15 percent Cu, 5.40 percent Pb and 3.79 percent Sb across 15 cm. Another intersection, in banded to massive pyrite, gave 0.04 oz Au/t across approximately 4.6 m.

Fraleck (1907) described a quartz vein located to the west of the main workings bearing chalcopryite, jamesonite and pyrite. A trench 0.6 m wide, 5 m long and 1.3 m deep exposed the vein, which cuts the general north-south structural trend at the Blakely Mine at approximately 45°. Remnants of two trenches were located by the author at the Blakely. No bed rock is exposed at these excavations, which

have long since been filled in with organic debris. Sangster (1970) located a small shear zone cutting the felsic metavolcanics between the main pyrite lens of the Blakely Mine, located near shaft No. 1. The zone reportedly contains scattered veinlets of jamesonite and abundant disseminated, 4 mm grains of gahnite (zinc spinel). At the shear zone the felsic metavolcanics are altered to a fine grained aggregate of quartz and sericite with fine grained disseminated pyrite and abundant euhedral staurolite porphyroblasts.

GEOLOGY-REGIONAL

The Canadian Sulphur Ore Company and Blakely Pyrite Mines are located in the Central Metasedimentary Belt (as defined by Wynne-Edwards 1972) of the Grenville Province in south-eastern Ontario. Rocks in the region belong to the Grenville Supergroup, and include mafic to felsic metavolcanics of the Hermon Group and a sequence of clastic and carbonate rocks of the Mayo Group. Igneous rocks of the biotite diorite suite and of the syenite-monzonite suite (Lumbers 1980) intrude the Hermon and Mayo Group rocks in the area.

Small outliers of Paleozoic carbonate rocks locally overlie the Precambrian in this area.

Structurally, the deposits lie in the Hastings Basin as defined by Wynne-Edwards (1972). According to Lumbers (1964) the regional metamorphic grade of the area concerned

is middle to upper greenschist facies. The region has a very complex structural history, resulting from repeated intense deformation associated with several periods of tectonism, the most pervasive of which is known as the Grenville Orogeny. Major faults have a general northwesterly trend, and show only limited displacements where field data are available.

GEOLOGY- LOCAL

Locally, the Canadian Sulphur Ore Company and Blakely Pyrite Mines occur within a synclinal structure known as the Queensborough Syncline (Hewitt 1968). The axis of the syncline trends at approximately 110° , and plunges steeply too the south east.

Within the study area eight rock units were identified in the field by the author. They include: 1) mafic metavolcanics, 2) intermediate metavolcanics, 3) felsic metavolcanics, 4) agglomerate, 5) dolomitic marble, 6) calcitic marble, 7) garnitiferous hornblende amphibolite, and 8) rusty schist.

UNIT 1, MAFIC METAVOLCANICS

The mafic metavolcanics are fine to medium grained, weakly to moderately foliated, and comprised of plagioclase, quartz and actinolite, with lesser amounts of biotite, epidote, chlorite and carbonate. Relic plagioclase

phenocrysts are not uncommon. Opaques include iron oxide and sulphides. Locally the mafic metavolcanics are pillowed, indicating that stratigraphic tops face westerly. Analysis: CV-804, 805, 819, Table 21.

UNIT 2, INTERMEDIATE METAVOLCANICS

The intermediate metavolcanics are grey to black in colour and are comprised of a fine grained ground mass of anhedral plagioclase and quartz with lesser amounts of coarser grained subhedral to euhedral biotite, chlorite carbonate and epidote. Relic subhedral to anhedral, medium to coarse grains, presumably of plagioclase and quartz are distinguishable in thin section. Locally hornblende porphyroblasts constitute the major mafic mineral. Graphite is the major opaque mineral, grading up to 2 - 3 percent. The intermediate metavolcanics are weakly to strongly foliated, and stratigraphically overlie the mafic metavolcanics. Analysis CV-808, Table 21.

UNIT 3, FELSIC METAVOLCANICS

The felsic metavolcanics are white to grey to pink in colour, massive to finely laminated, and are commonly fragmental and/or brecciated. This unit lies stratigraphically within the intermediate metavolcanics, and consists of a very fine grained equant mosaic of quartz and

TABLE 21: PETROCHEMISTRY OF ROCKS OF THE QUEENSBOROUGH
AREA

Sample No.	CV-804	CV-805	CV-819	CV-808	CV-807	CV-809	CV-814	CV-811
Rock Type	M	M	M	I	F	F	F	RS
SiO ₂	50.54	48.58	50.79	53.07	83.90	85.91	78.47	78.29
TiO ₂	1.74	1.41	2.05	3.15	0.23	0.30	0.20	1.05
Al ₂ O ₃	14.47	16.95	13.08	17.70	11.09	5.51	13.10	14.09
Fe ₂ O ₃	16.90	11.50	15.90	13.46	0.48	3.64	1.73	0.78
FeO	12.59	8.04	11.50	0.00	0.00	0.00	0.52	0.00
MnO	0.21	0.14	0.23	0.11	0.00	0.05	0.06	0.00
MgO	5.30	8.28	5.84	5.33	0.08	1.11	1.16	0.59
CaO	8.56	9.81	8.54	2.65	0.86	1.62	1.79	0.16
Na ₂ O	2.75	3.09	3.89	1.90	1.82	0.00	1.89	0.00
K ₂ O	0.38	0.59	0.23	1.77	1.25	1.16	0.98	4.15
P ₂ O ₅	0.14	0.10	0.13	0.14	0.00	0.09	0.0	0.00
CO ₂	0.04	0.10	1.21	1.70	0.12	2.09	0.07	2.96
S	0.13	.08	0.11	0.03	0.28	0.84	0.10	0.09
L.O.I.	0.20	1.10	1.60	3.40	1.20	2.90	1.50	2.70
TOTAL	99.55	97.71	99.52	96.69	99.28	99.99	98.63	99.65

ROCK TYPE ABBREVIATIONS:

M - Mafic Metavolcanic
 I - Intermediate Metavolcanic
 F - Felsic Metavolcanics
 RS - Rusty Schist

lesser plagioclase. Sparse components include muscovite, zoisite, tourmaline, actinolite, chlorite, and biotite. Locally the felsic metavolcanics contain up to 15-20 percent sericite. Relic feldspar phenocrysts are occasionally observed in thin section. Analyses-807, 814, Table 21.

UNIT 4, AGGLOMERATE

The agglomerate is composed of intermediate to felsic subrounded fragments, 1 to 5 cm in diameter. The matrix is fine to medium grained material of mafic to intermediate composition. The fragments have no preferred orientation. This unit is relatively small and discontinuous, and outcrops within the felsic metavolcanics.

UNITS 5 AND 6, DOLOMITIC MARBLE AND CALCITIC MARBLE

The dolomitic marble is grey to buff coloured, fine to coarse grained, and thinly bedded in places. It is usually cut by numerous quartz-carbonate stringers. Dolomitic marble is intercalated with intermediate and felsic metavolcanics, and also occurs as thin beds within the calcitic marble.

The calcitic marble is grey-blue in colour and thinly bedded, and overlies the sequence of metavolcanic rocks. This thick succession of carbonate metasediments is locally interbedded with minor siliceous clastic metasediments.

UNIT 7, GARNITIFEROUS HORNBLENDE AMPHIBOLITE

Garnitiferous hornblende amphibolite, grey to black in colour, has a fine to medium-grained ground mass composed of plagioclase and lesser quartz. The mosaic is overgrown by coarser subhedral, highly poikiloblastic garnet, poikiloblastic hornblende, multilamellar chlorite (formed at the expense of hornblende), and carbonate, with minor amounts of biotite, graphite and pyrite. This unit is massive to moderately foliated. Analysis CV-816 in Table 21 is from this unit at the Blakely Pyrite Mine. The garnitiferous hornblende amphibolite is spatially related to pyrite deposits at the Canadian Sulphur Ore Mine and the Blakely Pyrite Mine (Figure 19a). This association is recognized at other pyrite occurrences in the region. It is therefore assumed that the granitiferous hornblende amphibolite is an alteration of the country rocks, and is genetically related to the process or processes which produced the sulphide mineralization.

UNIT 8, RUSTY SCHIST

The rusty schist is fine grained and grey to black, and highly foliated. It is composed of variable amounts of quartz, sericite, pyrite and graphite. Fine disseminations of graphite, along with banded and disseminated pyrite, formed parallel to the foliation. The rusty schist unit

occurs as narrow discontinuous bands conforming to the local structural trends, and hosts the massive and banded siliceous pyrite at the Canadian Sulphur Ore Mine and Blakely Pyrite Mines. Miller and Knight (1913) described a cross-section through the east-west striking rusty schist zone from north to south at the Canadian Sulphur Ore Company Mine; quartzite in the footwall; banded pyritic quartzite (8 ft) sparsely mineralized quartzite (5 ft); massive pyrite (17 ft); and pyritic schist in the hanging wall.

Similar such zones are recognized throughout the region in a variety of host rocks including mafic to felsic metavolcanics and clastic and carbonate metasediments. Rusty schist zones are particularly common within the Queensborough Syncline. Numerous such zones exist west of the Canadian Sulphur Ore Company Mine, and were explored in the late 1960's by Syngenore Explorations Limited.

DISCUSSION

METASEDIMENTS OR METAVOLCANICS?

Miller and Knight (1913), Hewitt (1968) and other writers interpret the non-carbonate rocks of the Queensborough Syncline to be predominantly sedimentary in origin. Well-defined non-carbonate metasediments such as metaconglomerates are recognized within the synclinal structure and outcrop, extensively on the westerly limb of

the syncline. However, the author believes that in the vicinity of the Canadian Sulphur Ore Company and Blakely Pyrite Mines the non-carbonate rocks are predominantly of volcanic origin, having an original composition of basalt to andesite to rhyolite. Evidence such as relic anhedral to euhedral, medium to coarse grained plagioclase and quartz phenocryst observed in thin sections of the intermediate and felsic metavolcanics suggests an igneous origin for these rocks.

RUSTY SCHIST

The physical characteristics of the rusty schist have been previously described under the heading of local geology. It is generally a fine to medium grained aggregate with variable amounts of quartz, sericite, pyrite and graphite. The zone grades from an almost monomineralic polygonal mosaic of quartz, referred to by Miller and Knight (1913) as quartzite, to a sericite-quartz-pyrite-graphite rock referred to as pyritiferous black slate. Assuming that the host rocks at the Canadian Sulphur Ore Company and Blakely Pyrite Mines are of volcanic affinity deposited in a marine environment indicated by the existence of pillows in mafic metavolcanics, it would, therefore, seem very unlikely that mature sediments such as quartz arenites typical of strand deposits would be deposited in such an environment. The author suggests that these units are actually chemical

precipitates (exhalatives) related to volcanic fumarolic activity and have been subsequently altered during regional metamorphism.

Lumbers (1968) concluded that "some rusty schist zones are post-metamorphic hydrothermal replacement, others may represent tuffaceous iron sulphide-bearing sediments or black shales, and still others could be regionally metamorphosed sedimentary and volcanic rocks which were altered initially by fumarolic activity during volcanism."

FELSIC METAVOLCANICS

Comparisons of the petrochemistry of the felsic metavolcanics of the Queensborough Area with that of the Mazinaw Lake Area and global analyses of felsic igneous rocks from different localities around the world, show distinct variances in chemical make-up, (Table 22). The most significant differences are in the SiO_2 content, which is anomalously high (78.47 percent to 85.91 percent SiO_2) and the Na_2O and K_2O values, which are anomalously low, in the felsic metavolcanics of the Queensborough Area. The difference in the chemistry of these rocks cannot be attributed to the regional metamorphism since the metavolcanics of the Mazinaw Lake Area which are of equal metamorphic grade as the rocks of the Queensborough area, show no significant petrochemical difference in comparison with unmetamorphosed felsic rocks worldwide.

Table 22: Petrochemical Comparison of Felsic Metavolcanics of the Queensborough Area, Mazinaw Lake area and Unmetamorphosed rocks from various locations around the world.

	Queensborough Area	Mazinaw Lake Area (Ayer, 1979)	Global Analyses
No of Samples	3	8	?
SiO ₂	82.76	73.0	73.86
TiO ₂	0.24	0.4	0.20
Al ₂ O ₃	9.9	13.0	13.75
FeO	1.95	—	0.78
FeO	0.52	4.1	1.13
MnO	0.36	0.1	0.05
MgO	0.78	0.5	0.26
CaO	1.42	1.1	0.72
Na ₂ O	1.24	4.4	3.51
K ₂ O	1.13	3.2	5.13
P ₂ O ₅	0.03	0.1	0.14

* From Nockolds, S.R. 1954:

Average chemical composition of some igneous rocks, Geological Society of America, Bulletin, 65p.

The chemistry of the felsic metavolcanics near Queensborough may suggest a sedimentary origin; however, relict feldspar phenocrysts are common.

The author believes this unit is a highly altered volcanic rock which was subjected to volcanogenic or later metasomatic processes involving in part the addition of SiO_2 and the removal of Na_2O and K_2O . The original composition of the felsic metavolcanics was probably andesitic to rhyolitic.

Features of these two properties are presented in Table 23.

CANADIAN SULPHUR ORE COMPANY MINE

The Canadian Sulphur Ore Company operated between 1908 and 1919. At time of closing, the development work consisted of 3 shafts and 2 production pits. The No. 1 and No. 2 shafts were sunk to 75 feet and 100 ft respectively. Open pits No. 3 (60 by 25 ft by 60 ft deep) accounted for large part of the production. Shaft No. 3 collared at the bottom of open pit No. 3 reached 460 feet in depth with six developed levels (Figs. 20, 21). The pyrite ore was shipped by rail to the Grasselle Chemical Company, Hamilton, Ontario and to the Nickels Chemical Company at Sulphide, Ontario.

TABLE 23: COMPARISONS OF CANADIAN SULPHUR ORE COMPANY AND BLAKELY PYRITE MINES

<u>Deposit</u>	<u>Location in Relation to Structural Environment</u>	<u>Strike and Dip of Deposit</u>	<u>Mode of Occurrence</u>	<u>Host Rock(s) hosted by</u>	<u>Mineralogy</u>
Canadian Sulphur Ore Company	located along the fold axis of the Queensborough Syncline	striking generally east-west conforming to the synclinal structure; dipping steeply to the south	massive and banded siliceous pyrite occurring as lenticular bodies within rusty schist	intermediate metavolcanics which have been partially altered to garnetiferous hornblende schist in close proximity to felsic metavolcanics	massive and banded pyrite cut by veinlets of quartz, carbonate and secondary pyrite. Isolated pyrrhotite with very minor chalcopyrite
Blakely Pyrite Mine	located on the east limb of the Queensborough	striking generally north-south conforming to the synclinal structure; dip is vertical	massive and banded siliceous pyrite occurring as lenticular bodies within rusty schist	occurs at the contact of felsic metavolcanics and garnetiferous hornblende amphibolite (interpreted to be altered intermediate metavolcanics)	massive and banded pyrite cut by quartz stringers, and banded pyrite and sphalerite with jamesonite. Secondary veins of quartz chalcopyrite and jamesonite. Shear zones containing jamesonite, gahnite and staurolite.

The mine, as of 1913, employed approximately 50 men and was equipped to produce 50 to 100 tons of ore grading 40 percent sulphur per day (Miller and Knight 1914). The pyrite was used in production of sulphuric acid, a basic chemical feedstuff.

- 1906: property discovered by Mr. Stephen Wellington - several pits and trenches on the property.
- 1908: shafts No. 1 and No. 2 were sunk and one carload of ore was shipped.
- 1909: property purchased by Canadian Pyrite Syndicate - shipped five hundred tons - one shaft reached 50 ft with drifting at that level - the other shaft reached 20 ft.
- 1910: property purchased by Canadian Sulphur Ore Company - began shipping in summer of 1910.
- 1912: property was supplied by electrical power by the Seymour Power Company.
- 1913: Pits no. 3 and 4 were developed with No. 3 shaft better than 120 ft. deep with levels at 50 and 120 ft at the 120 ft level, development work consisted of 150 ft of drifting.

1919: mine closed with No. 3 shaft reaching 460 ft with 6 developed levels.

Current status: mineral rights are patented and held by Mr. E.C. Sager of Madoc Township.

BLAKELY PYRITE MINE
(QUEENSBOROUGH PYRITE MINE)

The Blakely Pyrite Mine was operated by the British American Development Company between 1905 and 1908. Development work by 1908 consisted of 2 shafts and 1 open cut. The main shaft reached 135 ft in depth with about 175 ft of drifting on the 50 and 85 ft levels. A shallow shaft, 30 ft in depth is located 150 ft west of the main shaft. The open cut is located about 100 ft south of the main shaft. Production figures are not available, however, 65 carloads of ore was shipped by the fall of 1906 (Fraleck 1907).

Recent work on the property by Syngenore Explorations Limited in the late 1960's and Freeport Canadian Exploration Company in 1973-74 was aimed at delineating minable grades of base metal sulphides and precious metals. Mr. E.C. Sager of Madoc Township currently holds the patented mining rights to the Blakely property.

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DEER LAKE ZINC-COPPER-SILVER PROSPECT

Location and Access

The Deer Lake Zu-Cu-Ag prospect lies principally within lots 27 and 28, and the south part of lot 29, Con. I, Belmont Township, in NTS quadrant 31C/12, at UTM co-ordinates 4939350N, 277250E. It is located about 4 km north of the village of Cordova Mines, just west of a paved concession road marking the boundary between Marmora and Belmont Townships (Figure 22). The main mineralized zone occurs within a wooded area west of some abandoned, derelict farm buildings at a point about 4.2 km by road north of the intersection of the concession road with the Cordova Mines road. The best exposures occur in an open field on the southwest edge of the forested area, about 500 metres from the road.

Economic Features

Mineralization at the Deer Lake Zn-Cu-Ag prospect consists of sparsely disseminated sulphides contained in a layer of rusty schist up to 50 metres thick. This rusty schist has been tectonically thickened in the nose of a syncline to form a mineralized zone approximately 200 to 250 metres wide and up to 600 metres long. A total of eight diamond drill holes ranging from less than 30 to 260 metres

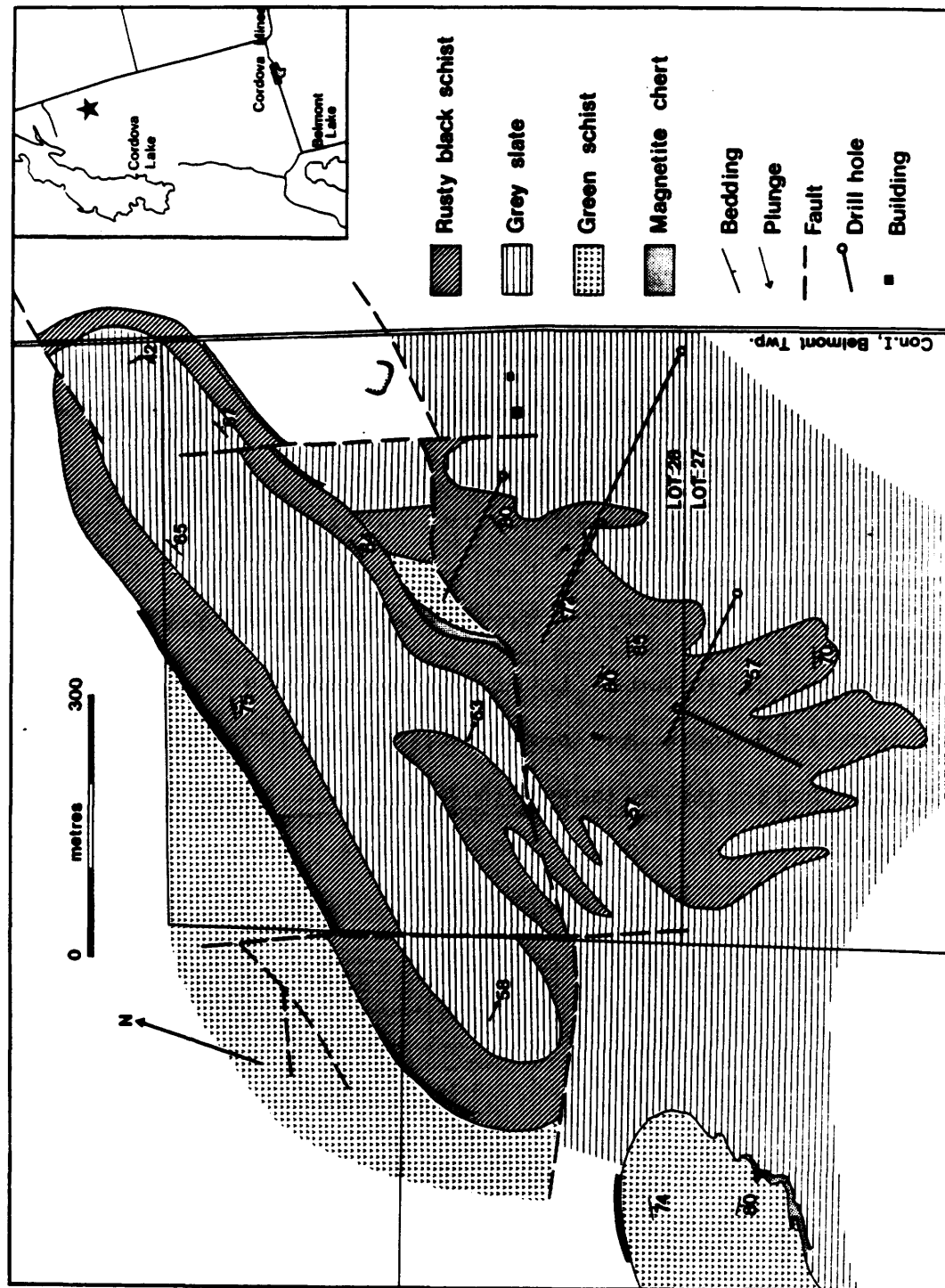


Figure 22: Geology of the Deer Lake Cu-Zn-Ag deposit, Belmont Township, adapted from a map by Benson (1967).

in length have been completed on the prospect (personal files, C.R. Young, Havelock). Mineralization was encountered over the entire length of all eight drill holes, with values ranging from 0.01 to 0.1 percent copper, 0.04 to 1.13 percent zinc, and trace to 0.5 oz of silver per ton (Diamond drill files no. 13,14 Belmont Township, Assessment Files Research Office, Toronto). Assays of up to 6.28 percent zinc over a length of 30 cm are also reported from one diamond drill hole (Technical File 63.952, Assessment Files Research Office, Toronto).

A series of representative surface chip samples were collected by the author from the southern part of the main mineralized zone (Table 24). Samples 80TRC-194 to 201 were collected at 50 metre intervals across the main part of the mineralized zone, and sample 80TRC-191 is unmineralized schist collected adjacent to the county road. The remaining samples were collected randomly from surface outcrops of the rusty schist.

TABLE 24: Metal contents of of rusty schist at the
Deer Lake Zn-Cu-Ag prospect.

<u>Sample No.</u>	<u>ppm</u>					<u>oz per ton</u>	
	<u>Cu</u>	<u>Zn</u>	<u>Pb</u>	<u>Sb</u>	<u>As</u>	<u>Au</u>	<u>Ag</u>
80TRC - 69	96	37	-	-	-	<0.01	<0.1
- 70	6720	1360	-	-	-	0.02	2.74
- 71	366	7350	34	-	-	<0.01	0.10
-191	92	62	-	1.2	260	<0.01	<0.1
-192	132	1280	-	15	72	<0.01	<0.1
-194	205	2250	-	2.2	172	0.01	0.21
-195	156	1670	-	5.0	180	0.01	0.27
-196	205	245	-	2.2	450	0.01	0.11
-197	122	500	150	20	53	0.01	0.29
-198	.86	340	24	0.5	120	<0.01	<0.1
-201	400	1410	20	0.7	92	0.01	0.13

The available assay results indicate average metal content of about 0.03 - 0.04 percent copper, 0.3 - 0.5 percent zinc, 0.2 oz Ag per ton, and 0.01 oz Au per ton could be expected for the main mineralized zone. Additional exploration might also reveal narrow high grade zones in the deposit, as suggested by the two high grade assay results.

Geology

The Deer Lake Zn-Cu-Ag prospect occurs between a major volcanic sequence and an overlying carbonate-clastic sedimentary succession on the northeastern edge of the Hastings metamorphic low. Bartlett et al (1980, 1982, 1983) have defined 3 distinct mafic to felsic volcanic cycles, and 2 probable additional cycles in the volcanic sequence. The Deer Lake mineralized zone occurs at the top of Cycle III, which consists principally of submarine basalt and subordinate intermediate pyroclastics. Minor amounts of magnetite ironstone occur at the top of the cycle.

The Zn-Cu-Ag zone occurs within a sequence of thinly laminated mudstones, siltstones, pelitic sandstones, and felsic volcanic tuffs, with minor interbeds of magnetite ironstone. The rocks are very thinly laminated (1-2 cm), consisting typically of alternating dark grey mudstone and buff coloured siltstone, sandstone, or tuffaceous layers, commonly containing disseminated pyrite. Thin beds of quartzite, chert, and calcareous, chloritic mudstone are

locally abundant. The mineralized zone is a sulphide-rich equivalent of these sedimentary rocks, consisting typically of very schistose, friable, 'rusty schists' that weather to a rusty black, porous gossan. Pyrite, pyrrhotite, and minor sphalerite and chalcopyrite occur disseminated within the rock, with total sulphide content ranging from 5 to 25 percent. The sulphides locally form very thin (2-10 mm), discontinuous, massive layers in the rusty schists, as reported by Miller (1957). Miller also reports the occurrence of thin seams of graphite in the mineralized schists, alternating with massive pyrrhotite and biotitic siltstone. Bartlett et al (1980) have noted the occurrence of garnet and garnet-cummingtonite schists in the mineralized zone.

Detailed mapping by Miller (1957) and Beavon (1967) indicates that the main mineralized zone lies in the nose of a syncline that plunges to the southeast at about 50-60 degrees. The axial plane strikes in an easterly direction and dips steeply to the southeast. Parasitic folds are common in the rusty schists around this structure.

The clastic and tuffaceous sediments of the host rock unit continue eastward across Marmora Township. Two other mineralized rusty schist horizons occur within this unit (Carter 1980) and horizons containing significant amounts of copper and zinc also occur at the tops of the Cycle I and II

volcanic sequences in Belmont Township (Bartlett et al. 1980, 1982, 1983).

Microscopy: Five thin and polished thin sections of rusty schist were examined by the author. The sections are composed essentially of variable amounts of very fine-grained to fine-grained (0.01 - 0.2 mm) quartz, feldspar, sericite, opaque minerals, and minor chlorite, with locally abundant biotite, garnet, and carbonate. Compositional layering is defined by variations in the relative proportions of mica to quartz and feldspar. All sections have a strong mica foliation conformable with the compositional layering. The foliation is crenulated in some of the sections.

Sulphide content of the sections varies from 1 to about 15 percent. The sulphides occur as scattered grains, as thin (2-3 mm) concordant lenses, or rarely as dispersed grains within narrow, discontinuous quartz veinlets. Pyrite is the most abundant sulphide, with about equal amounts of pyrrhotite, chalcopyrite, and sphalerite. Pyrite sometimes occurs as large (1-3 mm), irregular, partly recrystallized, oval aggregates that strongly resemble primary framboids. Abundant very fine grains of sericite and chlorite occur as inclusions within the framboidal structures. More commonly the pyrite forms scattered anhedral to euhedral grains. Pyrrhotite usually occurs as intergrowths within pyrite.

Sphalerite and chalcopryrite usually occur together, either intergrown or as separate irregular grains.

History of Development:

- 1955-1957: The property was acquired by two local prospectors, Roger Young and James Cumming, in 1955, to investigate an aeromagnetic anomaly. In 1956 and early 1957 three diamond drill holes totalling 84.7 metres intersected minor disseminated sphalerite and chalcopryrite along with pyrite and pyrrhotite. In 1957 Texas Gulf Sulphur Co. completed geological mapping and vertical loop electromagnetic and magnetometer surveys (Assessment Files Research Office, Toronto, Technical File No. 63-952).
- 1964: One diamond drill hole 112.2 metres in length completed by Keevil Mining Group on lot 27. Disseminated sulphides were encountered over the entire length. Assays ranged from 0.02 - 0.1 percent Cu, 0.2 - 0.5 percent Zn, 0.1 - 0.5 oz Ag per ton over a length of about 35 metres (Assessment Files Research Office, Toronto, Diamond Drill File No. 13, Belmont Township).
- 1967-1968: Four diamond drill holes totalling 808.7 metres completed by Syngenore Explorations Ltd. The

entire core length was mineralized. Assay values ranged from 0.04 - 1.13 percent Zn, 0.01 - 0.08 percent Cu, trace - 0.2 oz Ag per ton (Assessment Files Research Office, Toronto, Diamond Drill File 14, Belmont Township). Tonnage in the order of 40 to 50 million tons is indicated (Syngenore Explorations, personal files of C.R. Young, Havelock).

1969: Geochemical soil survey completed for Metalridge Mining Corp. Ltd. by Syngenore Explorations Ltd. Copper-zinc anomalies corresponding with rusty schist outcrops were outlined (Assessment Files Research Office, Toronto, Technical File 63 G. 11).

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WILCOX COPPER-ZINC PROSPECT

by

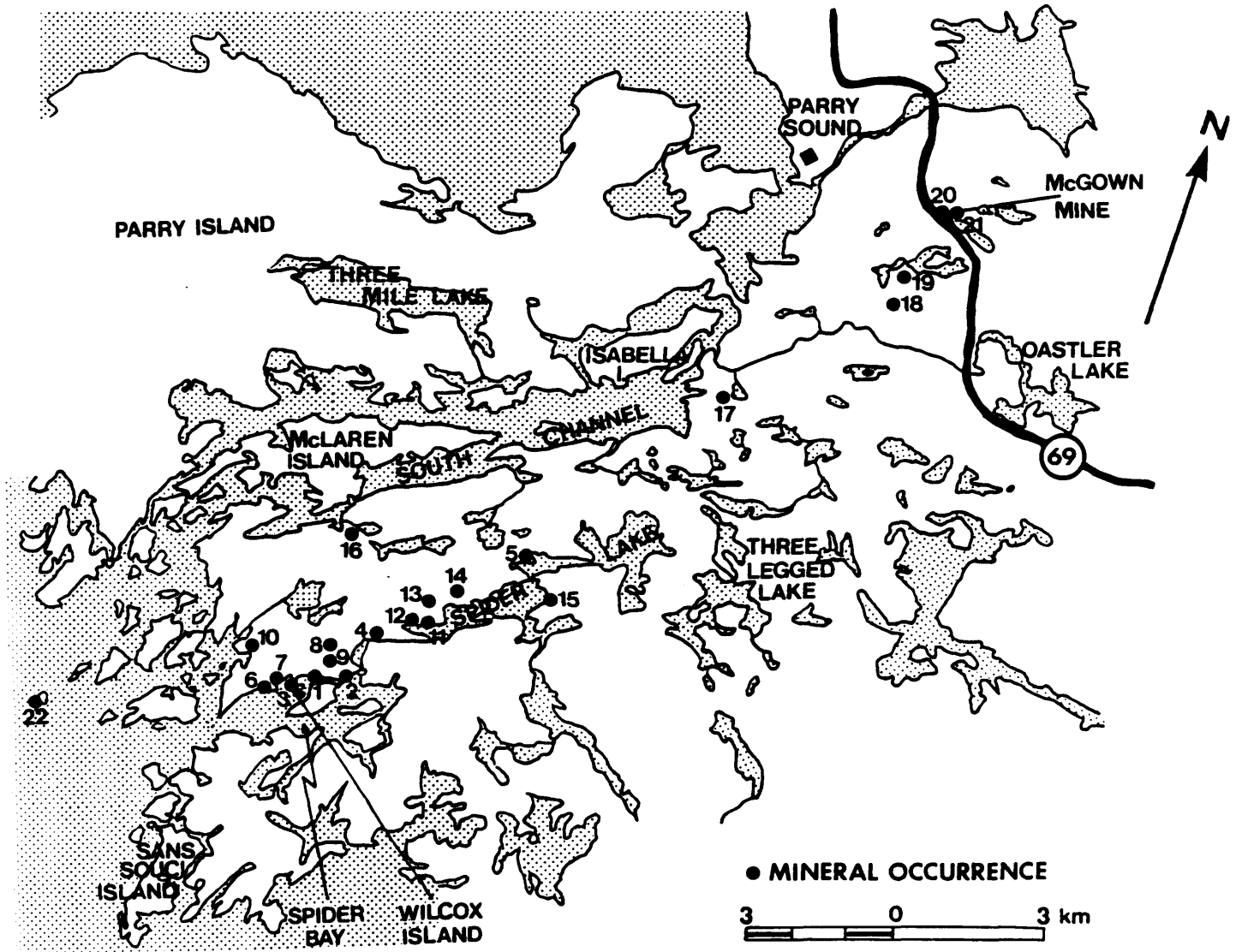
D. Villard
Ministry of Natural Resources
Huntsville, Ontario

Location and Access

The deposit is located in the southern half of Cowper Township (Concession IV, Lots 18-22) on the north shore of Spider Bay, approximately 17 kilometres from Parry Sound. The U.T.M. co-ordinates are 500820 N, 576990 E within N.T.S. quadrant 41 H/1. This deposit can be reached by boat from Parry Sound and, except for the latter part, channelways are well marked and easy to follow.

Economic Features

The Parry Sound/Sans Souci area contains a variety of metallic mineral deposits, of which the Wilcox is one of the better known. It occurs within a zone of mineralization, consisting mainly of chalcopyrite, sphalerite and pyrite, which stretches from west of Wilcox Island (Figure 23) to the McGown Mine about 17 kilometres



Sketch map showing location of mineral occurrences in the area south of Parry Sound.

Figure 23: Mineral occurrences south of Parry Sound, keyed to Table 25.

to the northeast. A quick summary of available information outlines twenty-two occurrences within this zone. Table 25 shows assays from selected samples from most of these occurrences. There are also sporadic occurrences of copper mineralization northeast from the McGown. An interesting point is that the McGown deposit was originally operated as a gold mine with reported (Hewitt, 1967) gold of \$5./ton in 1899.

The Wilcox deposit is the centre of three zones of mineralization that occur over a strike length of approximately 850 metres (Figure 24). The Wilcox deposit has been the most extensively worked of the three zones. The mineralization consists of stringer type chalcopyrite-pyrite-pyrrhotite mineralization, with rare sphalerite, with minor lenses of massive sulphides of the same composition measuring 3 metres in length and 0.2 metres in thickness. The sulphides occur in a narrow irregular zone from 0.3 to 5 metres thick of coarse garnet-biotite-pyroxene gneiss. An irregular cross-cutting alteration zone approximately 100 metres wide consisting of 5 to 10 percent garnet occurs in the footwall rocks. The deposit is immediately capped by a more felsic gneiss with a zone of garnet alteration and minor disseminated sulphides 1 to 10 metres wide and subsequently by a more mafic gneiss in the form of a pyroxene feldspar gneiss.

Table 25: Representative assays of base metal sulphide occurrences in the Parry Sound area.

<u>Deposit Name</u>	<u>Assay Results %</u>	
	<u>Cu</u>	<u>Zn</u>
1. Wilcox Mine Shaft #1	1.82	Tr
2. Wilcox Mine Shaft #2	1.00	6.40
	4.30	7.60
3. Wilcox Island	.94	18.90
4. Bayshore	0.10	5.79
5. Consolidated Copper Mines	1.62	0.27
6. Wilcox Showing # 1	-	-
7. Wilcox Showing # 2	-	-
8. Wilcox Showing # 3	0.07	0.01
9. Wilcox Showing # 4	0.12	0.03
10. Wilcox Showing # 5	0.05	0.01
11. Spider Lake Showing #1	1.74	1.30
12. Spider Lake Showing #2	4.18	1.39
13. Spider Lake Showing #3	0.90	0.32
14. Spider Lake Showing #4	0.42	0.25
15. Spider Lake Showing #5	2.78	0.94
16. Speyer Lake	0.03	0.02
17. Lafex Mine	-	-
18. Richmond Lake Showing # 1	-	-
19. Richmond Lake Showing # 1	-	-
20. McGown Mine Shaft # 1	-	-
21. McGown Mine Shaft # 2	-	-
22. McBrien Island	0.03	0.04

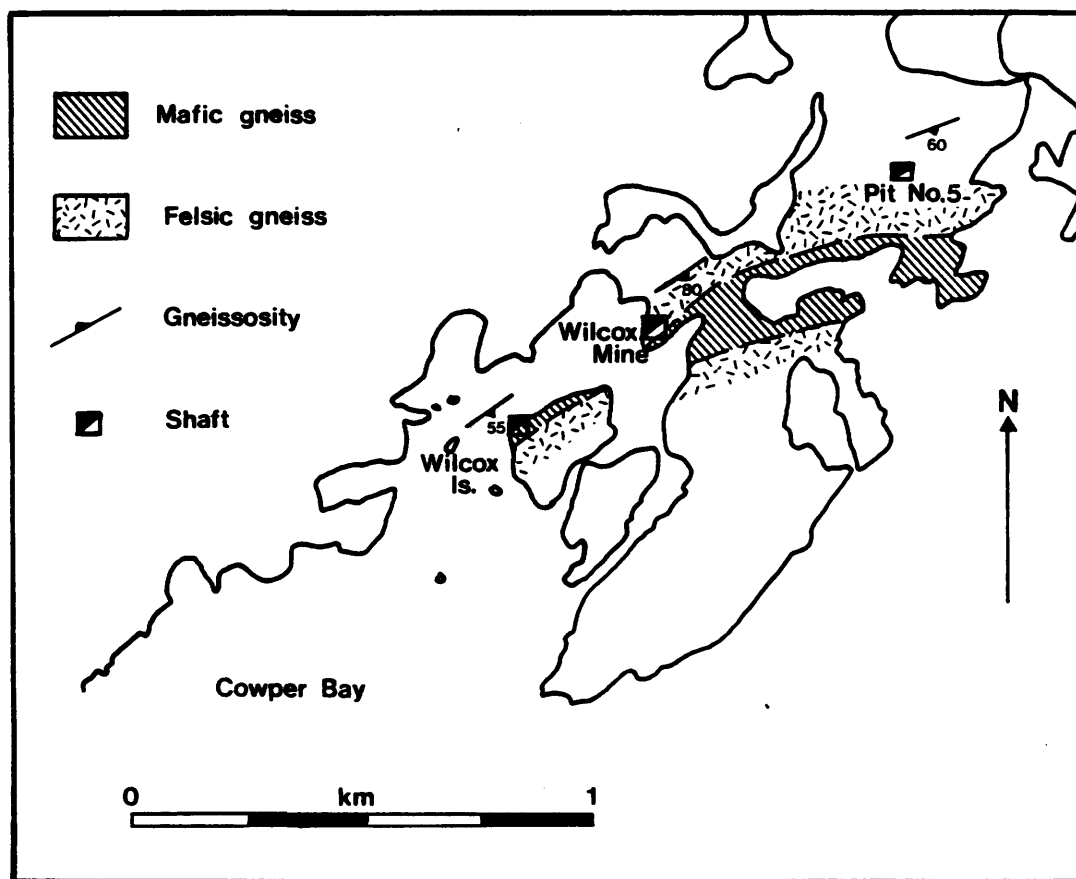


Figure 24: Geology of the three main zones of mineralization at the Wilcox copper-zinc deposit.

Near the northeastern end of the Wilcox property at pit 5 (Figure 24) another occurrence of sulphides in garnet-pyroxene-biotite gneiss is developed. A shaft and a pit worked here exposes massive and stringer type sphalerite and chalcopyrite-pyrite-pyrrhotite mineralization in a zone approximately 2 metres thick. In addition, some mineralization consists of small fragments of gangue and sulphides in a sulphide matrix.

The Wilcox Island deposit is exposed by a shaft and pit each approximately 2 metres by 2 metres across, and is apparently on strike, 400 metres southwest of the Wilcox Mine. Coarse garnet-biotite-pyroxene gneiss from 0.6 metre to 1.6 metres thick occurs within felsic rocks, dips at approximately 45° S and is mineralized with massive sphalerite, pyrite and minor chalcopyrite. Garnet alteration is present in the footwall but not the hanging wall of the deposit. The sulphide zone is overlain by 3 metres of felsic gneiss and subsequently, a more mafic rock in the form of a hypersthene-feldspar gneiss. Assays of this zone are impressive as well as for the Wilcox.

Several smaller deposits occur on the same horizon as the Wilcox Mine. This horizon is folded and its surface trace trends to the southwest from the Wilcox Mine and arcs back towards the northeast about 1500 metres southwest of the mine. The deposits occur at UTM 693 E 077 N, 693 E 080 697 E 085N. All the deposits are small about three metres

in diameter. These three deposits were difficult to trace for any length but appear to be on the north limb of the same contact. Each of these deposits is flanked on the north by mafic rocks and on the south by more felsic rocks.

Regional Geology

The Wilcox deposit is situated within the Central Gneiss Belt of the Grenville Province. Until recently these rocks had never been systematically mapped in detail and can probably be considered as representing some of the most ignored and least understood rocks in Ontario. Hewitt (1967), with limited field work, located the Wilcox deposit within a group of metasedimentary and granitic rocks. Several people have also raised the possibility that some of the rocks within this "Parry Sound Greenstone Belt" are volcanic in origin.

In 1980, Tony Davidson of the Geological Survey of Canada, initiated reconnaissance mapping in the area stretching east from Georgian Bay (Davidson and Morgan, 1981). Davidson et al. (1982) "... established several distinctive domains, based on differences in lithologic assemblages, structural style and grade of metamorphism." The Wilcox deposit is located within the Parry Sound Domain.

Davidson (1980) states that this part of the domain "... is underlain by a very complex mixture of mafic, intermediate and feldspathic gneiss with some marble and minor pelitic units, and hypersthene-bearing plutonic rocks. The whole of this eastern zone is in granulite facies, or has retrograded from it." It is notable to that most of the occurrences and deposits in the area are aligned parallel to northerly structural trends along the western edge of the Parry Sound Domain.

History of Development

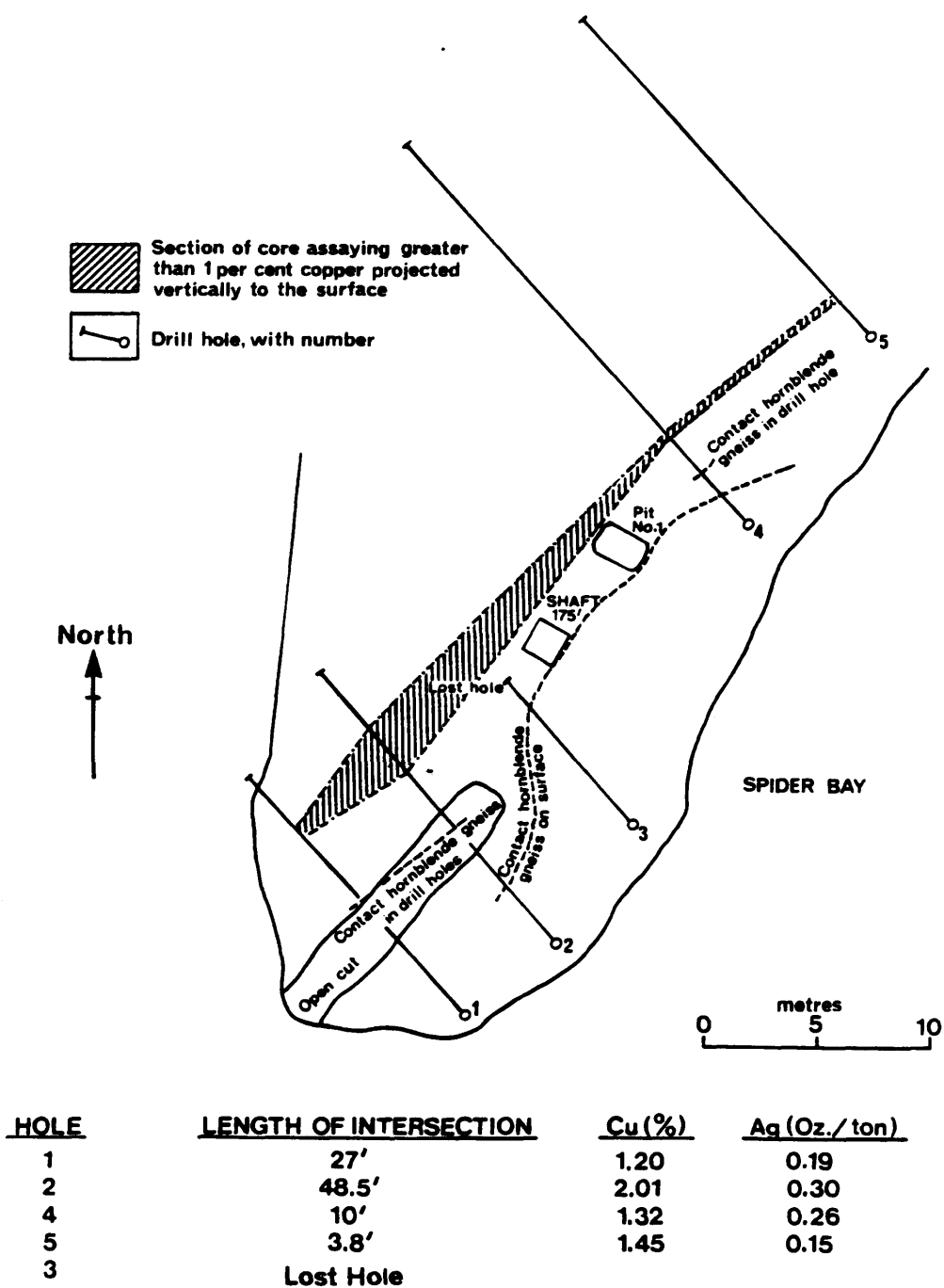
The Wilcox property was discovered in 1893 by Henry Harris and Thomas Wilcox. The Parry Sound Copper Mining Company Limited was incorporated in 1899 to develop this property and its holdings were sold in 1917. Active work took place between 1893 and 1904 with some additional work in 1910. Workings consist of an open cut 30 metres in length, a shaft to a depth of 53 metres and several deep pits. There has apparently been a small amount of cross cutting at the 30 metres level. In 1903 and 1904 the mine produced 87,000 kgs. of copper valued at \$7,680.

Waterways Copper Mines Limited, incorporated in 1939, had an option on the Wilcox property and staked a considerable amount of additional ground, 64 claims in all on strike to the northeast of the Wilcox property. The

company made a surface examination and apparently put down nine diamond drill holes in 1939. Apparently, five or six holes were put down in the area of the Wilcox deposit, (Figure 25); the remaining holes were put down to the northeast around a second shaft. In 1942 Bayshore Zinc and Copper Mines Limited acquired a five year option on the Wilcox property and staked an additional 18 claims. Geophysical work and diamond drilling uncovered a zinc-copper zone about 1/2 mile to the east of the old workings. The property was purchased in 1950 by Kalbrook Mining Company Limited. In 1957 Ventures Property Limited purchased the assets of Kalbrook Mining Company Limited. In 1961, Ventures Limited amalgamated with Falconbridge Nickel Mines Limited and shortly thereafter Ventures Property Limited sold the mining claims to Philips Island Association, a predecessor of Cowper Conservation Associates. Cowper Conservation Associates sold these mining claims to the Ontario Government in April, 1974.

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Figure 25: Location of diamond drill holes 1 to 5 at the Wilcox deposit (from Hewitt 1967).

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LONG LAKE ZINC MINE (PAST PRODUCER)Location and Access

The former Long Lake zinc mine is located approximately 8 km by road northwest of the village of Parham. It is accessible via a series of paved and gravel roads extending between Parham and the village of Mountain Grove, and lies approximately 670 metres west of the Long Lake post office and store, 120 metres north of a gravel concession road (see Fig. 26). It lies within lot 3, Concessions V and VI, Olden Township, in NTS quadrant 31C/10, at UTM co-ordinates 4949775 N. 359575E.

Economic Features

The Long Lake zinc deposit has supported small-scale mining operations by different operators several times since its discovery in 1897. Early production included more than 100 tons of ore removed in 1901; between 1902 and 1907 about 3442 tons of zinc ore valued at \$41,550 were shipped from the property; and in 1949 a total of 240 tons of zinc concentrates and 15 tons of lead concentrates were reported to have been produced, although there is no record of these having been sold. This early production was obtained from several small lenses of zinc mineralization occurring within two, separate, parallel horizons. The mineralized lenses

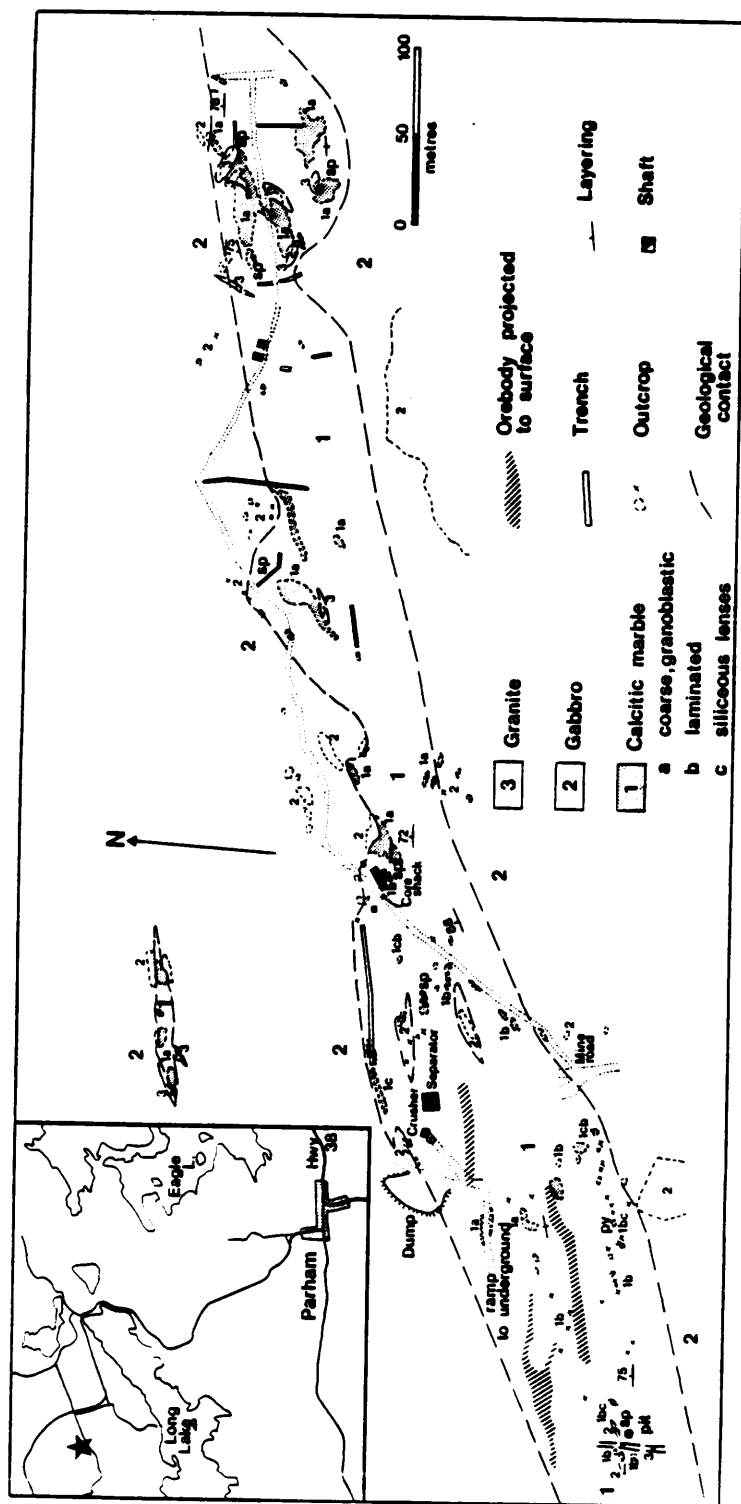


Figure 26: Geology of the Long Lake deposit. Adapted from Wolff 1979.

are reported to have been roughly circular in section, varying from 1.5 to 30 metres long, and a few centimetres to 4.3 metres wide. The largest single body mined is reported to have been 4.3 metres wide and 27 metres long, and was mined to a depth of about 12 metres (Alcock, 1930). Workings during these early periods of development are reported by Alcock (1930) to have included 5 shafts, varying in depth from 18 to 38 metres, about 100 metres of drifting, mainly in ore, 3 open cuts up to 18 metres long and 12 metres deep, and 25 pits and trenches varying in depth from 1 to 9 metres. An additional 90 metres of drifting was completed in 1949 (Thomson, 1952).

On March 1, 1973, Lynx-Canada Explorations Ltd. in partnership with Canadian Reynolds Metals Ltd. commenced mining of three newly discovered ore lenses (A,B, and C) immediately to the west of the previously mined orebodies, using an underground ramp for access and modern trackless mining equipment. Between March 1, 1973, and the closing of the mine on December 31, 1974, a total of 94,631 short tons of ore averaging 11.6 percent zinc were mined and milled (Ministry of Natural Resources, Mineral Resources Branch, Mineral Statistics Section, Toronto). According to D. Villard, Resident Geologist, Huntsville, personal communication 1982) the C zone was the smallest and richest with a zinc content locally exceeding 40 percent. The B zone, the largest of the three, graded approximately 23

percent zinc and was 100 metres long, 4 to 5 metres wide, and extended about 30 metres vertically. The A zone was variable in grade and very irregular in shape.

Geology

The Long Lake zinc deposit occurs within a remnant of calcitic marble which forms a xenolith within a large gabbroic intrusion (Fig. 26, 27) termed the Mountain Grove Mafic Intrusion by Wolff (1979). The marble remnant has total strike length of about 1 km and is up to 180 metres wide. Layering in the marbles strikes northeast and generally dips steeply to the northwest. Several lenses of gabbro, elongate parallel with layering, occur within the marble remnant. Discontinuous, cross-cutting dikes of granite cut both the marble and the gabbro, and in at least one place a granitic dike cuts a layer of zinc mineralization.

Three types of marble were distinguished by the author in the Long Lake marble remnant; 1. very coarse-grained (> 1cm), massive, calcitic marble. 2. laminated calcitic marble; and 3. layered, siliceous calcitic marble. Each type forms locally well-defined horizons that are gradational into each other over short distances. The coarse-grained marble is composed almost entirely of white calcite and is typified by its coarse grain size (10-80 mm), massive nature, and lack of impurities. It occurs

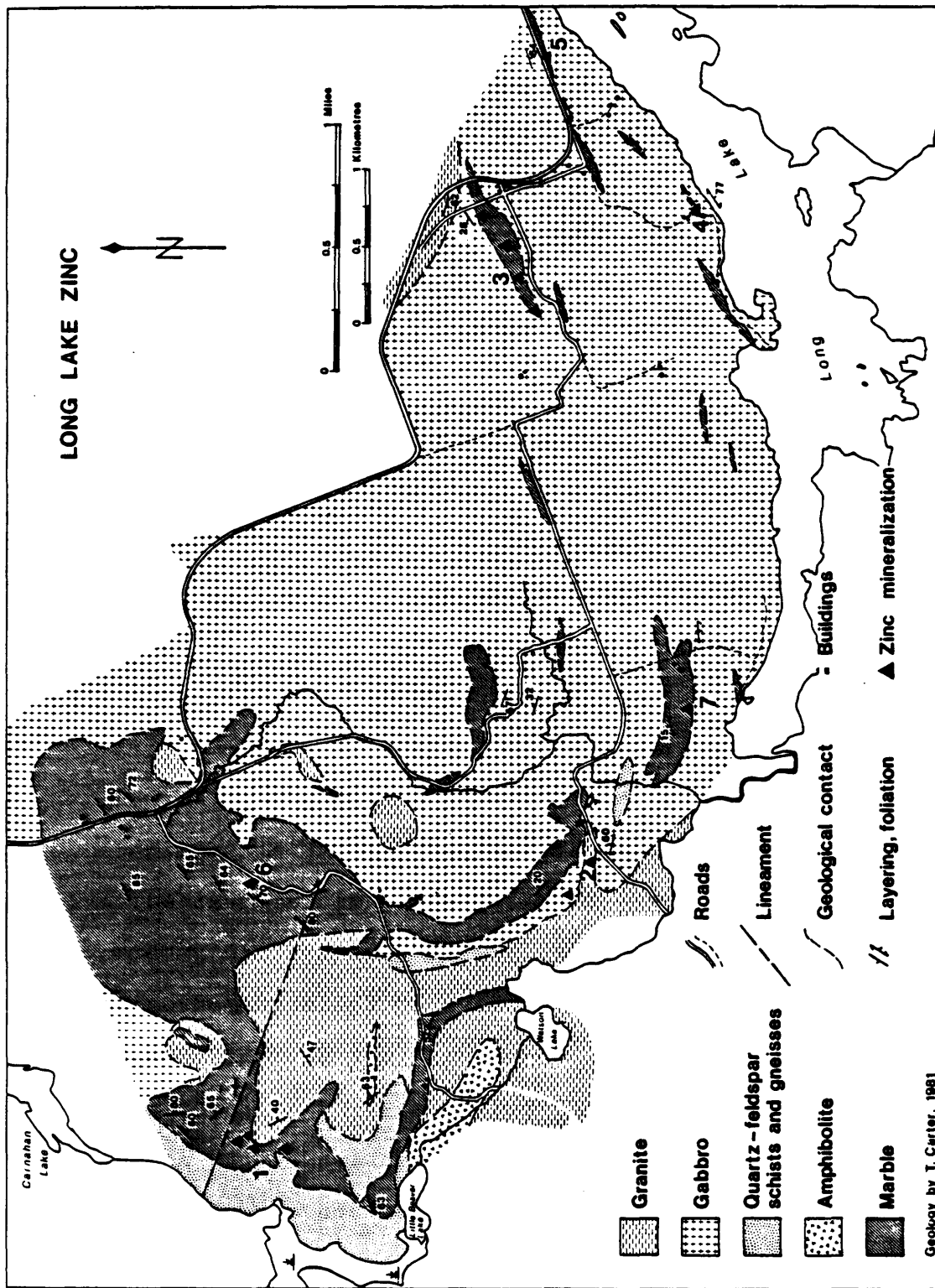


Figure 27: General geology of the Long Lake area, showing locations of zinc occurrences. The Long Lake deposit is no. 3 on the figure.

throughout the Long Lake marble remnant but is best developed in the eastern part of the belt. The laminated calcitic marble has very regular, well defined, white and grey layers 0.5 to 5 cm thick. The grey layers are generally finer-grained (3-5 mm) than the white layers (5-8 mm) and contain abundant (5-20 percent), very fine (<0.5 mm), disseminated flakes of biotite and phlogopite.

Dolomite and tremolite are minor constituents. The layered, siliceous calcitic marble is characterized by thin (0.5 to 50 cm) siliceous layers and lenses contained within either coarse-grained or laminated calcitic marble. The siliceous layers and lenses contain abundant fine-grained (1-3 mm) diopside, tremolite, and occasional quartz, in variable proportions, in addition to calcite. The siliceous layers often pinch and swell along strike, in a manner similar to boudin structures.

The surrounding mafic intrusive rocks are dominated by massive to foliated, black, fine to medium-grained (1-4 mm) gabbro which grades locally into anorthositic gabbro. Pink, fine to coarse-grained, massive to foliated monzonite occurs as scattered irregular lenses and dikes within the gabbros. The gabbros are composed principally of a granoblastic intergrowth of plagioclase and hornblende with accessory magnetite. Relict pyroxene is rare and unrecrystallized laths of plagioclase are locally common. The monzonite is composed principally of feldspar, with minor quartz. Large

augen of K-feldspar are common. Foliations in all the above intrusive rocks are conformable with the Long Lake marble remnant.

Granitic dikes intrude the mafic intrusive rocks and are probably associated with a large granitic intrusion which outcrops immediately northeast of the marble remnant. The granite is a pink, massive to weakly foliated, medium grained rock, with local pegmatitic and aplitic phases, which also form dikes.

Mineralization: Mineralization at the Long Lake zinc deposit consists principally of sphalerite, with accessory pyrite and pyrrhotite, and rare galena, chalcopryrite, and minor molybdenite, contained within conformable lenses in the Long Lake marble remnant. At surface, narrow conformable lenses of reddish-weathering, disseminated to massive sulphides are exposed in outcrops and in pits and trenches in several places (Fig. 26). These mineralized lenses usually consist of stringers 1 to 2 centimetres wide traceable for only a few metres along strike containing sparsely disseminated, fine- to medium-grained (1-4 mm) sphalerite with minor pyrite and rare galena and sphalerite. Several such stringers sometimes occur parallel to each other, separated by barren marble. The largest mineralized lens observed by the author is 10 cm wide, can be traced along strike for about 15 metres, and contains up

to 60 percent disseminated sulphides. Abundant, fine-grained, disseminated diopside, and occasional tremolite and quartz occur within the sulphide lenses in addition to calcite. The lenses usually lie within laminated calcite marble and, less commonly, within coarse-grained massive calcitic marble. Siliceous lenses commonly occur in the marble along strike from the mineralized lenses.

Early mining development of the deposit was confined to several lenses of massive sulphides occurring in two general horizons about 25 metres and 60 metres south of the north contact, in the western part of the marble remnant. According to Uglow (1916) the ore formed a series of thickened and flattened conformable lenses that varied from circular in section to cigar-shaped, pitching to the east or west down the strike. Each particular body pinched or swelled several times along its length. Individual lenses were usually entirely separate, with sometimes a narrow stringer of disseminated sulphides connecting large lenses. The coarser-grained ore consisted essentially of sphalerite, while fine and medium-grained ore generally consisted of mixtures of sphalerite and other sulphides. Massive pyrite and pyrrhotite, devoid of sphalerite, were often abundant on the outside edges and extensions of ore zones.

"Apart from the ore horizons, diopside and quartz are not abundant. Around the edges of the ore "lenses" and

especially along a general horizon in which ore occurs, localities rich in diopside are common. It is not unusual to find an outward transition in the plane of the banding of the limestone from zinc ore to a zone of iron sulphide disseminations and then finally to a zone of mixed calcite and diopside grains." (Uglow, 1916a, p.237).

The recently mined (1973-1974) orebodies formed massive lenses lying conformably within marble to the west of the previously mined orebodies. Orebody shapes, mineralogy, and geologic associations were similar to the earlier known orebodies, as described above. Silicate minerals were again noted to be intimately associated with the mineralization and were reported to include grossularite and chondrodite (Brown, 1976) in addition to diopside and quartz. Some narrow cross-cutting veins containing colloform overgrowths of sphalerite, pyrite, marcasite, and calcite were exposed and have been interpreted to be post-metamorphic in origin (Cone, 1976; Brown, 1976). Except for these late veins, textures of the ore minerals in polished sections (Cone, 1976; Brown, 1976) are indicative of metamorphic recrystallization with no preservation of primary depositional features. This is consistent with the previously described macroscopic features of the Long Lake zinc deposit, all of which indicate the deposit has been metamorphosed along with its host rocks.

History of Development

- 1897 : Report of first work done on this property (Uglow, 1916a).
- 1901: First significant discovery of zinc mineralization made by Leslie Benn on land owned by Howard Ritchie. Benn sank a pit and removed more than 100 tons of ore (Harding, 1951).
- 1902-1913: The land was subsequently bought by James Richardson and Sons who owned the property for nearly 50 years. During this time 5 shallow shafts 18 to 47 metres deep and numerous pits and trenches were excavated. Shipments of zinc ore were made in 1902-1904, 1906, and 1907, totalling 3,442 tons valued at \$41,550 (Thomson, 1952; Shklanka, 1969).
- 1914-1915: The property was optioned by the Long Lake Zinc Company which dewatered the old workings and completed about 300 metres of diamond drilling (Shklanka, 1969).
- 1927: Some of the pits and shafts were dewatered, and examined by M.E. Wilson of the Geological Survey of Canada (Alcock, 1930).

1947-1950: In 1947 the mine was leased from the owners, James Richardson and Sons, by Rochette Gold Mines Ltd, who subsequently reorganized as Consolidated Rochette Mines Ltd in 1950. In 1949 a 35 tpd mill was installed and an unsuccessful attempt was made to process oxidized ore from surface dumps. One of the old shafts was dewatered and about 90 metres of drilling in mineralized lenses was completed. A total of 240 tons of zinc concentrate and 15 tons of lead concentrate were reported to have been produced, but apparently were not sold. In 1950 a total of 25 diamond drill holes were completed (Thomson, 1952).

1966: The property was optioned by Mid-South Explorations Ltd who carried out surface exploration (Shklanka, 1969).

1970-1974: Lynx-Canada Explorations Ltd (45%) in partnership with Canadian Reynolds Metals Ltd (55%) purchased the mining rights and leased the surface rights on the recommendation of Dr. W.D. Beaton of Montreal. Initial diamond drilling consisted of 25 holes totalling about 1830 metres and resulted in the discovery of a number of lenses of massive sulphides (Brown, 1976).

The second phase of drilling consisted of 66 holes totalling 5651 metres and outlined the mineralized zones in detail. Ore reserve estimates varied but the most optimistic indicated 84,750 tons grading 21.6 percent Zn with minor lead and silver., Subsequent drilling involved 68 holes totalling 5041 metres (Wolff, 1979). In addition a total of 114 underground diamond drill holes were completed during production from the mine, totalling about 1370 metres (Brown, 1976).

Magnetic, induced polarization, spontaneous polarization, gravity, and soil geochemical surveys were completed in conjunction with exploration of the deposit. Telluric and electromagnetic (EM16) surveys were conducted after definition of the orebodies was complete. Production commenced on March 1, 1973, at a rate of about 200 to 300 tons per day. Mining was by trackless equipment using a peripheral ramp for access to the orebodies. Maximum depth reached during mining was approximately 45 metres. Ore was crushed and beneficiated to approximately 20 percent zinc in a heavy media concentrator on site. The concentrate was then shipped to the Balmat mill of St. Joe Minerals Corporation in

New York State. The mine closed on December 31, 1974 (Brown, 1976; Wolff, 1979; Mikkelsen, 1973). Total production amounted to 94,631 short tons of ore averaging 11.6 percent zinc (Ministry of Natural Resources, Mineral Resources Branch, Mineral Statistics Section) from which were recovered approximately 22.3 million pounds of zinc (The Financial Post, 1976, p.119).

1981: The author visited the mine site and vicinity in the summer of 1981. The mine workings were flooded and all openings were fenced or sealed. The heavy media separator was still on the site and apparently in good condition. All other buildings and equipment had been removed.

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- Wolf (1979)

CADIEUX (RENPRIOR) DEPOSIT

by

D. Robertson
formerly Sulpetro Minerals Ltd.
Toronto, Ontario

Manuscript submitted May 1982.

Location

The Cadieux Deposit is located in Admaston Township, Renfrew County, approximately 100 kilometres west of Ottawa and 7 kilometres southwest of Renfrew. The deposit is easily accessible by County Road #2, south of Renfrew and a secondary township road to the southwest. (Fig. 28a). Zinc mineralization occurs on parts of lots 1 and 2, Con. III and IV (Fig. 28b). The reference point for the deposit, the site of the Renprior Mines pit on the Hisko mineralized zone, is located at UTM co-ordinates 5030020N, 366120E, in NTS quadrant 31C/7.

History and Previous Work

The first discovery of sphalerite on the property was reportedly made during the summer of 1922 by Joseph Legree, on Lot 2 Concession III, Admaston Township (Fig. 28a). Joseph Legree and William Dean acquired mineral rights to the property and opened an exploration pit later that year.

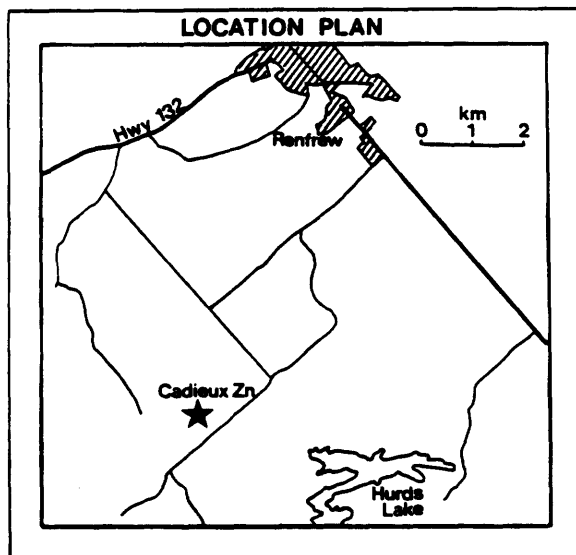


Figure 28a: Location of the Cadieux property, Renfrew County.

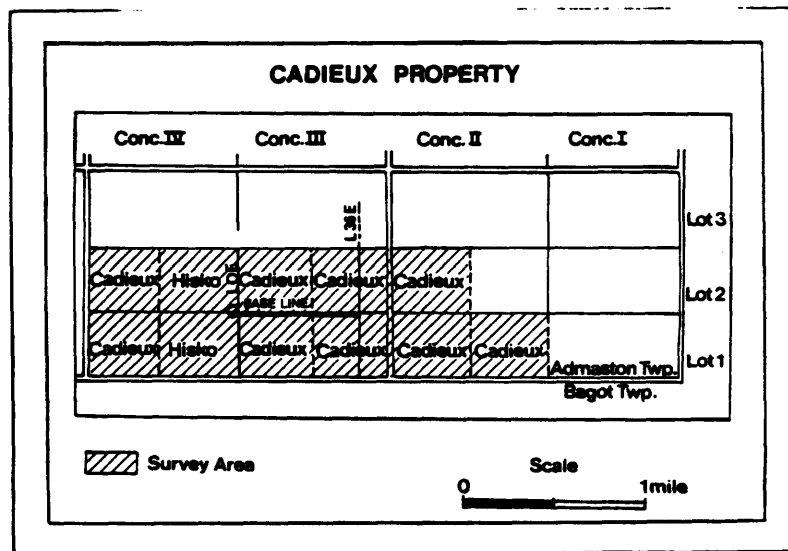


Figure 28b: Plan survey of the Cadieux property.

Early exploration continued in the area as two separate mining properties, controlled by two different companies. During the period 1922 to 1924 the showing was commonly referred to as the 'Renfrew zinc prospect'. In 1925, Conigas Mines Limited optioned the property and continued exploration with numerous surface strippings and five diamond drill holes. Early in 1926, Ottawa Valley Mines Limited optioned the property, sinking four more diamond drill holes. In 1926, the British Metal Corporation Limited attained ownership, continued surface exploration and drilled seven more diamond drill holes.

After an eighteen year lapse. In 1944, the Canadian Department of Mines and Resources carried out a flotation test and metallurgical study on two ore specimens from the showing. In 1947, New Calumet Mines Limited acquired control of Lots 1 and 2, Concession III, placing thirteen (13) more diamond drill holes. In 1948, this property was transferred to Cadieux Mines Limited, who placed seven more subsurface holes. Lomega Gold Mines Limited took a lease on the east half of Lots 1 and 2, Concession IV in 1950 (Hisko property). In September of 1950, Lomega transferred control to Renprior Mines Limited who constructed a 35-50 tpd mill on the property and operated for two months on an open cut.

During June and July of 1951, the first mining operation on the showing successfully extracted over 60 tons of concentrate, containing 55% zinc, 6% lead and minor amounts of silver and gold. In September of 1951, Renprior Zinc Mines Limited acquired the property (Hisko Property, E 1/2 Lot 1, Concession IV) and began the most extensive exploration carried out in the showing's history. This work included numerous trenches, forty-five drill holes, detailed geological mapping and electrical and magnetic surveys.

Discouraging results forced Renprior Zinc Mines to abandon the property. In 1972, the third major period of exploration in the area began when Kerr Addison Mines Limited optioned the property from Cadieux Mines Limited. Kerr Addison carried out detailed geochemical, geological and geophysical surveys searching for other hidden zinc bearing horizons in the area but limited diamond drilling (5 drill holes) and trenches failed to outline any new horizons.

During the summer of 1978, Sulpetro Minerals Limited negotiated an option to acquire the mineral rights on the Renfrew property. Before Sulpetro Minerals involvement) the total exploration on the showing consisted of over seventy (70) trenches, detailed geological mapping, two geochemical

surveys, two geophysical surveys and nearly one hundred (100) drill holes totalling nearly 6096 metres (20,000 feet).

Since acquiring the property in 1978 Sulpetro has undertaken diamond drilling (4,423 metres, 27 holes) plus detailed geology, soil geochemistry, geophysical surveys, overburden drilling and trenching.

Based on the results of work to date, four zones of significant zinc and minor lead mineralization (the Hisko Zone, Central Zone, East Zone and Swamp Zone) have been outlined. A tentative ore reserve calculation of 280,000 metric tonnes of 9% Zn to an average depth of 130 metres has been indicated in the four zones. The zinc mineralization outlined on the Cadieux Property is sub-economic at the present time. However, high grade intersections in the Swamp Zone and East Zone indicate that there is greater tonnage potential and that a better grade can be expected.

General Geology

The Cadieux zinc deposit occurs within a sequence of Grenville Supergroup marbles in an area dominated by late Precambrian supracrustal and intrusive rocks of the Grenville Province. These Supergroup marbles of Ontario, Quebec and New York State host numerous occurrences of zinc mineralization, several of which have periodically been mined since the beginning of the century.

More specifically the Cadieux zinc deposit is located within a belt of northeast-southwest trending dolomitic marbles, at least 25 kilometres long, intercalated with or overlying rocks of probable volcanic derivation. These lithologies were later intruded by biotite-diorite, syenite and granite-granite pegmatite bodies. High grade metamorphism and multi phase deformation has complicated the geology of the property.

Host Rocks

The major mappable geologic units of the Cadieux Property are subdivided into eight (8) lithologic types, each of which contain additional recognizable sub-units based on field identified mineral constituents. The generalized geology of the property is shown in Figure 29.

The marbles of the property have been subdivided into three types: 1) calcitic marble; 2) dolomitic marble; 3) silicated dolomitic marble. The marbles host all known zinc (minor lead) mineralization on the property.

The calcitic marble unit which is generally white, very soft and easily eroded serves as a stratigraphic marker unit for the property. The calcite marble is medium to coarse

grained, with generally less than 10% accessory minerals. These include phlogopite, dolomite, quartz, tremolite and with sparse diopside serpentine, tremolite and phlogopite. Minor pyrite and sphalerite are present. Variations include fine to coarse grained pink and fine to medium grained, grey (graphitic) calcite marble. Varying amounts of sphalerite have been noted within the calcite marble as well as at the contact of the calcite and silicated dolomitic marble.

The dolomitic marbles are commonly medium to coarsely crystalline, white to buff coloured and distinct in field appearance from calcite marble on the basis of weathering surface and non-reaction to dilute HCl. The dolomitic marble contains greater than 30% dolomite and 10-15% accessory minerals (phlogopite, calcite, diopside-serpentine, tremolite, quartz, apatite). Variations include pink and grey dolomitic marble. Hematitization of the dolomitic marble is locally extensive. Sphalerite, galena, pyrite, pyrrhotite and graphite occur in the dolomitic marble unit, with zinc and lead mineralization approaching significant proportions.

The most commonly mineralized unit on the property is the silicated dolomitic marbles. This unit contains greater than 20-25% calc-silicate minerals, principally diopside, tremolite and quartz. A spatially related rock type

occurring within the silicated dolomitic marble unit is a quartz-diopside rock and/or quartzite unit. Varying shades of pea green diopside characterize the silicated dolomitic marble. The diopside is usually white to green in colour, fine to very coarse grained. Yellowish-brown to green serpentine clots and patches are common. Tremolite is generally very acicular and rosettes are common. Quartz is not nearly as abundant and is generally fine grained and smokey in colour. Small clots and patches (cm scale) of mauve anhydrite occur within silicated dolomitic marble unit.

These three types of marble make up the bulk of the rocks on the property. Grey graphite-bearing calcitic and dolomitic marbles are interpreted to represent a facies change from the cleaner marbles (Fig. 29).

Cadieux Structure

Metasediments of the Cadieux property have undergone at least three phases of deformation resulting in a complex three dimensional geometry. Figure 30 is a plan view of the surface geology with the interpreted axial traces of the three phases of folding. For clarity, some structural features such as the antiform fold axes of first phase deformation (D_1) have been omitted.

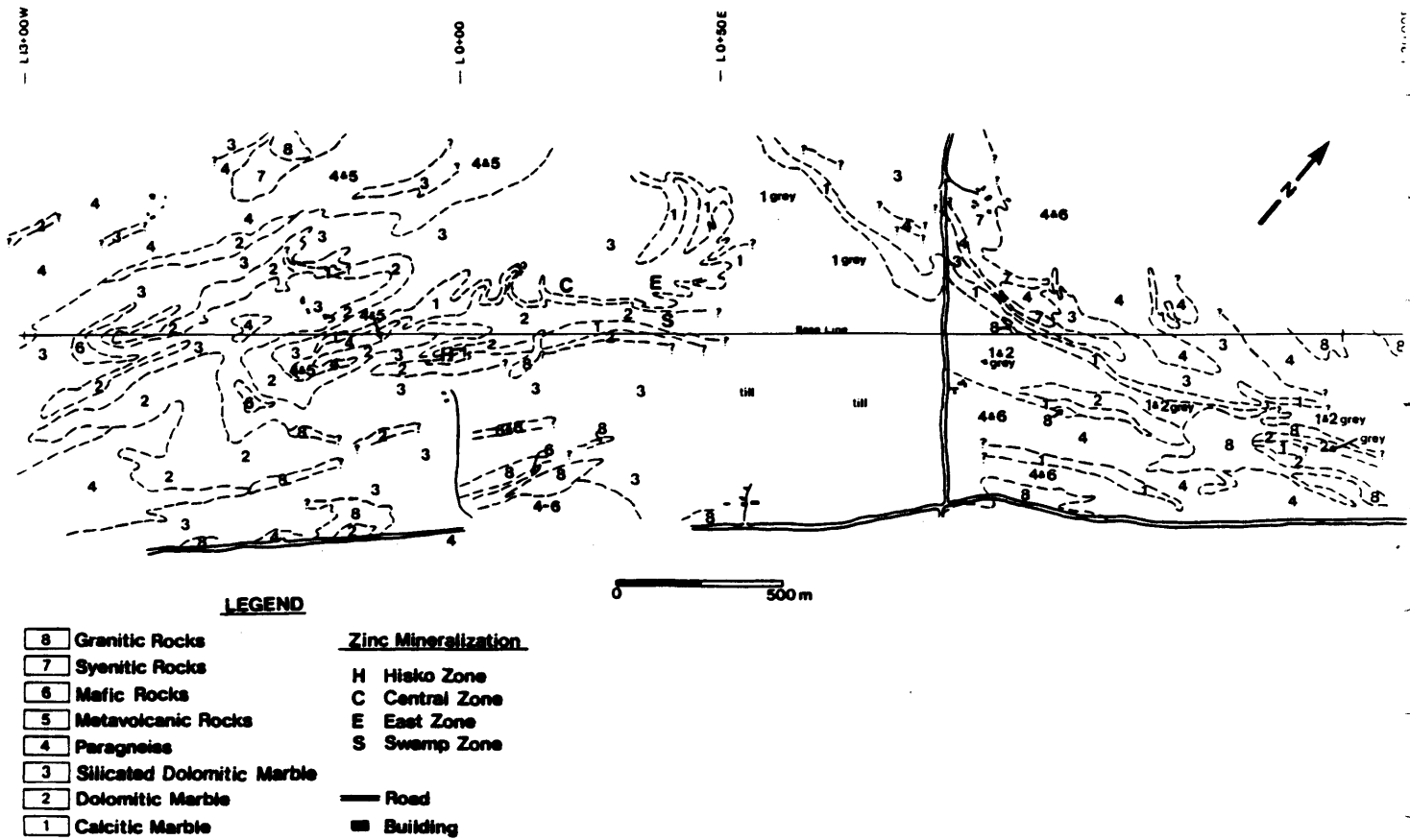


Figure 29: The Cadieux property, generalized geology and location of zones of zinc mineralization

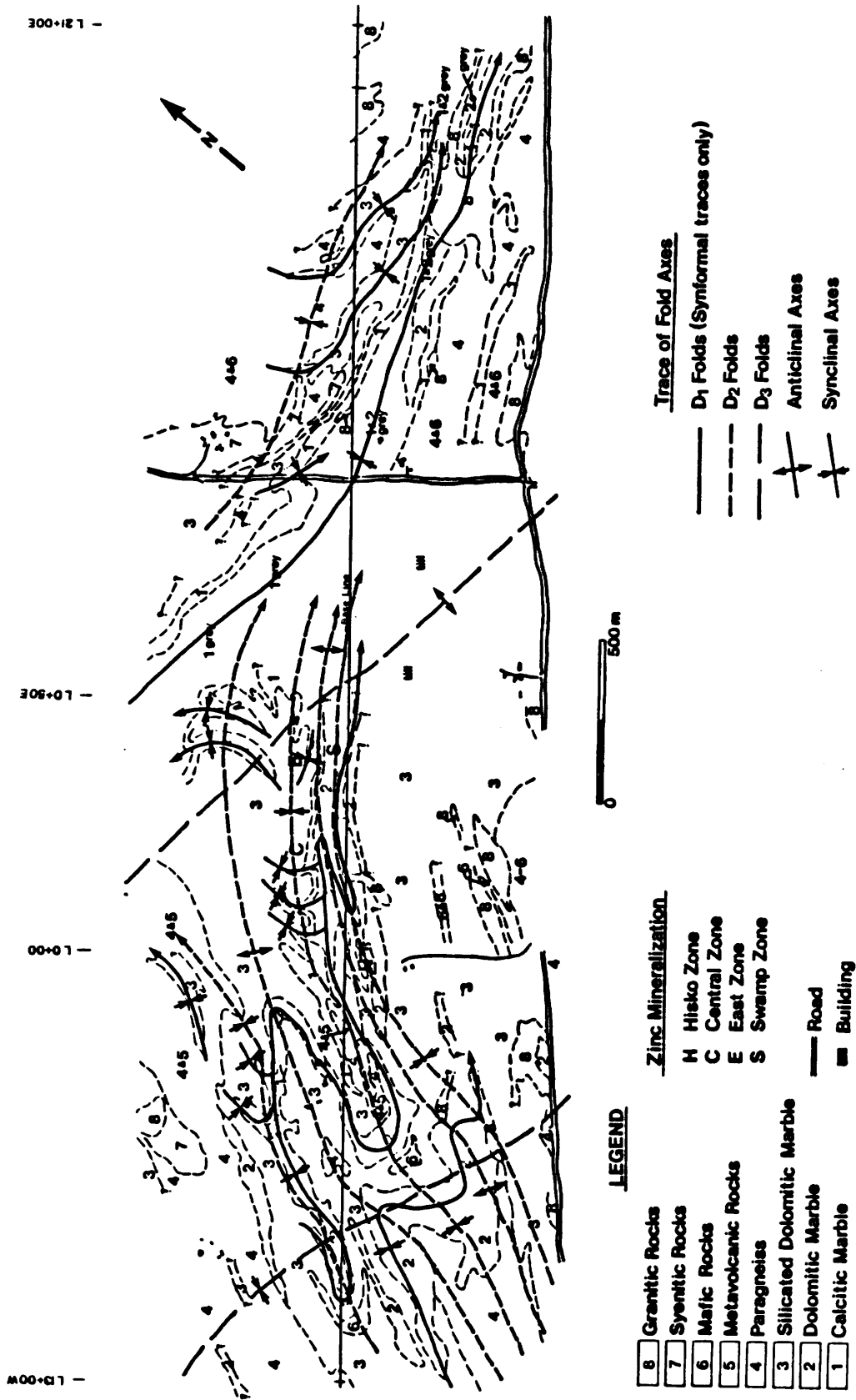


Figure 30: The Cadieux property, structural interpretation.

The first phase of deformation resulted in the development of isoclinal folds. A prominent axial planar foliation-gneissosity was developed in the marble and paragneiss units. This foliation parallels lithologic trends and is interpreted as possibly being subparallel to original compositional layering. Second phase folds (D_2) refold early isoclinal folds and their axial surfaces, and are best reflected by the distribution of calcite marble (Fig. 30). Axial surfaces of the D_2 folds trend NE and dip south 40° - 50° . The orientation of the D_2 axial surface is well exhibited by the alignment of the micaceous minerals of the paragneiss. Locally the foliation developed during second phase folds (as defined by preferred orientation of micaceous minerals) is observed crosscutting the earlier foliation (defined by compositional layering). D_2 fold axes generally trend $N60^\circ E$ and plunge 30° - 50° . This direction is reflected in the orientation of diopside boudins, tremolite needles in the marble and the alignment of rod-shaped minerals, particularly the amphiboles in the paragneiss. Subsequently the early phase isoclinal folds and second phase folds were warped by open third phase folds with northwest trending axial surfaces. This deformation causes variations in the D_2 plunge direction from almost horizontal to 45° northeast.

Economic Geology

Four zones of sphalerite (minor galena) mineralization have been outlined along a strike length of 1000 metres on the property. The zones are customarily referred to as the Hisko Zone, Central Zone, East Zone and Swamp Zone (Fig. 29 and 30). The Swamp Zone is the only zone of mineralization having no surface expression.

There is diversity in characteristics of the mineralized zones, but it is possible to make some generalizations (Fig. 31). The sulphides may be classified as stratiform; in detail the sphalerite (minor galena) mineralization is spatially related to the boundaries of dissimilar lithologies such as the contact of calcitic and silicated dolomitic and dolomitic marble. The sphalerite mineralization, containing up to 29% Zn, commonly occurs as elongated lenticular masses or narrow shoots with the large dimension in an easterly plunge direction (30° - 40°). The shoots occur in clusters, displaying a rudely en echelon arrangement generally parallelling the D_2 fold axes (Fig. 30). Thickening of sulphides may occur in tightly folded crest and trough structures, with thinning out along the limbs of folds. All known sphalerite mineralization is confined to the sequence

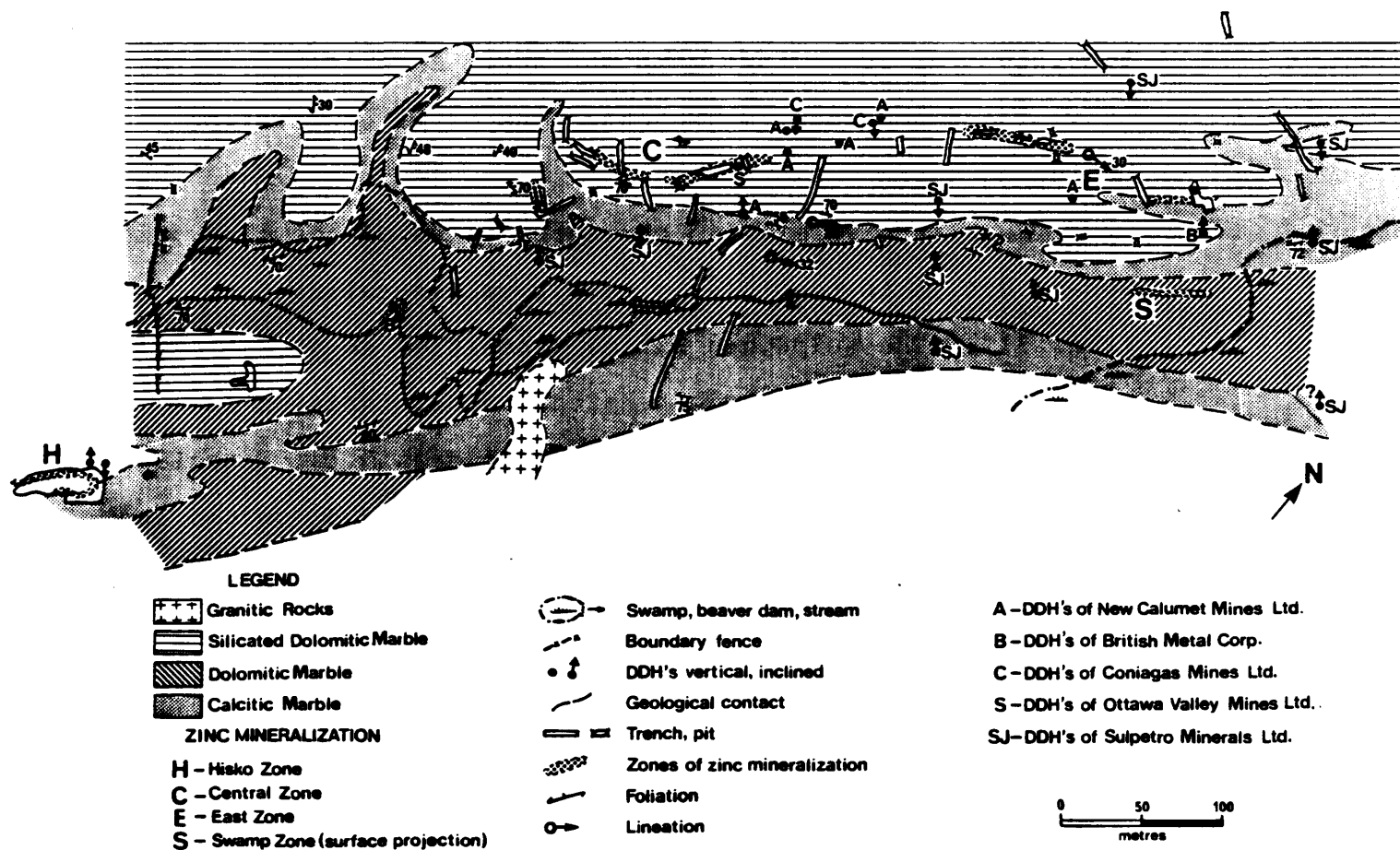


Figure 31: Plan of the surface workings on the Cadieux Zinc deposit, showing the mineralized zones in relation to general geology.

of marbles. Significant mineralization is found not only associated with the silicated dolomitic marbles, as is the case for the Hisko, Central and East Zones; but also associated with the pure dolomitic marbles as evidenced by the Swamp Zone mineralization.

Sulphide mineralogy is simple, consisting of semi-massive to disseminated or streaky, medium to coarse grained aggregates of sphalerite and minor varying quantities of galena and trace pyrite. Chalcopoyrite is locally present in trace amounts. Sphalerite is generally medium to dark brown, locally honey-coloured, in which cadmium and mercury are important trace elements in the sphalerite. Associated gangue minerals include calcite, dolomite, diopside, serpentine, tremolite and to a lesser extent quartz and phlogopite.

The Cadieux mineralization exhibits features which suggest some mobilization and recrystallization of previously existing sulphides during regional metamorphism.

Localization in structural sites such as fold noses constitute strong evidence that is consistent with mobilization and migration of sulphides during metamorphism.

CLYDE FORKS CU-SB-AG HG PROSPECT

Location and Access

The Clyde Forks base metal-barite prospect is located about 4 km west of the village of Clyde Forks, and is accessible via a series of Ministry of Natural Resources forest access roads, lumber roads, and an abandoned railroad. A short dirt bush road leads to the prospect from a gravelled clearing on the forestry access road, at a point 6.1 km (by road) from the railroad (Fig. 32). The prospect lies within lot 20, Con. VIII, Lavant Township, at UTM co-ordinates 4997975 N, 364205 E, in NTS quadrant 31 F/2.

Economic Features

Mineralization at the Clyde Forks prospect consists of erratically dispersed chalcopyrite, pyrite, tetrahedrite, and barite, with subordinate stibnite, cinnabar, arsenopyrite, chalcostibite, and getchellite. It occurs in a lens that has been traced for 91 metres along strike, 183 metres down-dip, and has an average width of 1.6 metres. Diamond drilling by West Branch Explorations Ltd and Carndesson Mines Ltd has outlined approximately 60,000 tons grading 0.67 percent Cu, 0.37 percent Sb, 0.03 percent Hg, and 1.32 oz Ag per ton (Sullivan, 1969; Northern Miner, 1970, Vol. 56, No.2).

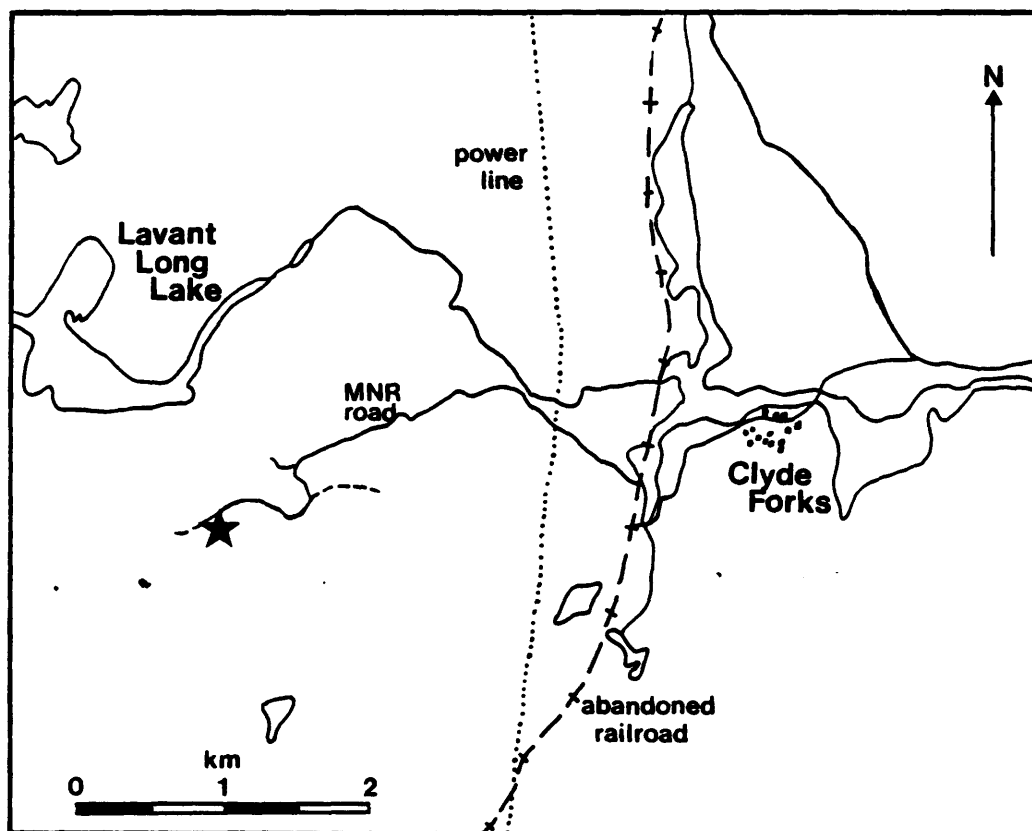


Figure 32: Location and access to the Clyde Forks base metal-barite deposit.

The mineralization is exposed by a pit and a short adit in a large bulldozed clearing, and by a series of small pits on the hill above the adit (Fig. 33). The main pit, in the clearing, is approximately 5 metres in diameter and about 3 metres deep, and exposes a layer of massive barite about 1 metre wide containing dispersed sulphides. One carload of crude barite was reportedly mined from this pit and shipped to the United States in 1919 (Spence, 1922). Two grab samples collected from the pit by the author gave the following assay results:

Cu-8-1: 1.04 percent Cu, 1100 ppm Sb, 380 ppm Hg, 20 ppm Bi, and 0.32 oz Ag per ton.

Cu-8-2: 0.82 percent Cu, 0.53 percent Sb, 830 ppm Hg, 20 ppm Bi, and 2.96 oz Ag per ton.

Soil and stream geochemical surveys completed by different companies have outlined several copper, mercury, and zinc anomalies near the known mineralized zone. Most of these have never been examined. In addition, available records indicate that the main mineralized lens is open both along strike and down-dip.

Geology

Regionally the major rock types of the area include marble, amphibolite, quartz-biotite paragneiss, siliceous

marble, and pegmatite. The stratified rocks have been folded into asymmetrical cylindrical folds trending N 55°E and plunging northeast at 20°. Their axial surfaces dip 40 degrees southeast. The folding is weak and is superimposed on a succession of beds which dip homoclinally to the northeast over much of the area. Faults in the area generally trend northeast, parallel to the regional strike (Nikols, 1972).

In the vicinity of the Clyde Forks prospect (Fig. 33) the main rock type is calcitic marble, with intercalated biotitic dolomite, biotite-quartz-feldspar paragneiss, amphibolite, and cross-cutting dikes and irregular masses of tourmaline-bearing white pegmatite. The stratified rocks have been folded about northeast trending axes.

The calcitic marble is white to pink, medium-grained, and well layered. It weathers to a dull brownish-white colour and is very friable. It is composed principally of calcite and contains abundant disseminated biotite and coarse silvery muscovite. The biotite-quartz feldspar paragneiss is fine-grained, well foliated, and is composed of quartz, feldspar, and biotite. The amphibolite is similar except for the presence of abundant hornblende and lack of quartz. Both rock types, together with the biotitic dolomite, form narrow interlayers within the calcitic marble. The pegmatite is white, massive,

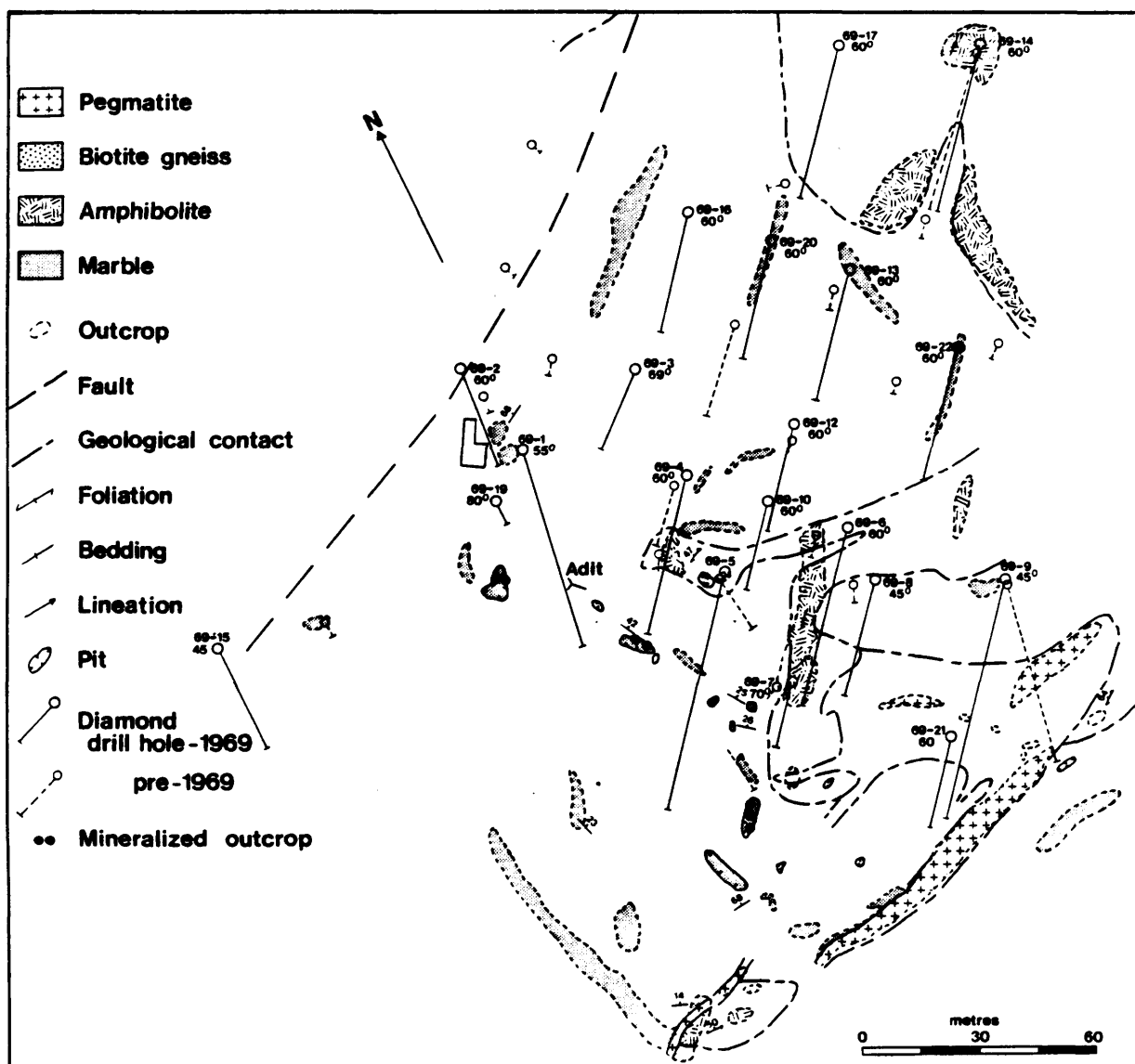


Figure 33: Geology near the Clyde Forks base metal-barite prospect, adapted from Nikols 1972.

coarse-grained, and is composed of feldspar (50 - 60 percent), quartz (40 percent), and tourmaline.

Mineralization: Mineralization consists of mercurian tetrahedrite, chalcopyrite, stibnite, arsenopyrite, chalcostibite, getchellite, cinnabar, and pyrite, in association with barite (Nikols, 1972). The author found barite, tetrahedrite, chalcopyrite, and pyrite, in order of abundance, to be most common. The mineralization is confined to an apparently conformable layer, within the calcitic marble, which has been traced by diamond drilling for about 90 metres along strike, 180 metres down-dip, and has an average thickness of 1.6 metres. According to Sullivan (1969) this mineralized zone occurs within a fold or drag fold which plunges to the northeast at approximately 35 to 40 degrees. The structure is believed to be open for further exploration.

Mineralization is very erratically distributed within the zone. In the pit opposite the adit, a layer of massive barite at least 1 metre thick, containing disseminated tetrahedrite, is exposed. Within the adit, 20 metres to the east, the sulphides occur in nodular segregations and disseminations along bedding plane shears in calcitic marble, often accompanied by small irregular masses of barite.

Tests conducted by the Geological Survey of Canada on samples of pure tetrahedrite from the prospect gave assays of 37 percent Cu, 21 percent Sb, 4 percent Hg, and 89 oz Ag per ton (Northern Miner, vol.55, no. 40, Dec. 25, 1969), indicating most of the mercury occurs in the tetrahedrite. This was confirmed by Nikols (1972) who observed microscopic fractures filled with cinnabar in the tetrahedrite.

Polished thin sections of mineralized barite-rich marble examined by the author are composed essentially of massive mosaics of medium-grained (0.8 - 25 mm) calcite, barite, and disseminated interstitial sulphides. Accessory minerals include quartz, biotite, tremolite - actinolite, and diopside. Chalcopyrite and tetrahedrite are the most common sulphides and occur as dispersed, irregular grains that are frequently intergrown with each other. Tetrahedrite also occurs as small grains within carbonate, and chalcopyrite sometimes forms fine blebs within gangue minerals, especially diopside. Pyrite forms scattered anhedral to subhedral grains which are sometimes associated with tetrahedrite and chalcopyrite. They occasionally contain inclusions of tetrahedrite and gangue minerals. Arsenopyrite is present as small round blebs within a single grain of chalcopyrite. The textures, and occurrences of sulphide inclusions in gangue minerals, are indicative of recrystallization as a result of metamorphism.

History of Development

1918-1919: T.B. Caldwell stripped and pitted a barite lens exposed in outcrop. Spence reports that one carload of crude barite was shipped to the United States (Spence, 1922).

1957-1960: Lanark Silver Mines Ltd. completed geochemical soil sampling, magnetometer, and self potential surveys, drilled 6 diamond drill holes totalling 335 metres. Several self-potential anomalies with coincident copper-silver and/or zinc soil anomalies were outlined (Lanark Silver Mines prospectus, 1957; Bergman, 1960; Assessment Files, Diamond drill report no. 11, Lavant Twp.).

1964-1968: Reconnaissance soil and stream geochemical surveys and 30 diamond drill holes totalling approximately 1220 metres were completed by West Branch Exploration and Mining Co. Ltd. In 1967 an adit was driven into the mineralized zone for a distance of about 30 metres, with two short cross-cuts. The geochemical surveys outlined a fairly widespread mercury-rich formation with scattered occurrences of copper (Sullivan, 1969).

1969-1970: Soil geochemical surveys, geological mapping, and at least 24 diamond drill holes totalling 1631 metres completed by Carndesson Mines Ltd (Northern Miner, Dec. 25, 1969; Feb. 5, 1970; April 2, 1970; Assessment Files Research Office, diamond drill report no. 12, Lavant Twp.).

References

Bergman (1960)
Nikols (1972)
Shklanka (1969, p.195)
Spence (1922, p.53-54)
Sullivan (1969)

BELMONT TOWNSHIP IRONSTONE OCCURRENCES

Four bands of siliceous ironstone are reported to occur in Belmont Township; the Belmont Lake, Deer River, Tomahawk, and Round Lake occurrences. None of the occurrences was visited by the author. Descriptions are taken largely from Sangster (1970), Gross (1967), and Miller and Knight (1914).

Belmont Lake: The Belmont Lake iron occurrence is the largest and best exposed. It is located approximately 500 metres west of Deer Bay of Belmont Lake, just east of a gravel road, in lot 20, Con.IV, at UTM co-ordinates 275330 E, 4934000 N, in NTS quadrant 31C/12 (Fig. 34).

Mineralization consists of a sharply defined bed of thin-bedded cherty grey quartz with narrow interlayers of disseminated magnetite, specular hematite, and jasper. Dark green amphibole occurs in some layers and garnet, mica, and amphibole-rich bands occur near the borders of the ironstone unit. In thin sections studied by Sangster (1970) and Gross (1967) the quartz forms an equigranular (0.25 mm) mosaic with scattered fine (0.1 - 1 mm) grains of magnetite and specular hematite. Gross reports the iron oxides sometimes form oval-shaped rings or dusty patches, similar to metamorphosed oolites.

The ironstone unit is approximately 15 to 18 metres wide and has been traced along strike for about 400

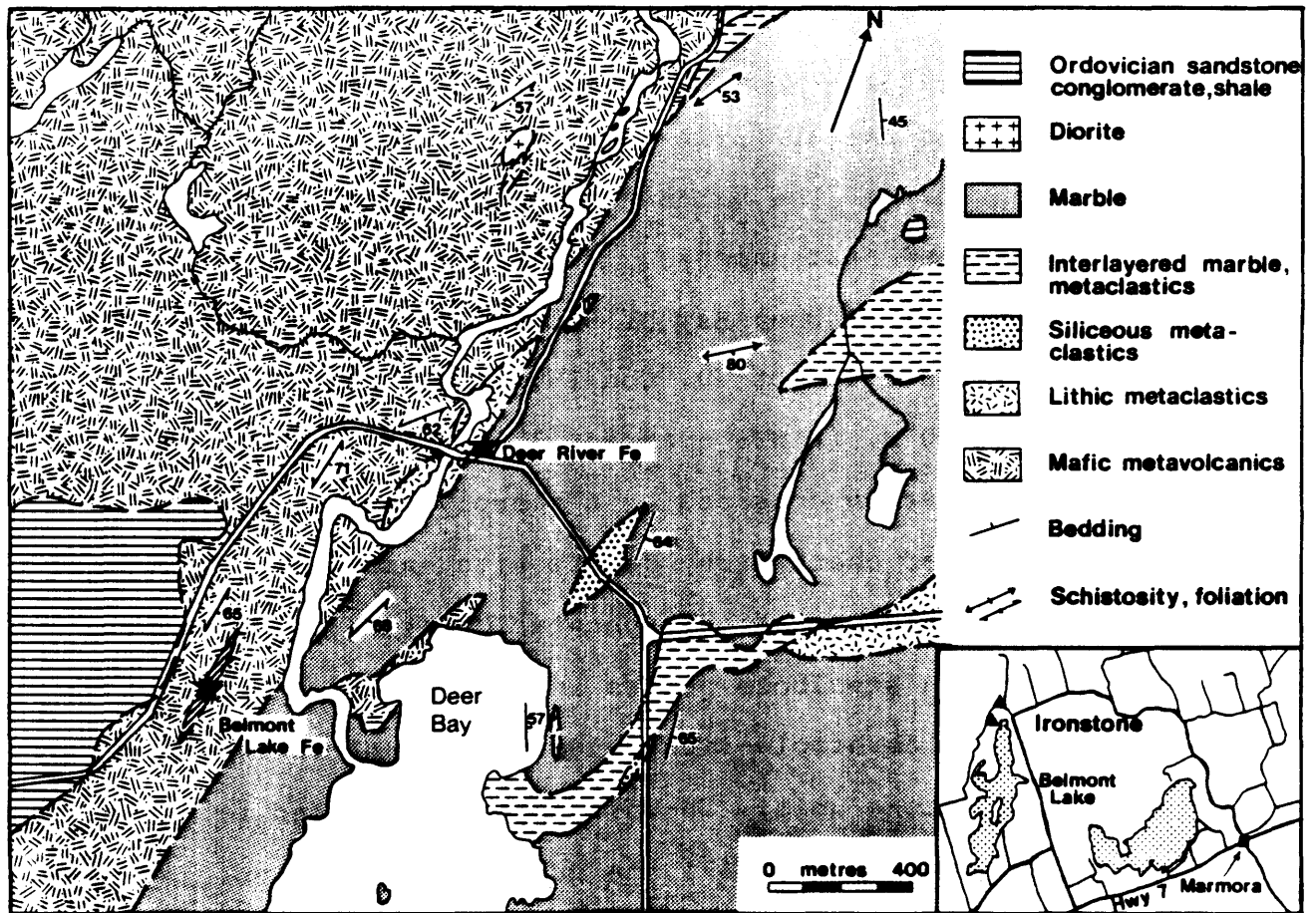


Figure 34: Geology in the vicinity of the Belmont Township ironstone occurrences, adapted from Bartlett et al. (1982).

metres. It strikes north to northeast and dips steeply to the southeast. It lies conformably within massive to foliated, dark green, mafic metavolcanic rocks near their contact with an overlying unit of calcareous metasedimentary rocks. An analysis of the richer part of the ironstone by Miller and Knight (1914) indicated 24.06 percent iron, 0.024 percent sulfur, and 0.126 percent phosphorus.

Deer River: The Deer River occurrence is located about 1 km north of the Belmont Lake occurrence, 30 metres east of the bridge over the Deer River at the north end of Belmont Lake (Fig. 34). It lies on lot 21, Con. III, at UTM co-ordinates 4935000 N, 275930 E.

Mineralization consists of scattered, microscopic grains of magnetite and hematite contained in narrow layers of dark red, cherty, granular quartz interlayered with calcitic marble. The cherty layers range in thickness from about 2 cm to 60 cm, and sometimes have fine, alternating, light and dark laminations. The ironstone unit is approximately 6 metres wide and 60 metres long and lies within calcitic marble immediately overlying a thick sequence of mafic metavolcanic rocks. Two samples of ironstone analysed by Miller and Knight (1914) contained 11.8 and 15 percent iron respectively.

Round Lake: The Round Lake iron occurrence is described by Miller and Knight (1914) as a small remnant about 76 metres wide, traceable for only 46 metres along strike, contained within mafic metavolcanic rocks. It is reported to occur on lot 25, Con. VI, about 6 kilometres north of Round Lake.

Tomahawk: The fourth occurrence lies within lot 15, Con. V and is described by Satterly (1943) as a "north-south band of lean iron formation with an exposed width of 20 feet". It is hosted by mafic metavolcanic rocks and consists of "blue-grey sugary quartzite with films of specular hematite parallel to the bedding." The ironstone is exposed in several small outcrops, two small trenches, and a small pit. Tomahawk Iron Mines Ltd owned the mineral rights in 1943.

References

- Bartlett et al. (1982)
Gross (1967, p.84-85)
Miller et al. (1914, p.25-26)
Sangster (1970, p.62-67)
Satterly (1946a, p.48-49)
Shklanka (1968, p.286, 288-290)

CHROMASCO MAGNESIUM MINE

Location and Access

The magnesium mine operated by Chromasco Limited is located about 4 km northeast of the village of Haley Station, about 32 km southeast of the town of Pembroke. It is accessible via a series of paved roads from Haley Station (Fig. 35). The mine lies within lot 20, Con. 5, Ross Township, approximately at UTM co-ordinates 5050700N, 363250E, in NTS quadrant 31F/10.

Economic Features

The Chromasco magnesium mine and associated mill and reduction plant commenced full scale production in February 1943, having a rated capacity of 5000 tons of magnesium metal per year. Various additions to the plant since that time have increased capacity to approximately 12,000 tons of magnesium metal per year. According to the statistical files of the Ministry of Natural Resources (Mineral Statistics Section, Toronto), production to the end of 1980 totalled 475,056,312 pounds of magnesium metal. In addition 21,575,794 pounds of calcium metal had been produced, and an unspecified amount of strontium metal, both from imported materials.

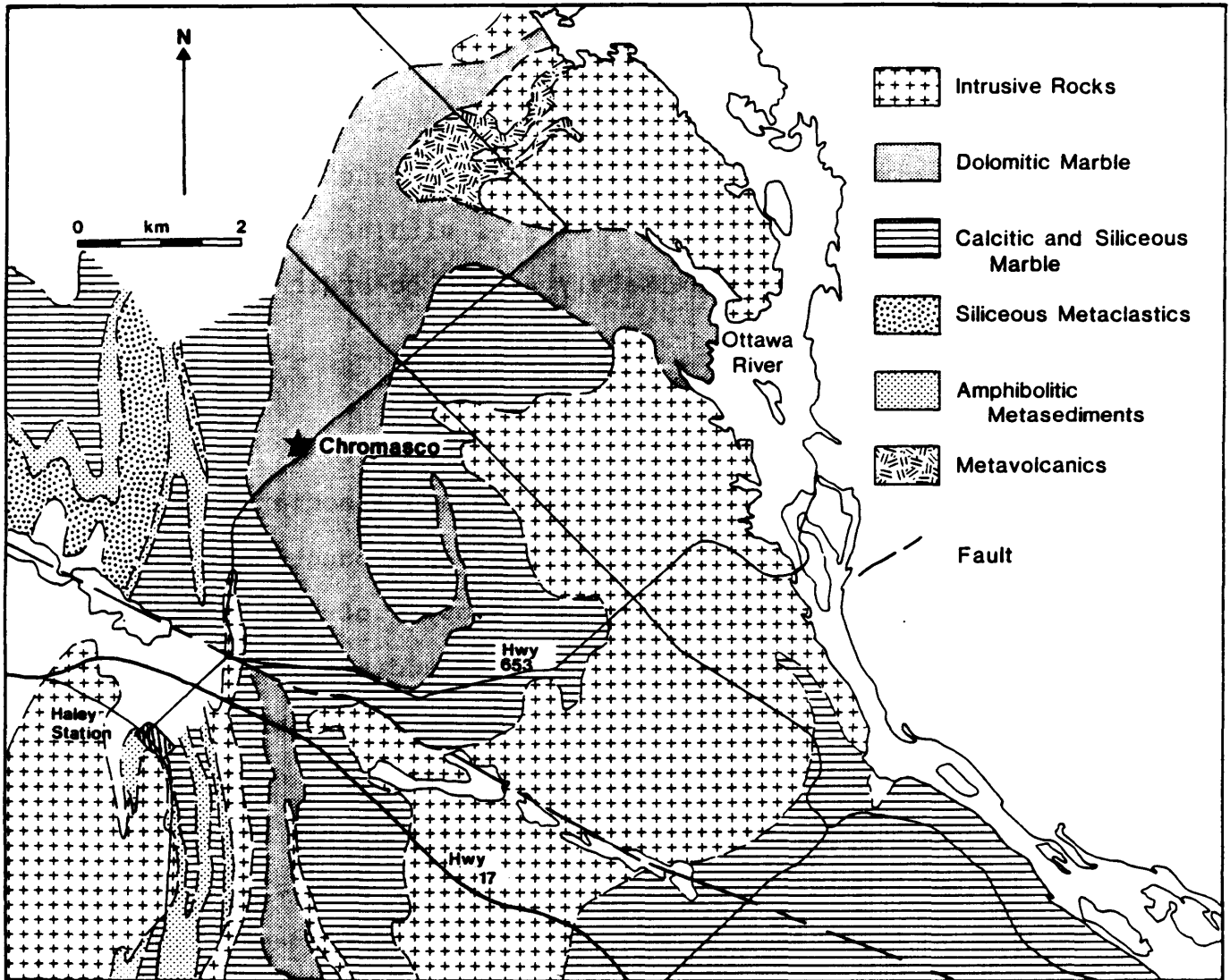


Figure 35: Geology near the Chromasco magnesium mine.

Chromasco Limited produces magnesium metal at the Haley reduction plant utilizing the 'Pidgeon process'; reduction of dolomite lime by ferrosilicon (Pidgeon, 1944). The dolomite lime is produced from Grenvillian dolomitic marble which is crushed and burned in a rotary kiln to remove the CO₂. The marble is mined from a large deposit which, as originally defined, had an indicated length of 1070 metres and a width of 76 metres (Satterly, 1945). The marble is of very uniform composition; the range in composition of thirteen samples analysed by Pidgeon is: 20.48 to 21.55 percent MgO, 30.85 to 31.95 percent CaO, 0.25 to 0.65 percent insoluble, 0.25 to 0.60 percent R₂O₃, and 46.8 to 47.1 percent loss on ignition.

The marble is mined from two large open pits located adjacent to the reduction plant. At present most production is obtained from the pit closest to the plant which is about 45 metres deep and measures 260 x 120 metres. The other pit is presently about 21 metres deep and measures 360 x 150 metres. Approximately 150,000 tons of dolomitic marble are mined from these pits in an average year (personal communication, 1982, Paul McCann, Manager of Operations, Chromasco Limited).

Geology

The Chromasco magnesium deposit is of a band of very pure dolomitic marble that occurs within a completely deformed sequence of interlayered dolomitic and calcitic marble, siliceous marble, quartzo-feldspathic and amphibolitic metasediments, and metavolcanics. These supracrustal rocks have been invaded by a variety of intrusive rocks, including gabbro and granite, which form large plutons to the east and southwest of the marble deposit (Figure 35). The marble band strikes in a northerly direction and dips at about 50 degrees to the east. It is medium to coarse-grained (2-5 mm), well layered, and varies from white to pink to grey in colour. Minor amounts of impurities including white mica, calc-silicate minerals, and graphite, generally occur as sparse, scattered, fine grains. Lenses of calc-silicate rock occur locally within the marble deposit, necessitating selective mining in some places. Calcite veins and potassic alteration along fractures also constitute local quality control problems.

History of Development

1937: L.M. Pidgeon of the National Research Council of Canada was assigned the problem of developing a method of recovering magnesium metal from Canadian sources of raw material.

- 1941: By January of 1941 magnesium metal had been successfully produced in the laboratory. In March, Dominion Magnesium Limited was formed using funds supplied by Bobjo Mines Limited, Moneta Porcupine Mines, Limited, and Ventures Limited, to develop the process further. Magnesium metal was successfully produced in a pilot plant by October.
- 1942: Construction of the main plant, financed by the Canadian government, commenced in February, 1942. The first magnesium ingot was poured in August.
- 1943: Full scale production was attained in February at a rated capacity of 5000 tons of magnesium metal per year. Production in 1943 amounted to 7,153,974 pounds of magnesium (Satterly, 1945, p.66).
- 1945: The plant was purchased from the Canadian government by Dominion Magnesium Limited.
- 1961, 1965: New furnaces were installed in each of these years, and in combination with previous technical improvements increased the production capacity to approximately 12,000 tons of magnesium per year.
- 1970: In July, 1970, Timmins Investments Limited acquired controlling interest in the company (The Financial Post Corporation Service).

- 1971: Dominion Magnesium Limited changed its name to Chromasco Corporation Limited on August 16.
- 1974: Chromasco Limited was formed through the amalgamation of Chromasco Corporation Limited, Chromium Mining and Smelting Corporation Limited, and Light Alloys Corporation Limited (The Financial Post Corporation Service).

References

Lumbers and Vertolli (1980)
Pidgeon (1944, p.16-34)
Satterly (1956, p.65-66)

MACASSA COPPER-NICKEL PROSPECT

Location and Access

The Macassa copper-nickel prospect is located approximately at UTM co-ordinates 285150E, 4972100N, in NTS quadrant 31C/13, straddling the mutual boundaries of lots 28 and 29, Con. VI and VII, Limerick Township, about 2.3 km southeast of the village of Ormsby. An overgrown bush road provides vehicle access to the prospect from Highway 62, passing through a stripped area on the mineralized zone about 1.3 km west of the highway. The Coe Hill branch line of the Canadian National Railway passes through the northern end of the property.

Economic Features

Mineralization at the Macassa copper-nickel prospect consists of erratically disseminated pyrrhotite, pentlandite, chalcopyrite, and pyrite contained within a band of metapyroxenite in a mafic intrusion. The mineralized zone forms a reverse L shape (Fig. 36), with an aggregate length of about 320 metres, and varies in width from less than 4 metres to 34 metres, averaging approximately 17 metres. The mineralized zone narrows down and pinches out to the north, while electromagnetic surveys indicate the southwest end may continue further south (Long

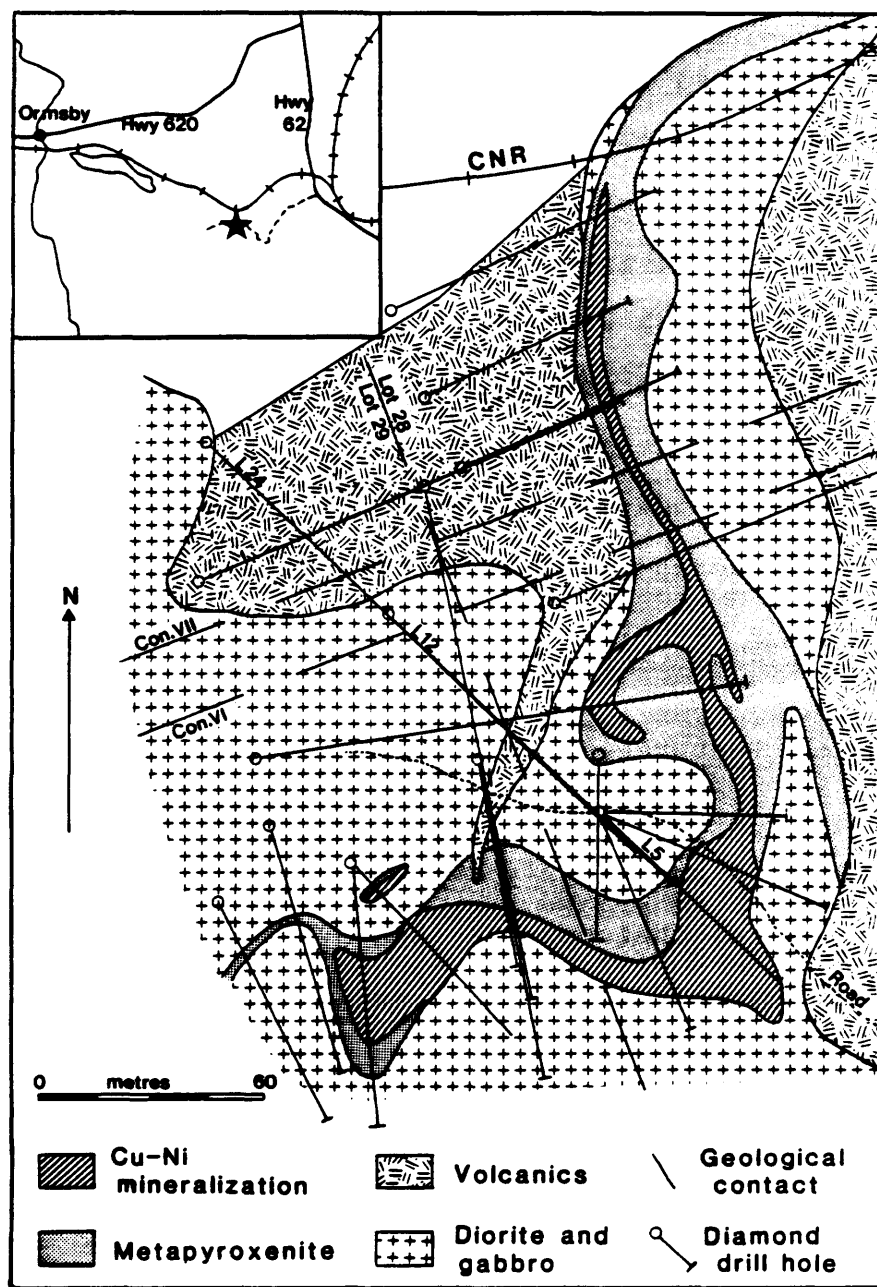


Figure 36: Geology of the Macassa copper-nickel prospect, Limerick Township. Adapted from Lumbers (1969).

Lac Mineral Exploration Ltd, unpublished files). Diamond drilling indicates that the mineralized zone continues to a depth of at least 365 metres, and is open below this depth.

Differing reserve estimates have been made of the mineralized zone. According to P.D. Timms, of Long Lac Mineral Exploration Ltd. (Northern Miner, May 27, 1971, and Oct. 14, 1971) the deposit contains an estimated 1.8 million tons grading 0.91% Ni, 0.26% Cu, and 0.06% Co to a depth of 365 metres. Previous, and currently accepted estimates (Northern Miner, May 14, 1970; Financial Post Current Information Card, March 7, 1981) indicate the presence of 3,894,000 tons grading 0.825% Ni, 0.253% Cu, and 0.054% Co to the 335 metre horizon. Only trace amounts of gold and silver are reported. About 1200 metres to the south a further 1.2 million tons of mineralization grading about 0.3% Ni have been indicated by diamond drilling of a second mineralized zone termed the H+I Zone (Long Lac Mineral Exploration Ltd, unpublished files). A representative chip sample collected by the author in a bulldozed area on the main mineralized zone assayed, 2240 ppm Cu, 1.54 percent Ni, and less than 5 ppb each of platinum and palladium.

Geology

The following description is taken largely from Lumbers (1969).

The Macassa copper-nickel deposit occurs within the northeast corner of the Thanet Complex, a composite intrusion. Three intrusive units have been recognized by Lumbers (1969), including 1. gabbro and minor diorite; 2. diorite and minor gabbro; and 3. tonalite and quartz-bearing diorite. Pyroxenite dikes are associated with all three intrusive units, but are usually closely associated with gabbro and diorite. Pyroxene in the gabbro, diorite, and quartz diorite is usually uralitized and plagioclase is often completely saussuritized. The pyroxenite is commonly altered to a complex mixture of serpentine, chlorite, talc, amphibole, carbonate, and iron-titanium oxide minerals.

Mineralization at the Macassa deposit is confined to a band of metapyroxenite within an apophysis of gabbro, diorite, and metapyroxenite that extends northwards into mafic volcanics and rusty-weathering siliceous metasediments (Fig. 36). Contacts of the intrusive rocks dip at 60 to 85 degrees west to northwest, parallel to the dip of the country rocks. A few dikes and sill-like bodies of tonalite, diorite, and metapyroxenite occur within the country rocks. A second, partly mineralized metapyroxenite unit (not shown) within the Thanet complex was intersected by four of the diamond drill holes, but its extent is not known.

The metapyroxenite is generally in sharp contact with its wall rocks, but locally it grades into gabbro and diorite. Within the metapyroxenite, the mineralized zone is distinguished by a sulphide content greater than ten percent and by a dark grey gangue composed largely of talc and minor actinolite. The mineralized zone and the metapyroxenite are either in sharp contact or the mineralized zone grades into sparsely mineralized actinolite-talc schist and metapyroxenite over a few centimetres to a metre. The contact of the mineralized zone with other rock types is sharp or is marked by a narrow silicified zone generally less than 30 cm wide. The metapyroxenite unit and the mineralized zone vary in width both along strike and down the dip and branching is common, especially down the dip (Fig.37).

The mineralized zone contains 10 to 80 percent fine to medium-grained sulphide minerals, including, in order of abundance, pyrrhotite, pentlandite, pyrite, chalcopyrite, and trace amounts of cubanite and sphalerite. Pentlandite usually occurs as fine flames and lamellae in pyrrhotite, but some fine-grained pentlandite is interstitial to the pyrrhotite. Pyrite usually forms less than 10 percent of the sulphides and occurs as separate grains intergrown with pyrrhotite, as inclusions in pyrrhotite and pentlandite, and as narrow rims on pyrrhotite grains. Chalcopyrite generally

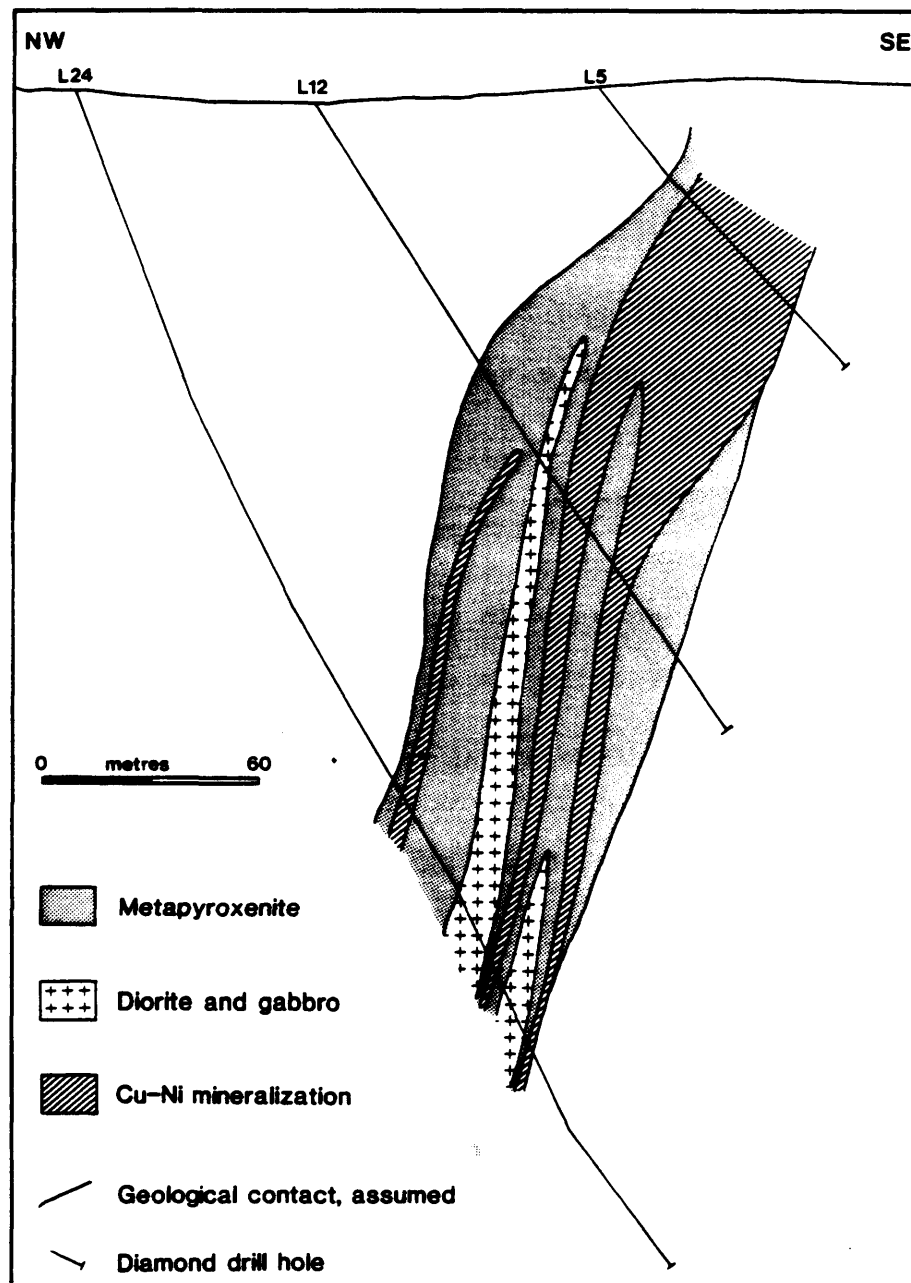


Figure 37: Vertical cross-section through the main mineralized zone of the Macassa copper-nickel prospect.

forms less than five percent of the sulphides and commonly replaces pyrrhotite and pentlandite and forms inclusions in pyrite. Chalcopyrite veinlets occur locally in the mineralized zone. Veinlets composed of various mixtures of pyrite, chalcopyrite, and pyrrhotite occur in carbonatized and silicified metapyroxenite, and in gabbro and diorite near the mineralized zone.

History of Development

- 1961-1962: Copper-nickel mineralization was discovered on the property during the summer of 1961 by Macassa Gold Mines Ltd. as a result of an electromagnetic survey of an aeromagnetic high. An access road was constructed in late 1961 and by mid 1962, 23 diamond drill holes had been completed totalling 4,157 metres (Lumbers, 1969).
- 1970: On Dec. 31, 1970, Macassa Gold Mines Ltd was acquired by Willroy Mines Ltd.
- 1973: A bulldozer was used by Willroy Mines Ltd to expose portions of the mineralized zone at the surface (Long Lac Mineral Exploration Ltd, company Files).

1961-1973: In addition to the work cited above the following work was completed; the specific dates are uncertain. Geological, IP, magnetometer, and Ronka surveys, and a detailed feasibility study including metallurgical testing and engineering studies were completed. During this time a total of 65 diamond drill holes totalling 14,722 metres were completed. This figure includes the previously mentioned drilling. (Long Lac Mineral Exploration Ltd, Company Files).

1973: The property was optioned by Willroy Mines Ltd to another company on a royalty deal. The option was dropped and ownership reverted to Willroy Mines Ltd.

1981: Willroy Mines Ltd owns 4000 acres of land in Limerick Township, including the copper-nickel deposit.

References

Lumbers (1969, p.72-75)

NEWBORO IRON-TITANIUM PROSPECTLocation and Access

The Newboro iron prospect is located about 2 km southwest of the village of Newboro in North and South Crosby Townships. There are two orebodies on the property, formerly referred to as the Matthews and Chaffey iron mines, minor past producers of iron ore. The open pit of the former Matthews mine is located on the main orebody approximately 300 metres north of the shore of Newboro Lake, and is accessible via a farm road leading south from Highway 42. The pit lies within lot 1, Con. VI, N. Crosby Twp in NTS quadrant 31C/9 at UTM co-ordinates 4943300N, 393800E. The former Chaffey mine is located on Chaffey Island in Newboro Lake approximately 800 metres southeast of the Matthews pit. It lies within lot 27, Con. VI, S. Crosby Township in NTS quadrant 31C/9 at UTM co-ordinates 4942750N, 394150E (Fig. 38).

Economic Features

Iron ore was mined from the Matthews and Chaffley orebodies between 1858 and 1871 and shipped down the Rideau Canal to Kingston and markets in the United States. Production amounted to approximately 17,000 tons of iron ore from the Chaffey mine, and 3300 tons from the Matthews mine.

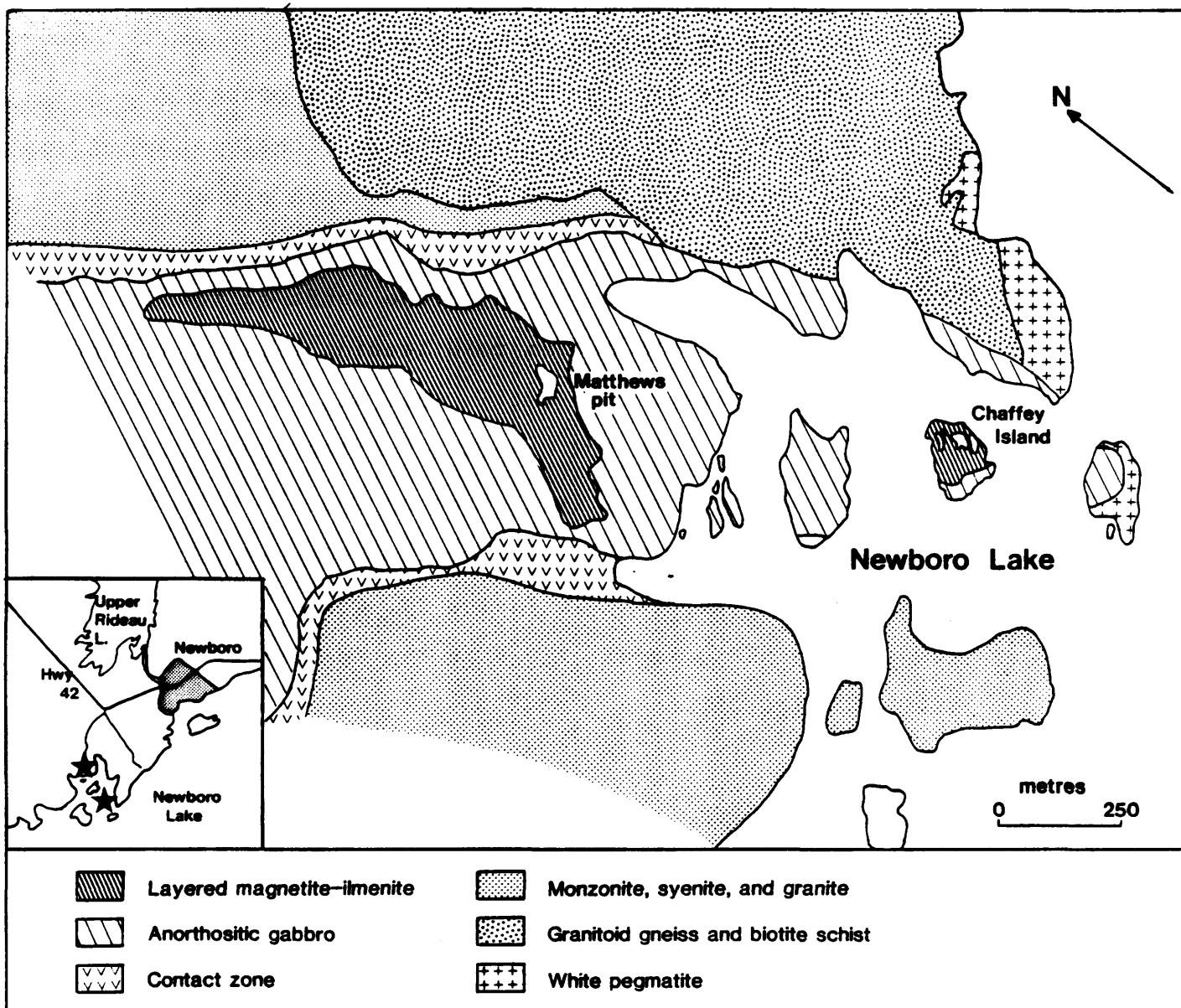


Figure 38: Geology in the vicinity of the Newboro iron prospect, adapted from a map by New Mylamaque Explorations Ltd.

The Chaffey mine workings consist of three elongate pits on a small island in Newboro Lake and the Matthews mine workings consist of a single small open pit about 100 metres long, 30 metres wide, and reported to be about 15 metres deep.

The Matthews mineralized zone is approximately 1100 metres long, averaging about 100 metres in width, with a central high grade zone about 580 metres long and 60 to 90 metres wide. To the west of this zone, lower grade mineralization averaging about 20 percent iron continues for 90 metres or more, while to the east the mineralized zone grades rapidly into unmineralized gabbro. The Chaffey orebody is a triangular zone with sides measuring approximately 230x230x200 metres. New Mylamaque Explorations Ltd. (now Dynamar Energy Ltd.) initiated a major exploration program on the Newboro iron deposit in 1957 which involved completion of over 7000 metres of diamond drilling, geological and magnetometer surveys, and a detailed feasibility study. An open pit with a length of 670 metres, 190 metres wide and 120 metres deep at the north end, and 265 metres wide and 150 metres deep at the south end was designed for mining the Matthews orebody. Within the pit outlines are contained 33,727,000 gross tons of proven ore averaging 25.08 percent iron, with a central high grade core amounting to 11,861,000 gross tons averaging

31.36 percent iron. Overburden thickness averages 3 metres and no waste rock needs to be removed. The Chaffey orebody contains probable reserves of 11,110,000 gross tons averaging 29.76 percent iron to a depth of 150 metres. In total 44,837,000 gross tons of proven and probable ore are available for open pit mining, averaging 26.24 percent iron, and containing approximately 1 percent S, 0.05-0.20 percent phosphorus, and 6.60 percent TiO_2 (Samuel 1959).

Geology

The Newboro iron deposit is hosted by an intrusion of anorthositic gabbro which is bounded by monzonite to the north and west, by layered siliceous metasedimentary gneisses to the east, and a narrow zone of marble and white pegmatite to the south (Fig. 38). The intrusion is elongate in a northwesterly direction, nearly perpendicular to the strike of the metasedimentary rocks. Diabasic dikes similar to the gabbro in texture and composition are common within the country rocks along the east and west margins of the intrusion.

The metasedimentary gneisses include at least two distinct layers of quartzite, hypersthene-microcline gneiss locally containing garnet and cordierite, biotite-granite gneiss, and pyroxene-plagioclase paragneiss. They trend northeasterly, interrupted by the Newboro gabbro. Marble

occurs on the shore of Newboro Lake and forms a white, coarse-grained rock that dips vertically and strikes northeast. Pegmatite consisting of white microcline with associated plagioclase, quartz, and pyroxene also occurs along the shoreline. Monzonite is intrusive into all the metasedimentary rocks and forms a pink, massive, equigranular rock composed of microcline, plagioclase (An₈), and minor pyroxene and magnetite.

The gabbro is a coarse-grained rock with a sub-ophitic texture. It is massive along the margins of the intrusion but elsewhere there is a slight foliation defined by alignment of plagioclase laths, and faint dark and light layers 12 to 25 cm wide oriented parallel to the foliation. Near the ore zone the layering is more pronounced and layers are narrower, ranging to as little as 3 cms in thickness in high grade ore. On the east side of the orebody an arcuate zone of layered calcite-sphene-hornblende rock oriented parallel to layering was located during diamond drilling. Patches of pegmatitic gabbro occur randomly throughout the intrusion.

In normal, massive gabbro plagioclase (An₃₅₋₄₀) occurs as laths with pyroxene, ilmenomagnetite (magnetite containing ilmenite laths), ilmenite, and minor biotite and potash feldspar occurring in the interstices. Apatite crystals may occur enclosed within pyroxene, ilmenomagnetite, or

plagioclase, and spinel occurs as rounded grains in ilmenomagnetite. In layered gabbro the relative proportions of felsic and mafic minerals vary markedly, forming dark or light layers. In the dark layers plagioclase occurs as bent and broken laths surrounded by an intergrowth of ilmenomagnetite and ilmenite with subhedral pyroxene and minor rounded spinel.

Mineralization The Matthews iron-titanium orebody forms an arcuate oxide-rich zone within the central part of the intrusion that dips vertically to steeply to the west. Layering is well developed in the ore zone and is generally oriented parallel to the elongation of the intrusion. Mineralization consists of abundant ilmenite and ilmenomagnetite that may constitute up to 60 percent of the rock, the rest being mainly plagioclase and pyroxene. The oxides are concentrated within melanocratic layers in well layered gabbro and form an interlocking mosaic of fine (1-2 mm) grains surrounding silicate grains. Exsolved ilmenite laths in the ilmenomagnetite grains are oriented along octahedral planes. Pleonaste sometimes occurs along cubic planes. Plagioclase in the mineralized gabbro layers often shows more extreme brecciation than unmineralized layered gabbro and has a composition range of An₃₂ to An₄₀. Pyrite is a minor constituent of the ore and occurs as scattered

small rounded grains enclosed by ilmenite or ilmenomagnetite.

Discussion: The lack of foliation and unaltered mineralogy of the gabbro indicate that it was probably emplaced after metamorphism of the surrounding metasediments. According to Krogh (1961) the oxide-rich zone within the gabbro probably formed as a result of injection of late magmatic fluids into a series of parallel, dilatant shear planes in the gabbro. These developed parallel to flowage planes after the gabbro was sufficiently crystallized to yield by rupture.

The preceding description of the geology has been largely summarized from a master's thesis by Krogh (1961).

History of Development

1853-1859: 6000 tons of iron ore mined and shipped from the Chaffey deposit by the Chaffey brothers (Logan 1863, p.674; Harris, 1924, p.234).

1860: Development of Matthews mine begun by Chaffey brothers (Ingall 1901).

- 1870-1871: Total combined production of 14,250 tons of including approximately 3,300 tons from the Matthews mine and 11,000 tons from the Chaffey mine (Ingall 1901; Harris 1924). All ore was mined from open pits and shipped to Kingston for sale to markets in the United States.
- 1957-1959: Magnetometer and geological surveys by New Mylamaque Explorations Ltd. Completion of 44 diamond drill holes totalling 18,901 feet (5,760.6 metres) on the Matthews orebody and 11 diamond drill holes totalling 5,551 feet (1,692 metres) on the Chaffey orebody (Samuel 1959).
- 1966: Preliminary engineering studies, cost estimates, and metallurgical tests completed by Canadian Bechtel Ltd, commissioned by New Mylamaque Mining and Smelting Ltd. (formerly New Mylamaque Explorations Ltd). The estimated cost of preparation of open pit and mill construction was \$18,844,000. Letter of intent for purchase of a minimum of 275,000 tons of iron pellets per year from 1968 to 1978 inclusive received from Lake Ontario Steel Co. Ltd and Atlas Steels

Co. Ltd, a division of Rio Algom Mines Ltd
(Booth, 1967).

1969: Preliminary financing arrangements of Mymar
Mining and Reduction (formerly New Mylamaque
Mining and Smelting Ltd.) with Annett
Partners Ltd. and Northgate Exploration
cancelled due to increase in capital cost
estimates (Northern Miner, October 16,
1969).

References

Booth (1967)
Gross (1967)
Harris (1924)
Ingall (1901)
Krogh (1961)
Logan (1863)
Rose (1958)
Samuel (12959)
Shklanka (1968)
Wynne-Edwards (1976b)

MARMORATON IRON MINE (PAST PRODUCER)Location and Access

The open pit of the former Marmoraton iron mine is located approximately at UTM coordinates 288700E, 4928200N, in NTS quadrant 31C/5, within lots 4 and 5 in concession V and VI, Marmora Township, approximately 1.5 km southeast of the village of Marmora. A private road passes through the minesite and intersects Hwy 7 just over 1/2 km east of Marmora, and Hwy 14 about 3 km south of Marmora (see Fig.39).

Economic Features

The Marmoraton iron mine started operations in 1955 and was in continuous production until closing in 1978. During this time a total of 27,966,762 net tons of iron ore with an average grade of 42.8 percent iron was mined and 11,282,412 net tons of concentrate (pellets) having an average grade of 65.27 percent iron were shipped. A total of 80,296,857 net tons of waste was removed in addition to the ore. The estimated tonnage and grade of remaining reserves at the time of closing was 2,476,461 net tons with 43 percent iron (unpubl. files, Bethlehem Steel Corp). All production was from an open pit which at the time of closing was approximately 220 metres deep (700 feet), and 850 metres long by 460 metres wide.

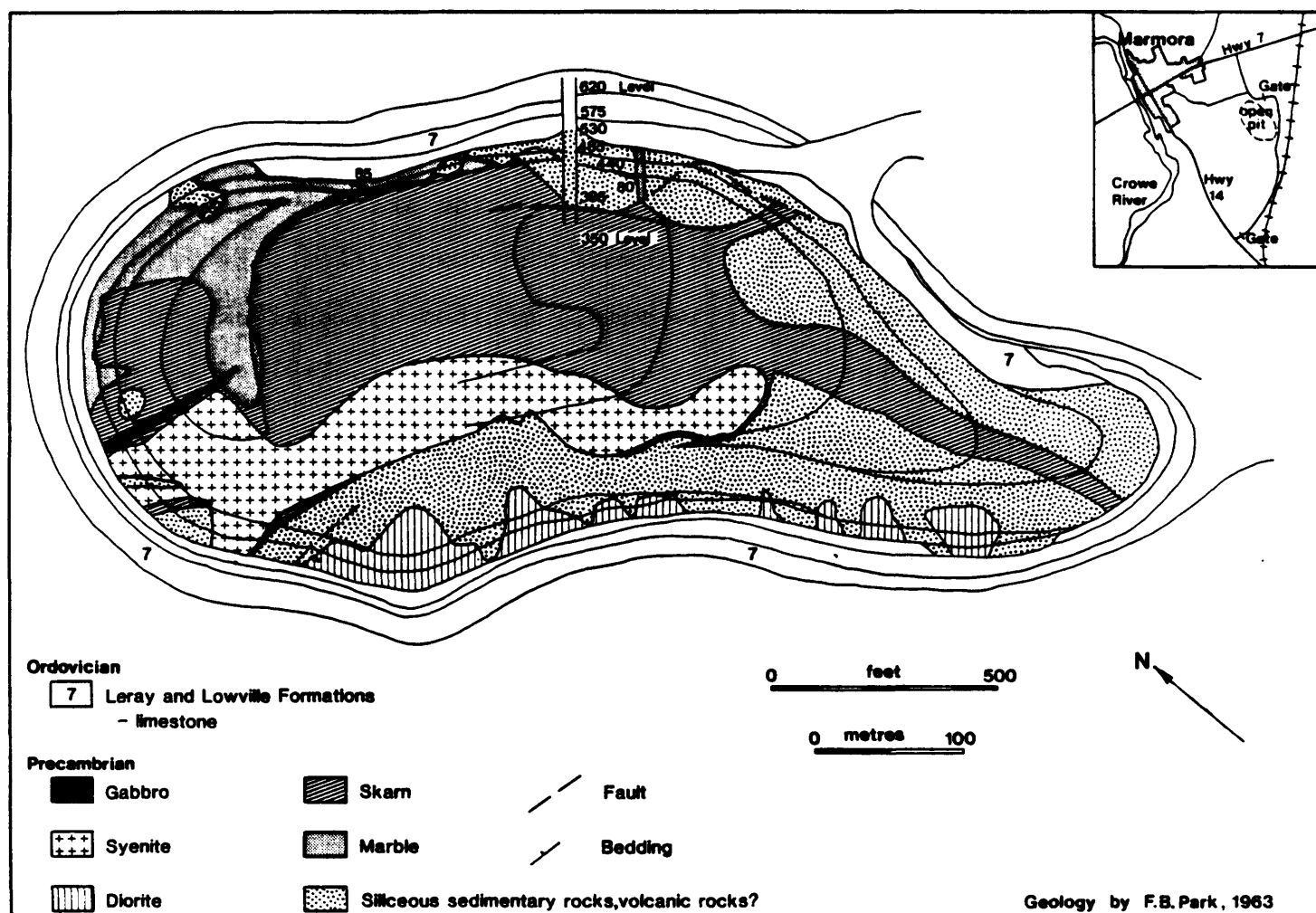


Figure 39: Geology of the Marmoraton Mine open pit.
 Adapted from Park 1966.

The orebody consisted of a lens of iron ore varying from 15 to 120 metres thick, approximately 610 metres long, and extending down-dip for at least 220 metres. The orebody had assay limits and was gradational into marble in the northwestern part of the pit over distances of about 12 to 15 metres (Park, 1966). Mineralization consisted of disseminated magnetite in a gangue consisting of a complex assemblage of skarn minerals. Layers of high grade ore were often separated by low or medium grade skarn but in general the grade was fairly uniform. The composition of a 3100 pound (590 kg) composite sample of iron ore analysed by Bethlehem Steel Corporation is presented in Table 26.

Geology

The Marmoraton iron orebody consisted of a tabular body of magnetite-bearing skarn that occurred at the contact between Grenville marbles and a syenitic intrusion. The orebody was unconformably overlain by approximately 38 metres of flat-lying Ordovician limestone which was stripped away prior to mining operations. The only exposures of the orebody and host rocks are in the open pit of the former mine.

Marble, skarn (including ore), syenite, diorite, siliceous metasediments, gabbroic dikes, and flat lying

TABLE 26: Chemical composition of composite samples of
Iron ore (Park, 1966). Samples were analysed by
Bethlehem Steel Corporation

<u>Element</u>	<u>Sample 1</u>	<u>Sample 2</u>
Fe	43.7 %	43.3%
Magnetic Fe	38.5	37.8
S	1.67	1.65
Cu	0.021	0.024
P	0.05	0.05
SiO ₂	19.1	20.0
CaO	8.4	8.9
Al ₂ O ₃	3.0	3.3
MgO	4.2	4.2
TiO ₂	0.17	0.17
Zn	0.1	
Ni	0.01	
As	0.1	
V	0.1	
Co	0.02	
Na ₂ O	0.25	
K ₂ O	0.06	
L.O.I.	0.07	

Ordovician limestone are exposed in the pit. The spatial relationships are illustrated in Figures 39 and 40.

Marble is predominant along the northern and eastern side of the deposit and siliceous metasediments are best exposed in the southern and eastern portions of the open pit. The marbles and siliceous metasediments are in conformable contact and strike north to northeast and dip steeply to the west. The marble is a rather homogeneous, white to green, fine to medium-grained (less than 2 mm) rock composed primarily of calcite with lesser amounts of dolomite, tremolite, phlogopite, and pyrite. Phlogopite and tremolite grains show preferential orientation into a weak foliation. The siliceous metasediments vary from dark green rocks composed mainly of hornblende and plagioclase to light coloured rocks composed of variable amounts of quartz, plagioclase, biotite, and chlorite. They generally have a poorly defined foliation and are poorly layered.

Syenite is best exposed in the northwestern and central parts of the pit. Diamond drilling (Fig. 40) indicates that syenite forms the western boundary and also underlies the ore zone. According to Park (1966) the syenite becomes increasingly altered near the contact with skarn and ore. Fresh syenite is pink, medium-to-coarse grained (2-5 mm), massive, and is composed of plagioclase, K-feldspar, and quartz, with minor amounts of magnetite, hornblende,

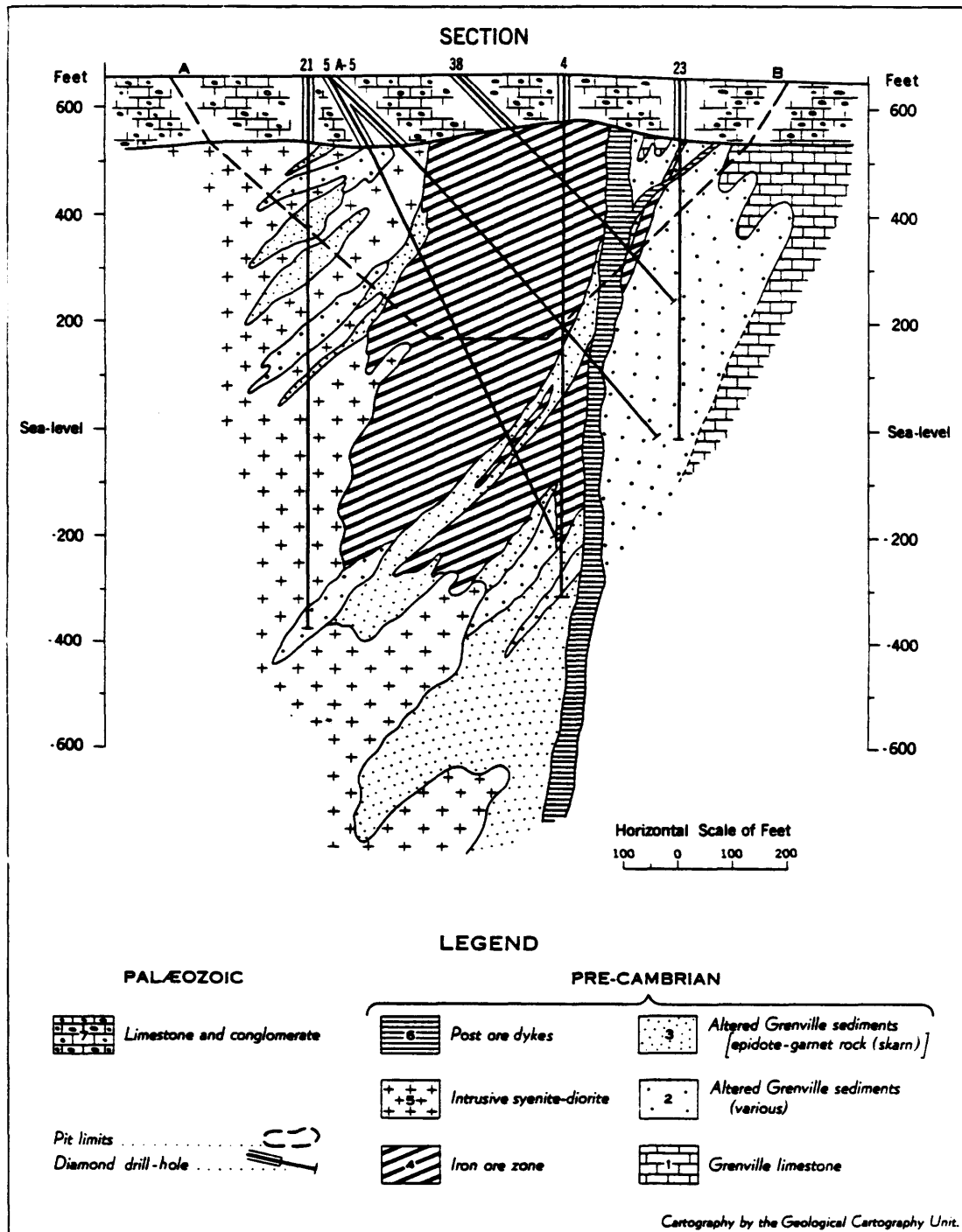


Figure 40: Cross section, Marmora Iron Mine.

chlorite, calcite, epidote, sphene, biotite, and muscovite. It is classified as quartz syenite by Park (1966). Altered syenite is grey to white in colour and is composed principally of plagioclase, quartz, and calcite, with minor pyrite, muscovite, sphene, and tourmaline.

Diorite occurs as small poorly exposed patches in the western part of the pit, intrusive into siliceous metasediments. Its age relationship to the syenite has not been determined. The diorite is green in colour, medium-grained, massive to locally foliated, and is composed of plagioclase, hornblende, chlorite, and clinozoisite with minor epidote, quartz, biotite, calcite, sphene, apatite, pyrite, and magnetite.

The skarn and ore zone occurs along the contact between syenite and marble and is inclined steeply to the west. The ore is a dark green to black rock composed principally of magnetite, salite, hornblende, chlorite, pyrrhotite, and pyrite, with minor calcite, apatite, sphene, epidote, clinozoisite, andradite, chalcopyrite, and sphalerite. Hornblende is the principal gangue mineral and decreases in abundance in less magnetite-rich areas. Pods and lenses of high grade ore are conformable with an internal foliation and occur as tabular and lenticular masses that are interlayered with and gradational into skarn (Park, 1966). The skarn rock varies from a massive, fine-grained

intergrowth of dark green pyroxene, amphibole, and variable amounts of epidote, garnet, chlorite, talc, and calcite in the eastern part of the deposit to a coarser-grained epidote-garnet-pyroxene skarn in the west near the syenite intrusion (Gross, 1967). Pyroxene (salite) is the most abundant gangue mineral. The skarn is often gradational into marble over distances of up to 15 metres (Park, 1966). Crude layering in the skarn and ore is generally conformable with layering in the marbles.

Paragenetic studies of the skarn and ore by Park (1966) indicate that andradite and salite formed first, followed successively by hornblende, magnetite, pyrite and pyrrhotite, chalcopyrite, and sphalerite. Textural evidence indicates hornblende occurs as a replacement of salite, and chalcopyrite and sphalerite replace earlier formed sulphides. These were followed by formation of a secondary suite of minerals, attributed to later hydrothermal alteration, including epidote, clinozoisite, chlorite, quartz, biotite, sericite, and calcite.

A dike of fine-grained gabbro is exposed in the northern part of the pit. It cuts all other rocks except the Paleozoic strata and is composed of hornblende, biotite, plagioclase, chlorite, magnetite, quartz, and calcite.

History of Development

- 1950-1951: The area was staked by Bethlehem Steel Corp. Ltd. after an ODM-GSC aeromagnetic map was released showing a strong anomaly over the area. Ground magnetometer, dip needle, and gravity surveys were completed along with 40 diamond drill holes for 37,000 feet (11,280 metres). This diamond drilling indicated approximately 20,000,000 tons of ore grading about 35% Fe.
- 1952-1955: Stripping of overburden for open pit mining began in March 1952 and entailed the removal of 22 million tons of limestone and overburden. Loading docks were constructed at Picton, on Lake Ontario, about 100 km by rail to the south. A concentrator and pelletizer were also completed. Work was by Bethlehem Iron Mines Ltd.
- 1955: The pelletizer, concentrator and open pit began operations on April 1, 1955 at a rated annual capacity of 500,000 tons of pellets. Pit dimensions were originally about 365 metres wide by 790 metres long. First shipments of pellets were made to Lackawanna, New York, from Picton on May 11, 1955. Operations conducted by Marmoraton Mining Co. Ltd.

1963: Pit dimensions were expanded to 460 metres wide by 850 meters long with a planned depth of 227 metres.

1978-1979: Operations ceased in March, 1978 and assets were auctioned in October, 1979.

References

- Gross (1967, p.80-82)
Olsen (1955, p.109-110)
(1957, p.53-55)
Park (1965, p.1366-1379)
(1966)
Rose (1958)
Shklanka (1968, p.166)
Wahl and Lake (1957, p.155-162)

CORDOVA GOLD MINE (PAST PRODUCER)Location and Access:

The former Cordova gold mine is located about 13 km by road northwest of the village of Marmora, immediately southeast of the village of Cordova Mines. It is readily accessible by paved roads from both villages (Fig.41,42). The workings and mineralized zones of the former mine are extensive and occupy parts of lots 20 and 21, Con.I, Belmont Township, and the west half of lot 20, Con.I, Marmora Township, in NTS quadrant 31C/12 (Fig.41). The main shaft (number 3) is located at UTM co-ordinates 4935250N, 279000E. A similar deposit, the former Ledyard gold mine, occurs immediately to the south in lot 19, Con.1, Belmont Township at UTM co-ordinates 4934450N, 279225E.

Economic Features

The Cordova gold mine has been the object of several mining and/or exploration programs since its discovery in 1890. Production by different operators in the years 1892-1893, 1898-1903, 1912-1917, and 1939-1940 amounted to 22,774 oz of gold and 687 oz of silver from 120,670 tons of ore milled (Ministry of Natural Resources, Statistical Files). There has been only minor production of gold concentrates, recovered from tailings, since that time. The

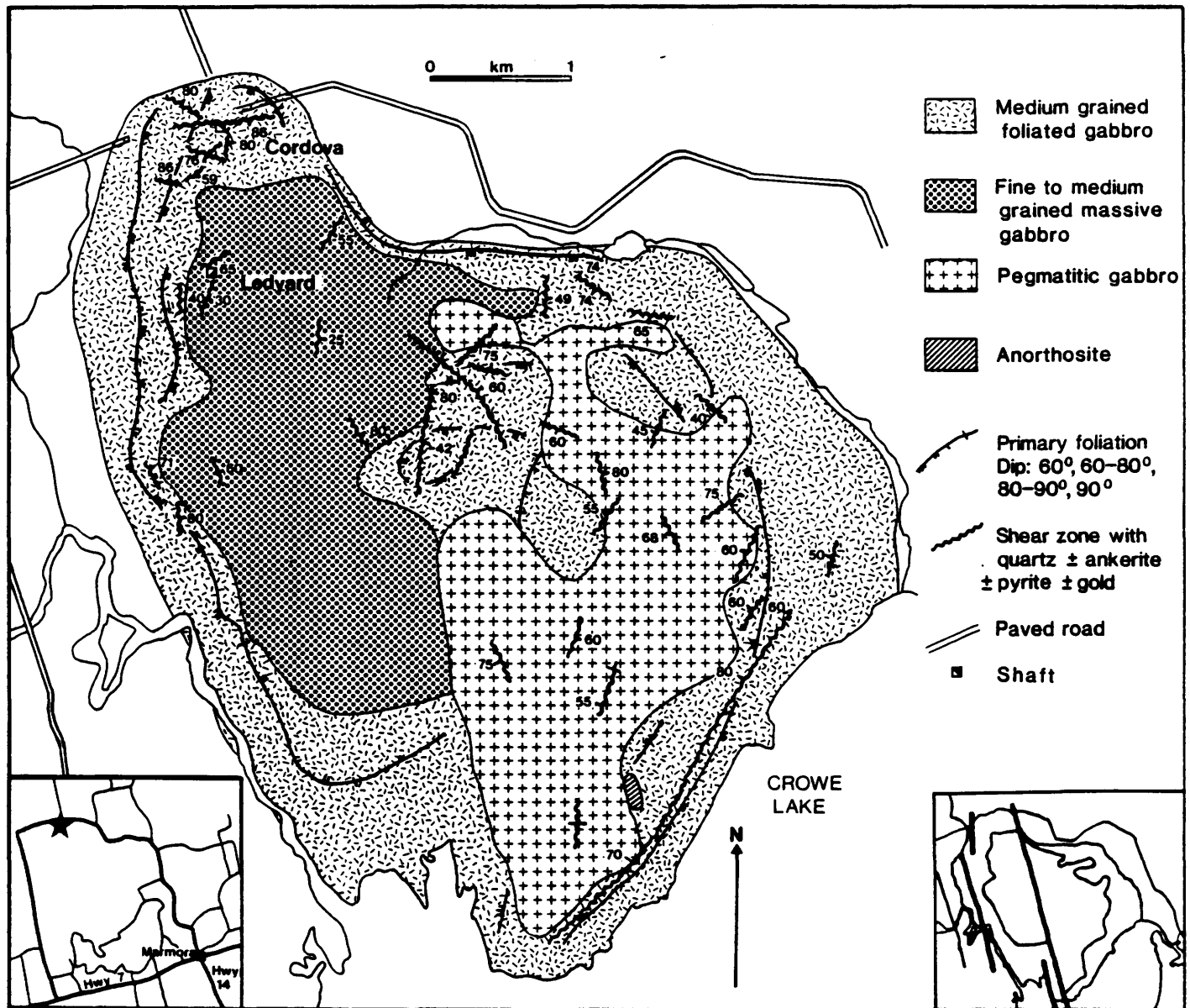


Figure 41: Geology of the Cordova gabbro. Adapted from Thomas and Cherry 1981. Inset shows structural interpretation (Springer 1982).

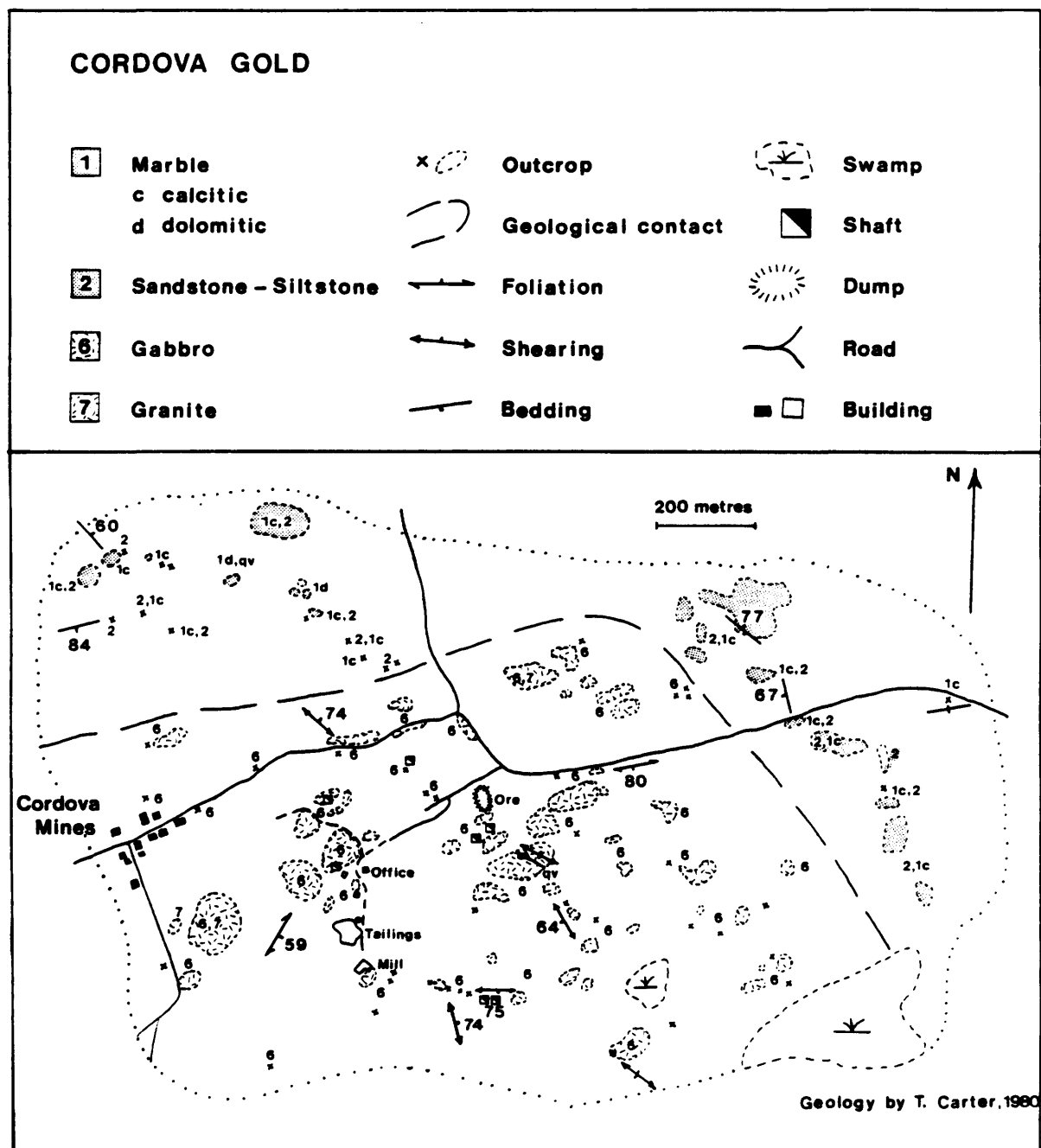


Figure 42: Geology in the vicinity of the Cordova gold mine.

property is currently owned by Lasir Gold Inc. Production from the related Ledyard deposit was valued at \$236, from 55 tons milled in 1893-1894 (Satterly, 1943).

The Cordova deposit has been explored by 10 shafts (Fig.43), a limited amount of diamond drilling, and a substantial amount of underground drifting, raising and crosscutting. Plans of the underground workings are presented by Satterly (1943). The No. 1 shaft is 125 metres deep with five levels, the no.2 shaft is 56 metres deep, connected to the no. 3 shaft on the second level, and the no. 3 shaft (inclined) is 320 metres deep with nine levels, with an inclined winze to the tenth level, 341 metres below the surface (Tower, 1940). The other shafts are shallow, with little or no underground development.

Mineralization is contained within quartz-ankerite-feldspar veins in shear zones. Several mineralized shear zones have been outlined in the vicinity of the mine with most of the development confined to the Main vein (Fig.43). The width of the individual shear zones ranges from about 30 cm to more than 12 metres, the average being about 2 metres (Satterly, 1943). A number of wide orebodies were mined out in the upper levels of the mine prior to 1935. According to Carter (1903) ore zones being mined at that time from the No. 1 shaft varied from 2.4 to nearly 18 metres in width. However, the extensive development carried out by the

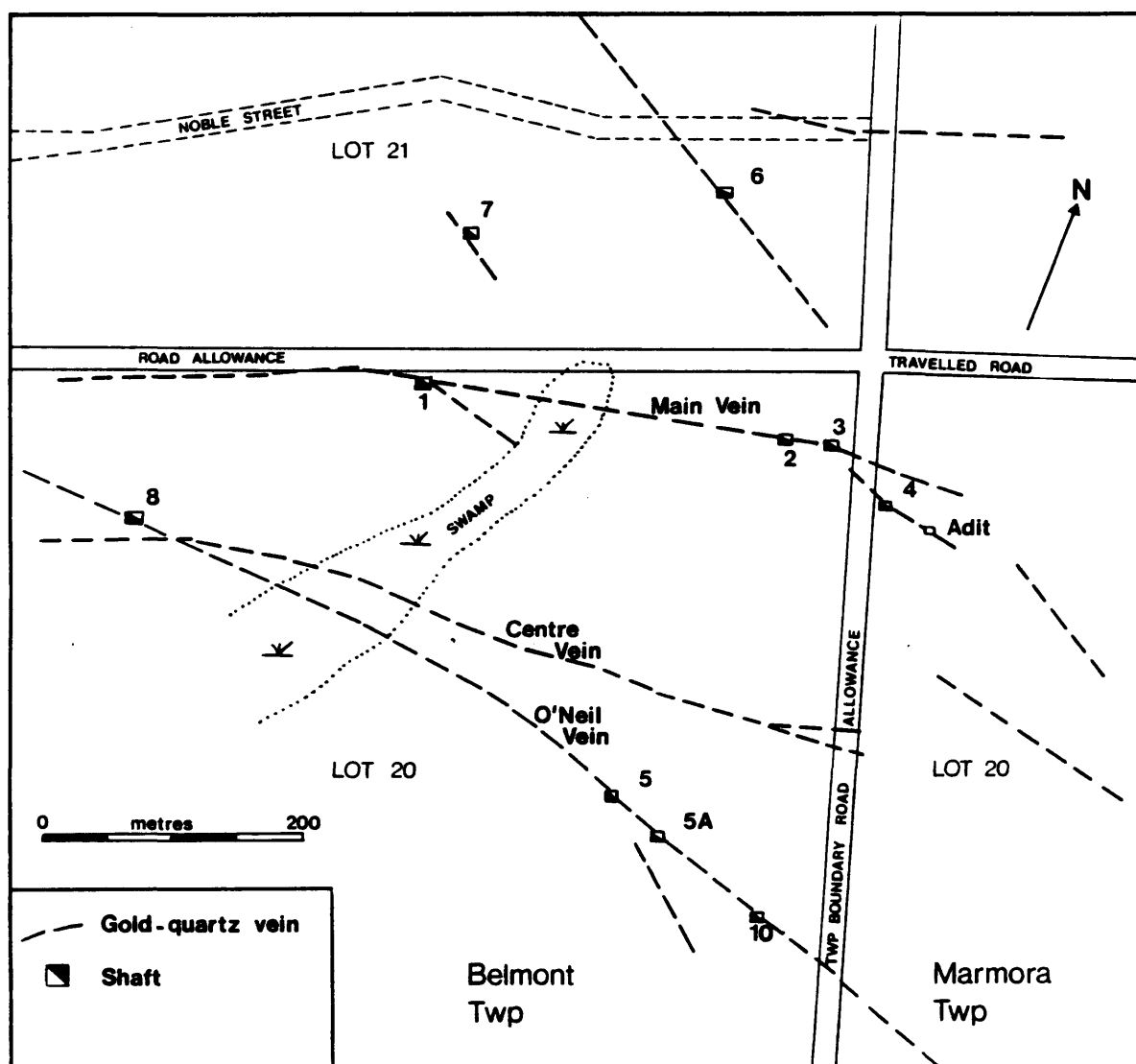


Figure 43: Location of shafts and gold quartz veins at the former Cordova gold mine. Adapted from the prospectus of Cordova Gold Mines Ltd. 1983.

Consolidated Mining and Smelting Co. of Canada Ltd. between 1935 and 1940 disclosed a number of orebodies of only moderate tonnage and grade (Satterly, 1943).

In January 1939, the ore reserves were estimated by the Consolidated Mining and Smelting Co. of Canada Ltd as 77,130 tons with 0.175 oz Au per ton, with 50,000 tons of probable ore of similar grade and 50,000 to 100,000 tons possible ore (Cominco Ltd. company files). The company recovered 3487 oz of gold from 33,434 tons of ore milled between October, 1939 and July 31, 1940 (Satterly, 1943) for a recovered grade of 0.104 oz Au per ton. Remaining reserves consequently total approximately 44,000 tons grading between 0.104 and 0.175 oz Au per ton, with 50,000 tons probable and 100,000 tons possible ore.

There is a substantial amount of broken rock believed to be development ore stockpiled on the surface near the No.1 and No.3 shafts, and a large amount of tailings from the milling operations. Orvana Mines Ltd. conducted a systematic program of measuring and sampling these dumps in 1964. Two tailings ponds were identified; one was built prior to 1918 and the other by the Consolidated Mining and Smelting Co. Ltd in 1939-1940. The ponds were sampled using a power auger. A total of 105 samples were collected from the Consolidated Mining and Smelting Co. Ltd tailings pond and these averaged 0.02 oz Au per ton. The results of the

other sampling programs are presented in Table 27 and indicate a total of 21,700 tons of broken ore and tailings on surface dumps averaging 0.17 oz Au per ton (H.G. Harper, unpubl. geological report for Orvana Mines Ltd, 1965). Lasir Gold Inc. has recently estimated the ore dumps to contain approximately 15,000 to 20,000 tons containing about 0.06 oz Au per ton. Approximately 1000 tons of tailings were outlined by the company which were estimated to contain an average of 0.33 oz Au per ton based on surface sampling of the pond. A small tonnage of tailings was test milled on the mine-site in a small pilot plant with recovery of a concentrate consisting of about 800 lb of charcoal grading 151 oz Au per ton (Walter Hood, Lasir Gold Inc., personal communication, 1982).

The tailings pond sampled by Lasir Gold Inc. was examined by the author in 1980 and found to consist of a hummocky pile of stratified sand. Samples collected by the author and analysed by the Geoscience Laboratories of the Ontario Geological Survey contained: i) 0.69 oz Au per ton and trace Ag in dark grey, magnetite-rich sand, ii) 0.11 oz Au per ton and trace Ag in reddish-brown, oxidized, magnetite-rich sand near the surface of the pond, and iii) 0.14 oz Ag per ton in magnetite-free, yellow tailings. A representative chip sample of broken ore from the ore stockpile at the No. 3 shaft contained 0.25 oz Au per ton.

TABLE 27: Composite Summary of Results of Sampling of
Surface Dumps and Tailings Ponds by Orvana Mines
Limited (H.G. Harper, Unpublished Report for
Orvana Mines Limited 1965).

	<u>Tailings Pond</u>	<u>No. 3 shaft</u>	<u>No. 1 shaft</u>
Number of samples	-	120	193
Estimated tonnage	6400	6500	8800
Average grade (oz/ton Au)*	0.144	0.200	0.164

Production figures indicate there should be at least 100,000 tons of tailings on the mine site. Only a portion of these, containing significant amounts of gold, have been accounted for, consequently location of these tailings should be a priority in any exploration program. In addition there has been little systematic exploration of veins other than the Main vein at the deposit. There is also a large unexplored block of ground above the sixth level between the No.1 and No.3 shafts which has never been explored.

Geology

The gold deposits occur entirely within, but near the northwest margin of a large gabbroic intrusion.

Intercalated calcitic and dolomitic marble and siliceous clastic sedimentary rocks are exposed to the north and east of the pluton. Marble and mafic volcanic rocks occur to the west and southwest and Paleozoic limestones unconformably overlie the intrusion to the south.

The gabbro is composed of variable proportions of plagioclase and hornblende. Lithologic variations defined by differences in texture and grain size have been described by Thomas and Cherry (1981) and are indicated on Figure 41. Four units have been defined: 1. fine to medium-grained, black to dark green, massive gabbro, 2. medium-grained,

well foliated gabbro, 3. pegmatitic gabbro, and 4. anorthositic gabbro. Massive gabbro (unit 1) is surrounded by and is gradational into foliated gabbro (unit 2) which forms a rim between it and the country rocks. Foliation in the foliated gabbro is defined by alternating monomineralic layers of hornblende and plagioclase and is believed to be a primary layering. The foliation defines a bowl shape and may indicate that the foliated gabbro is older than the massive gabbro. Pods of pegmatic gabbro intrude both units 1 and 2. Anorthositic gabbro occurs as small pods in both units 1 and 2. In addition to the above four units, many randomly oriented granitic dikes 10 cm to 3 metres in width intrude the gabbros. All of the dikes, as well as the anorthosite and pegmatite, are interpreted to be late stage differentiates of the gabbroic intrusion.

Shear zones cut all phases of the gabbro and occur throughout the pluton, but are most abundant in the northern and eastern parts of the pluton. These shear zones have variable attitudes but, according to Thomas and Cherry (1981), generally strike east in the northern tip of the intrusion and north to northeast elsewhere. Most are steeply dipping (65 to 90 degrees) with striations on the shear planes pitching at 45 to 60 degrees to the south or east. The shear zones exposed at surface are often curved

to some degree along strike. The wave-like form of the shear zones and the steeply pitching striations suggest a largely dip-slip movement (Thomas and Cherry, 1981).

The shear zones vary from about 30 cm in width to 50 metres. The shearing within the zones is irregular due to branching and contortion but is persistent along strike. According to Satterly (1943) underground work at the Cordova mine indicates at least one shear zone is less persistent on its dip than it is along its strike. The shearing across individual zones may be uniformly developed or may consist of a central core of more highly sheared rock flanked by poorly foliated, aphanitic material (Thomas and Cherry, 1981). The gabbro is commonly altered to biotite and chlorite within the zones.

Mineralization: Gold bearing vein material confined to shear zones in gabbro constitute the mineralized zones at the Cordova and Ledyard gold deposits. Gold mineralization is known to occur in all the shear zones in the vicinity of the Cordova mine, over much of their exposed lengths (see Fig. 3). However, to date, only the Main vein has been found to contain workable orebodies.

The Main vein, or shear zone, strikes approximately east-west and dips steeply to the south. Orebodies developed within it from the No. 1 shaft strike from N60° to N70°E and N80°W and generally dip from 60 to 70 degrees

southeast. Near shaft 3 the orebodies strike $N70^{\circ}$ to $N85^{\circ}E$ to $N85^{\circ}W$, with an average dip of about 65 degrees south. Many of the orebodies in the vicinity of shaft no.1 occur at or near the intersection of two shear zones trending $N80^{\circ}W$ and $N65^{\circ}E$. Orebodies also occurred where there were contortions and variations in the shearing, as in old stoped areas near No. 1 and No. 3 shafts (Satterly 1943).

A reconstruction of the structure relationships of the shear zones, the orebodies and the gross form of the Cordova gabbro has been briefly outlined by Springer (1982) who points out that, if the orebodies occupy a plunge intersection as old records imply, a calculated value of $65^{\circ}/170^{\circ}$ is obtained for their orientation. From the work of Thomas and Cherry (1981) Springer suggests that the gabbro is block faulted, and that the easterly, barren segment lies at a different structural level (inset Fig. 43).

Quartz is the principal vein mineral with subordinate amounts of ankerite and feldspar, including plagioclase and orthoclase. Pyrite is the principal metallic mineral, with minor amounts of pyrrhotite. The vein material is very variable in its mode of occurrence. Satterly (1943) and the author observed i) large massive lenses of quartz conformable with the shear planes, ii) series of closely spaced, parallel veins of quartz, ankerite, and feldspar

conformable with shear planes, and iii) irregular zones of branching veins and lenses. A fourth type, described by Satterly (1943) consists of replacement of sheared gabbro by vein material. All four types of vein material occur in the ore zones. A fifth type of vein material, which contains only minor gold mineralization, occurs on the 9th level of the Cordova mine. It consists of lenses of quartz and carbonate mineralized with pyrrhotite (Satterly 1943). Inclusions of sheared gabbro occur within all types of vein material, giving it a banded appearance.

Native gold was reported by the former operators of the Cordova and Ledyard mines and is quoted by Blue (1894), Miller (1902). Gold is apparently largely confined to pyrite, as evidenced by the following:

1. Samples of massive pyrite collected at the Ledyard mine by the author contained 0.76 oz Au per ton and 0.10 oz Ag per ton. Chip samples of quartz vein material collected nearby contained only trace to 0.01 oz Au per ton.
2. The better ore mined from the Cordova deposit is reported to have contained up to 50 percent pyrite (Satterly, 1943).

Springer (1982) discusses vertical zonation in the Cordova and Ledyard bodies, and records assays from pyrite, pyrrhotite and blue quartz at Cordova (Table 28).

TABLE 28: Assays of Minerals from Local Gold Mines

<u>MINE</u>	<u>ORE</u>	<u>GOLD</u>	
		<u>oz/per ton</u>	<u>\$ per ton</u>
Cordova (Miller 1902)	pyrite	5-6	
	pyrrhotite		13
Ledyard (Blue 1894)	pyrite		90
	assorted ore	4.7	94
	quartz-pyrite	4.6	
Pearce (Blue 1894)	arsenopyrite		8

History of Development:

1890-1893: Gold was discovered by H.T. Strickland in 1890.

In 1891 the property was acquired by a syndicate comprised of Messrs. Carscallen, O'Neil, Strickland, and Burnham who sunk the No. 1 shaft to a depth of 32 metres, excavated several open cuts, and raised about 1000 tons of ore. The property was optioned by Middleton Crawford on Oct. 7th, 1892 for one year. Mr. Crawford constructed a mill and is reported to have removed about \$5,000 worth of gold (Blue, 1893).

1898-1903: The property was optioned and later purchased from A.W. Carscallen by the Cordova Exploration Co. Ltd. (de Kalb 1899, 1900). Eight shafts of varying depth were sunk, with most work being confined to the No. 1, 2, and 3 shafts on the Main vein. The No. 1 shaft was extended to 125 metres with four levels, the No. 2 shaft was sunk to 56 metres, and the No. 3 shaft (inclined) was completed to a depth of 99 metres, with three levels. The No. 2 and No. 3 shafts were connected at the second level. A 10 stamp mill was constructed and expanded to 30 stamp capacity in 1901 (Carter 1902, 1903; Miller 1902; Cominco Ltd, Company Files). During the period 1898-1903

a total of 17,101 oz of gold are reported to have been produced from 70,185 tons of sorted ore milled (Mineral Deposit Files, Ontario Geological Survey, Toronto).

1911-1917: The mine was purchased by Cordova Mines Ltd. in 1911. The No. 3 shaft was deepened, two new levels were started and a large amount of stoping completed. The mill was overhauled and several test runs on ore were made, with recovery of a total of 2,186 oz of gold and 537 oz of silver from 16,491 tons of ore milled between 1912 and 1917 (Ministry of Natural Resources, Statistical Files). When operations ceased in 1917 the No. 3 inclined shaft was 152 metres deep with 732 metres of drifts on five levels. The No. 1 shaft was 125 metres deep with 550 metres of drifts on five levels. There were also small amounts of cross-cuts and raises. (Cominco Ltd., Company Files).

1933-1940: In 1933 the mine was dewatered and sampled by the Consolidated Mining and Smelting Co. of Canada Ltd, and in 1935 they purchased the property. Development work included the deepening of the No. 3 shaft to 320 metres (inclined) with the establishment of five new levels and sinking of

an inclined winze to a depth of 341 metres. A large amount of drifting, raising, crosscutting, and diamond drilling were completed. A 100 tons per day mill was operated from Oct. 23 1939 to July 29, 1940. A total of 3487 oz of gold and 150 oz of silver were produced from 33,434 tons ore milled (Mineral Deposit Files, Ontario Geological Survey, Toronto).

1948: Surface rights were sold to H.R. Bowen (Cominco Ltd., company files).

1954: Mineral rights were sold to H.R. Bowen (Cominco Ltd., company files).

1964-1965: Property was acquired by Orvana Mines Ltd.

Initial program consisted of a ratio resistivity survey to locate shear zones with subsequent drilling of 10 diamond drill holes totalling 622 metres to test anomalies. Results were discouraging except for one intersection of 1.2 metres averaging 0.23 oz Au per ton. Six additional diamond drill holes totalling 184.4 metres were drilled to test known vein structures. Surface ore dumps and tailings ponds were systematically sampled and measured (H.G. Harper, unpublished geological report, Orvana Mines Ltd., 1965).

1980-1982: Property bought by Cordova Gold Syndicate, now known as Lasir Gold Inc. Heap leaching tests were conducted on part of a surface stockpile of development ore and a small tonnage of tailings were processed in a small pilot plant with recovery of a concentrate consisting of 800 lb of charcoal containing 151 oz Au per ton (personal communication, Walter Hood, Lasir Gold Inc.). Feasibility study on reopening of the mine for production completed.

References

- Blue (1894, p.47-51)
- Carter (1902, p.234-236)
- (1903, p.111-112)
- Corkhill (1913, p.135)
- de Kalb (1899, p.40-41)
- (1900, p.92-93)
- Miller (1902, p.188-193)
- Satterly (1946a)
- Sinclair (1937, p.96)
- Slaght (1891, p.224)
- (1898, p.89)
- Springer (1982)
- Thomas et al. (1981, p.89)
- Tower (1941, p.104)

ADDINGTON GOLD MINE (PAST PRODUCER)

Location and Access

The Addington gold mine is located approximately 9 km north of the village of Kaladar, approximately midway between the villages of Flinton and Northbrook, straddling the boundary between lots 24 and 25, Con. VI, Kaladar Township. The main shaft is located at UTM co-ordinates 4953275 N, 327275 E, in NTS quadrant 31C/11. A private dirt road provides vehicle access to the workings of the former mine. The road intersects a paved sideroad leading to Flinton, at a point about 1.6 km west of Highway 41 (see Fig.44).

Economic Features

The Addington gold mine has been the object of several small mining and/or exploration programs since its discovery in 1881. Up to the end of 1921 total production is reported to have been valued at \$10,000 (Harding 1944). The Cobalt-Frontenac Mining Company Ltd. produced 15 oz of gold in 1919 and 50 oz of gold and 26 oz of silver in 1922, from an undisclosed quantity of ore (Ministry of Natural Resources Statistical Files, Toronto). There has been no production since.

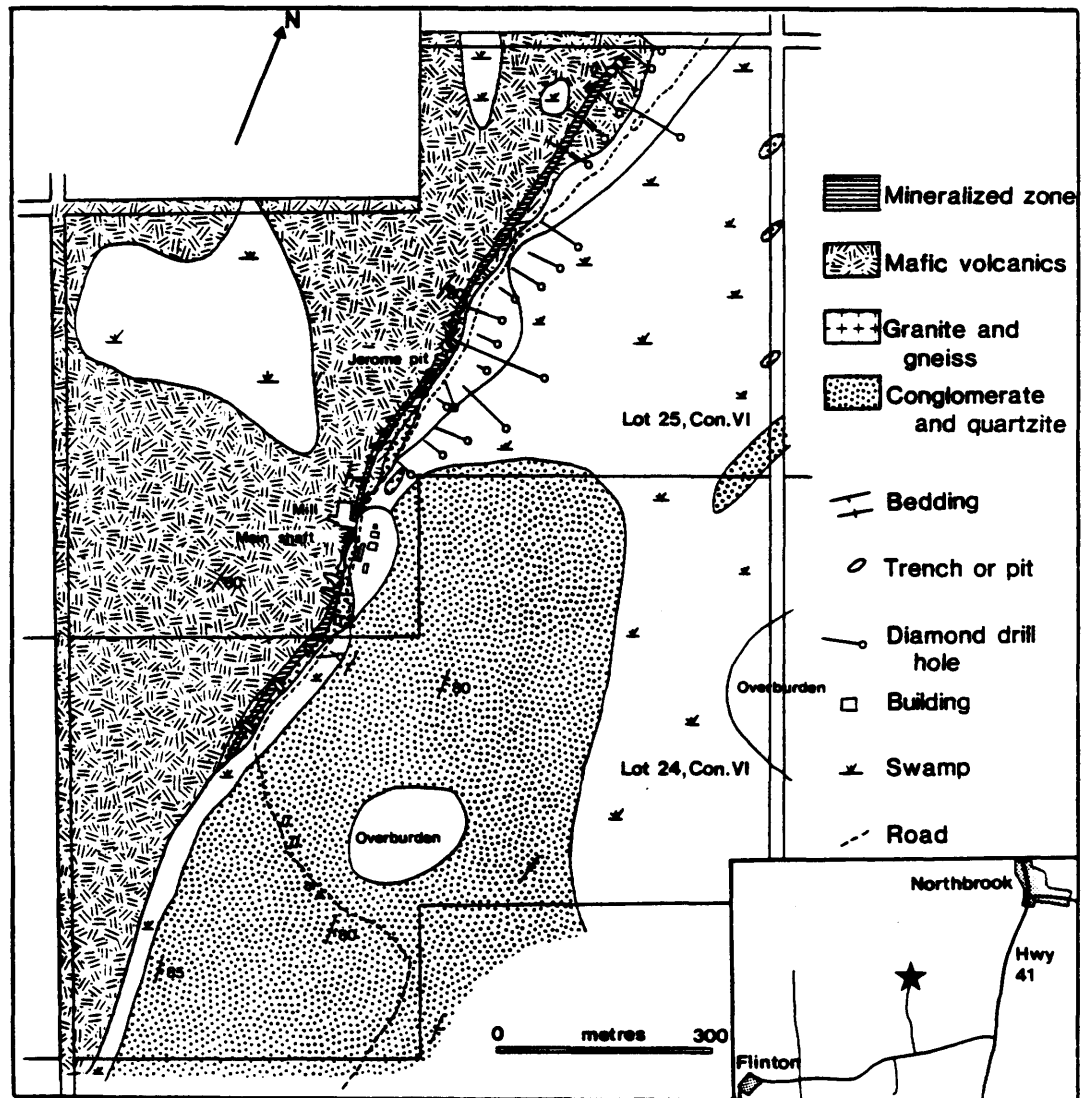


Figure 44: Geology of the Addington gold deposit, taken from Harding 1944.

The deposit has been explored to a depth of approximately 220 metres by a large number of diamond drill holes and a substantial amount of underground development. Underground development completed to May, 1982 totalled 221.1 metres of raising, 2262.1 metres of drifting, and 1054.7 metres of crosscutting, on six developed levels, accessible via an inclined shaft to the fifth level, with a vertical winze from the fifth to the seventh levels. Most of the work was completed by Addington Mines Ltd. between 1936 and 1939. The property is currently under option to E & B Exploration Inc. from the owner, Cominco Ltd.

Mineralization is contained within a vein zone which has been virtually continuously opened up by surface and underground workings over a strike of 1130 metres north from a point about 300 metres south of the shaft (Fig.44). A limited amount of diamond drilling has also intersected mineralized vein material at scattered intervals south of this point. Four 'ore' zones, termed the A,B,C, and D orebodies respectively from south to north, have been outlined within the main mineralized zone. The orebodies form pipe-shaped lenses with vertical dimensions generally exceeding lateral dimensions, and with average widths of perhaps 3 to 4 metres. Widths of the ore bodies are erratic, varying from less than 2 metres to nearly 15 metres in places, and gold values vary from trace to nearly 1 oz Au

per ton over comparable widths. The ore zones generally have assay limits, grading into sub-ore grade material both along strike and down-dip.

1. The A orebody lies immediately south of the shaft and has been developed to some extent by lateral underground workings on the first, third, fourth, and fifth levels, and by raises on the third and fifth levels, with numerous diamond drill intersections. It extends for an average length of 55 metres and averages 3 to 3.7 metres wide. On the first level it is about 6.1 metres wide but has an apparent width of only 1.5 metres on the fifth level. There are an estimated 94,000 tons of ore grading 0.14 oz Au per ton within the orebody. The zone is open below the fifth level.

2. The B orebody commences about 46 metres north of the shaft, separated from the A orebody by intervening vein material estimated to grade 0.07 oz Au per ton. It has been tested in workings on the third, fourth, and fifth levels, with several diamond drill intersections. The orebody has been assumed to apex above the third level and extends down to at least the fifth level, but does not persist to the seventh level. Its known vertical extent is about 91 metres, it averages about 30 metres in length, and has an average width of about 3.7 metres. Ore reserves are estimated at 41,000 tons grading 0.18 oz Au per ton.

3. The C orebody lies nearly 300 metres north of the shaft. It has been explored at surface in the Jerome pit, in the main drifts on the third and fifth levels, and by diamond drill holes. On the third level it has a length of about 61 metres. In 1939 it was assumed by Addington Mines Ltd. personnel to persist from the surface to below the fifth level. Reserve estimates made on this basis are 96,000 tons grading 0.16 oz Au per ton. However, according to Bell (1949), there has been sufficient development on only the third level to justify ore estimates. Bell calculates an ore reserve of only 30,000 tons grading 0.16 oz Au per ton based on a projection of the ore zone 15 metres above and below the third level.

4. The D orebody is located 685 metres north of the shaft about 30 metres west of and parallelling the main vein zone. Gold bearing vein material was exposed in surface pits and scattered but fair gold values intersected in surface diamond drill holes. Drifting on the third level makes ore grading 0.19 oz Au per ton across an average width of 2.7 metres for a length of 41 metres. Bell (1949) estimated ore reserves as 11,000 tons grading 0.19 oz Au per ton based on projections of the zone 15 metres above and below the third level. Addington Mines Ltd. personnel estimated an ore reserve of 25,000 tons grading 0.19 oz Au per ton in 1939.

TABLE: 29 Summary of underground development
completed by Addington Mines Ltd.

	<u>Drifting (metres)</u>	<u>Crosscutting (metres)</u>	<u>Raising (metres)</u>
1st level	9.1	-	-
3rd level	1048.1	518.7	89.8
4th level	268.3	134.2	45.4
5th level	589.0	233.0	85.9
7th level	<u>240.6</u>	<u>46.3</u>	<u>-</u>
Totals:	<u>2155.1</u>	<u>932.2</u>	<u>221.1</u>

Elevation of mine levels (in metres)

shaft collar	271.9
first level	248.4
second level	220.7
third level	194.5
fourth level	163.4
fifth level	132.3
seventh level	57.6

In total, Bell (1949) estimates developed ore reserves to be 176,000 tons grading 0.15 oz Au per ton, or 200,000 tons grading 0.13 oz Au per ton with 15 percent dilution but without cutting high assays. Addington Mines Ltd. personnel, in 1939, estimated an ore reserve of 256,000 tons grading 0.16 oz Au per ton, with 103,000 tons possible ore grading 0.08 oz Au per ton.

The above information is derived principally from company files of Cominco Ltd and an unpublished geological report by L.V. Bell (1949), also on file with Cominco Ltd.

Geology

The former Addington gold mine lies at the contact between a northeast trending belt of Hermon Group metavolcanic rocks and a belt of Flinton Group metasedimentary rocks to the east striking in a similar direction (Fig.44). The Flinton metasediments are preserved in a narrow syncline, 600 metres wide at this point, bounded by a large granitic intrusion to the east. A second, but narrower, infolded belt of Flinton metasediments lies within the volcanics immediately to the west.

The metavolcanic rocks are black, foliated, fine to coarse-grained amphibolites. Hornblende is the principal mineral constituent with lesser amounts of plagioclase and minor quartz. Definite pillow structures are preserved in

these rocks in the northwestern part of the property (Bell, 1949) and along strike to the north.

Quartzite and conglomerate comprise the two principal metasedimentary rocks exposed in the mine area. The quartzite is a white to grey rock consisting predominantly of fine-grained (1-2 mm) equigranular quartz with minor hematite, magnetite, biotite, and sericite. Cross-bedding and graded bedding are common. The conglomerates generally consist of a clast-supported framework of well-rounded, well sorted pebbles with a quartzite matrix. The pebbles consist predominantly of quartzite, often with well preserved bedding laminations. Quartzite forms the base of the sedimentary sequence, occurring along the contact with the metavolcanics and forming the hanging wall of the mineralized zone. According to Bell (1949) the quartzite varies from about 50 to 100 metres in width, thinning to the north, and is in sharp contact with conglomerate to the east. Grit horizons occur locally and schistose derivatives of the quartzite, including sericite schist and quartz-biotite schist, are developed near the contact with the metavolcanic rocks.

Several bands of hornblende-biotite, biotite, and hornblende-biotite-garnet schist representing shear zones oriented parallel to the volcanic/sediment contact, occur on the mine property. The main zone occurs along the contact

itself, extending throughout the length of the property, and is expressed as a narrow, well defined valley on the surface. The schists have gradational contacts with the volcanic and sedimentary rocks, consequently the location of the contact can often only be approximated. Biotite schist is most common along the eastern margin of the schist zone and is transitional from hornblende-biotite schist within the zone into quartzites which near the contact are commonly quartz-biotite schists. A band of hornblende-biotite-garnet schist occurs within the volcanics in the north part of the property, adjacent and parallel to the main zone. It commences a short distance north of the shaft. Near the north boundary of the property several lenticular bands of hornblende-biotite schist occur within the volcanics and one within the sediments.

The contact zone schist, or shear zone, strikes N10°E and dips at about 65° E. Schistosity within the sediments and volcanics strikes in a similar direction, with dips of 65 to 70 degrees east in the volcanics and averaging about 75 degrees in the sediments. The slight steepening of the schistosity on the east side of the contact and the sheared nature of the contact zone suggests the contact may be faulted, although at present the amount or sense of movement is not evident. Bell (1949) concluded this to be a normal fault with the down thrown block lying to the east. The

contact shear zone is intersected by at least two steeply dipping to vertical faults (not indicated on Fig. 44), which branch northeasterly from the contact shear zone into the sediments (Bell 1949). The No. 1 fault is marked by a minor valley on the surface and intersects the contact shear zone about 215 metres south of the shaft. It intersects the A orebody at the fifth level in the underground workings and has the effect of thinning and steepening it. Continuity of the orebody below the fault is not known, and amount and sense of movement along the fault is uncertain. The No. 2 fault occurs south of and parallel to the No. 1 fault and does not intersect any of the known ore zones. The relationship of the orebodies to the Flinton unconformity is discussed by Springer (1982). New observations from this property are recorded by Dillon (1983). Lithological units which can be recognized in the Flinton Group are cut off by the fault zone, suggesting that the fault is a distinctly discordant structure. The ore bodies relate to the sheared fault zone, less clearly to the basal unconformity of the Flinton Group.

Mineralization: Mineralization at the Addington gold deposit is confined to the shear zones, with the principal ore lenses occurring within the contact shear zone. Lenses and stringers of quartz are irregularly distributed

throughout the zones, with a tendency for concentration within certain sections. The lenses usually coincide with shear planes, but sometimes transect them. Subordinate carbonate, biotite, tourmaline, scheelite, magnetite, and ilmenite occur in association with the quartz lenses and stringers. Pyrite is the principal sulphide mineral, with lesser amounts of arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, and galena. The sulphides are sparsely disseminated within the vein material, with a tendency for concentration along the walls of the quartz lenses and veins. Native gold is reported to occur free in the gangue, in fractures in arsenopyrite, or in association with magnetite (Bell 1949).

The contact shear zone is virtually continually mineralized north from a point about 300 metres south of the shaft. This northern portion of the contact shear zone constitutes the principal mineralized zone at the deposit and contains the A,B, and C orebodies. Additional significant mineralization, including orebody D, occurs in a parallel, subsidiary band of hornblende-biotite-garnet schist west of the main contact zone near the north boundary of the property. Scattered lenses of sparsely mineralized vein material also occur in the southern portion of the contact zone.

The four orebodies form pipe-shaped lenses within the shear zones with their apparent down-dip continuity approximately twice that along their strike. The orebodies are gradational into sub-ore grade material along strike and down dip. There is no apparent reason for localization of the orebodies within the shear zones.

History of Development

1881: Mineralization discovered; property known as the "Golden Fleece" (Harding 1944).

1887-1915: Two shallow shafts were sunk and a ten stamp mill was erected. Initial work was by the Adelaide Mining Co. of Baltimore, and later by the A.B.P. Mining Co under an option agreement (Harding 1944).

1915-1922: The property was acquired by the Cobalt-Frontenac Mining Co in 1915 (Sutherland 1916). The two existing shafts on the property were deepened, one to 18 metres, and the other, an inclined shaft, to 30 metres with a level at this depth. A vertical winze was sunk an additional 20 metres from the bottom of the inclined shaft. A total of 107 metres of drifting and 122.5 metres of crosscutting were completed (Sutherland 1923). In 1922 a cyanide plant was constructed (Sutherland 1922). A total of 15 oz of gold was produced in 1919, and 50 oz of gold and 26 oz

of silver were produced in 1921 (Ministry of Natural Resources, Statistical Files, Toronto).

1927: Some development work by the Cobalt-Frontenac Mining Co (Rogers and Young 1929).

1928: Property purchased by Rich Rock Gold Mines (Mineral Deposit Files, Ontario Geological Survey, Toronto).

1932: The property was optioned by C.N. Thompson. The inclined shaft was dewatered and a bulk sample of approximately 150 tons of ore was mined and milled, giving an average of \$6.00 in gold values per ton (Sinclair 1933).

1935: The property was optioned by the Consolidated Mining and Smelting Co. of Canada Ltd (Harding 1944).

1936-1939: A new company, Addington Mines Ltd, 60 percent owned by Consolidated Mining and Smelting Co, was formed. The main shaft, inclined at 67 degrees to the east, was extended to the fifth level, 139.6 metres below the shaft collar. A vertical raise connects the fifth level to the seventh level. Seven levels were established, at elevations outlined in Table 29. Development work was confined mainly to the 3rd, 4th, 5th, and 7th levels, and totalled 2155.1 metres of drifting, 932.2 metres of crosscutting, and 221.1 metres of raising. 32 surface diamond drill holes totalling 2690 metres, and 144 underground diamond

drill holes totalling 4443.5 meters were completed. Milling tests on ore grading 0.19 oz Au per ton gave recovery of 96.3 percent with 0.007 oz Au per ton in the tailings. Straight cyanidation with grinding to 50 percent 200 mesh was recommended (unpublished company files, Cominco Ltd, Toronto). Operations ceased in October, 1939.

1940: Mill removed (Tremblay 1945).

1969: Cominco Ltd. purchased the property from Addington Mines Ltd (unpublished company files, Cominco Ltd.)

1980-1982: The property was optioned to E & B Explorations Inc. in 1980. Surface sampling, geological mapping, approximately 3000 metres of surface diamond drilling completed by 1981. Work continuing at time of writing with an additional 3000 metres of diamond drilling planned.

References

- Bell (1949)
 Corkhill (1907, p.76)
 (1908, p.83)
 (1913b, p.135)
 Dillon (1983, p.271-275)
 Harding (1944, p.70-72)
 Sinclair (1933, p.88-89)
 (1936, p.97)
 (1937, p.118)
 (1938, p.106-107)
 (1940, p.98)
 Springer (1982)
 Sutherland et al. (1916, p.128)
 (1917, p.126)
 (1919, p.154)
 (1920, p.116)
 (1921, p.131-132)
 (1922, p.63)
 (1923, p.83-85)
 Tower et al. (1941, p.103-104)
 Wolff (1982, p.76-78)

HUNT MOLYBDENUM MINE (PAST PRODUCER)Location and Access:

The former Hunt molybdenum mine is located on the southern slope of Kennellys Mountain, facing Condon Lake, in the Mount St. Patrick Mountains, about 4 km southeast of the village of Mount St. Patrick. It lies within lots 8 and 9, Con.XI, Brougham Township, in NTS quadrant 31F/7 at UTM co-ordinates 5018380N, 350620E. A cottage road to Condon Lake provides access to the deposit. The cottage road connects with a network of gravel roads that provide access from Hwy. 132, about 8 km to the north, or from Hwy 508 about 7 km to the southeast (Fig.45).

Economic Features

The property was operated as a mine from 1915 to 1918 by Renfrew Molybdenum Mines Ltd. Total production amounted to 96,660 pounds of concentrates, 85 percent of which averaged about 95 percent MoS_2 (Eardley-Wilmot, 1925), making the Hunt mine the largest producer of molybdenum in southeastern Ontario. A summary of production figures from 1916 to 1918 are presented in Table 30.

All the ore mined and milled was obtained from underground workings consisting of "approximately 1,800 to 2,000 feet of crosscuts and drifts on four levels between

TABLE 30: Production by Renfrew Molybdenum Mines Ltd.,
from Eardley-Wilmot (1925,p.94)

<u>Year</u>	<u>Ore Mined</u> (tons)	<u>Ore Milled</u> (tons)	<u>MoS₂</u> (percent)
1916	1,200	100	1.29
1917	4,500	3,656	0.75 (approximate)
1918	3,449	3,155	0.50

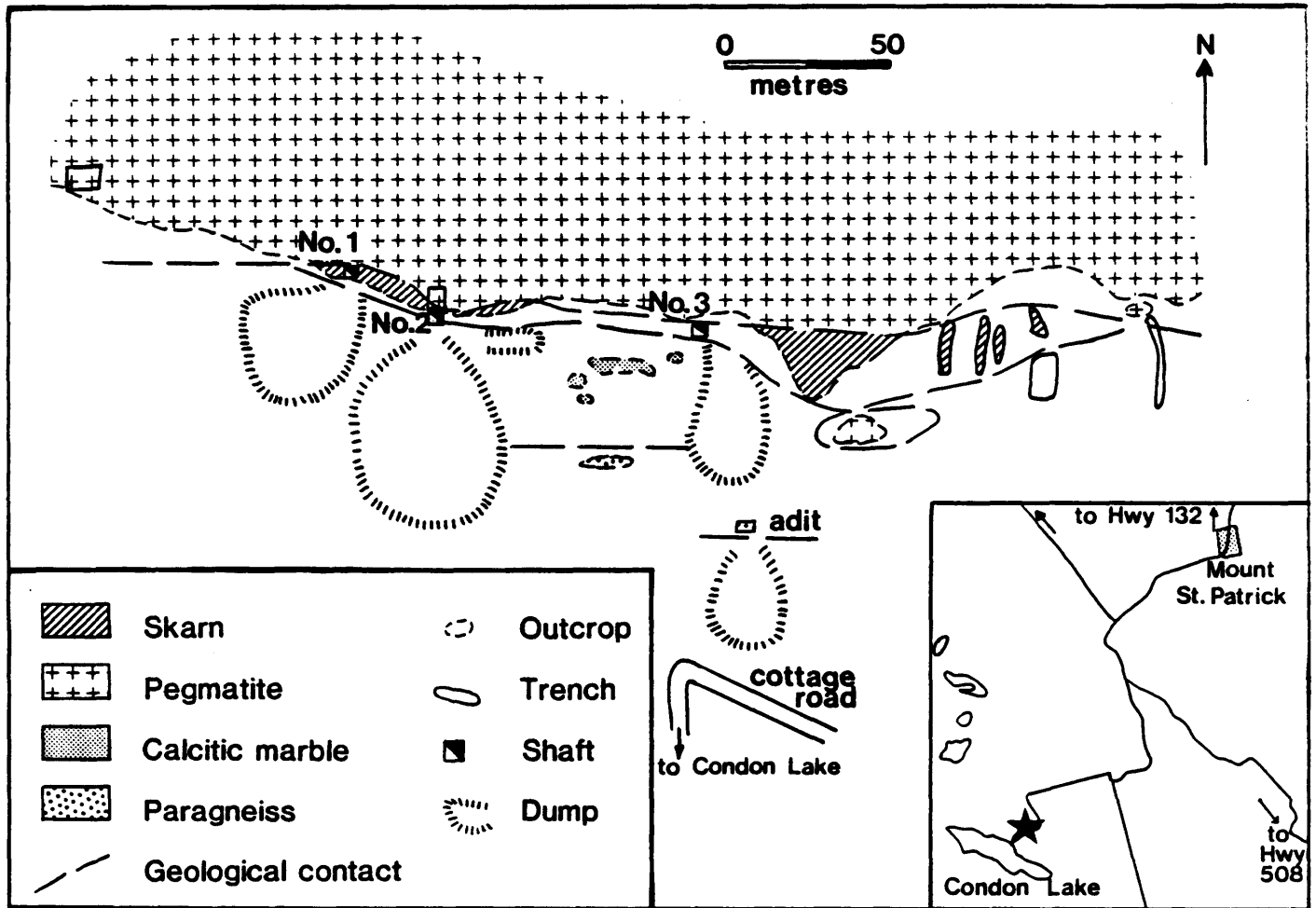


Figure 45: Geology of the former Hunt molybdenum mine, Brougham Township.
Geology by T.R. Carter 1978.

the depths of 40 and 150 feet, and they are connected by about 230 feet of shafts and raises. Besides this, about 400 feet of drifts have been widened out into slopes from 20 to 25 feet wide" (Eardley-Wilmot 1925, p.89)(see Fig.46,47 and 48). These shallow shafts and an adit provide access to the underground workings. Surface workings consist of a series of trenches, open cuts, and strippings that extend along the strike of the deposit for about 200 metres.

Mineralization consists of erratically dispersed coarse flakes of molybdenite, usually associated with massive lenses of pyrite and pyrrhotite, contained within two stratabound bodies of pyroxenite skarn. The upper mineralized zone is reported by Eardley-Wilmot (1925) to average about 2 metres in width, has been traced along strike for about 120 metres, and has been proven downdip for a depth of 45 metres. The dimensions of the lower zone are uncertain. According to Eardley-Wilmot (1925) the lower zone is the richest and good ore was still present when mining operations ceased, but no estimates of grade or tonnage are available.

Geology

The Hunt molybdenum deposit occurs within a sequence of northwesterly-trending marbles and paragneisses along the contact with a large sill-like mass of granitic pegmatite.

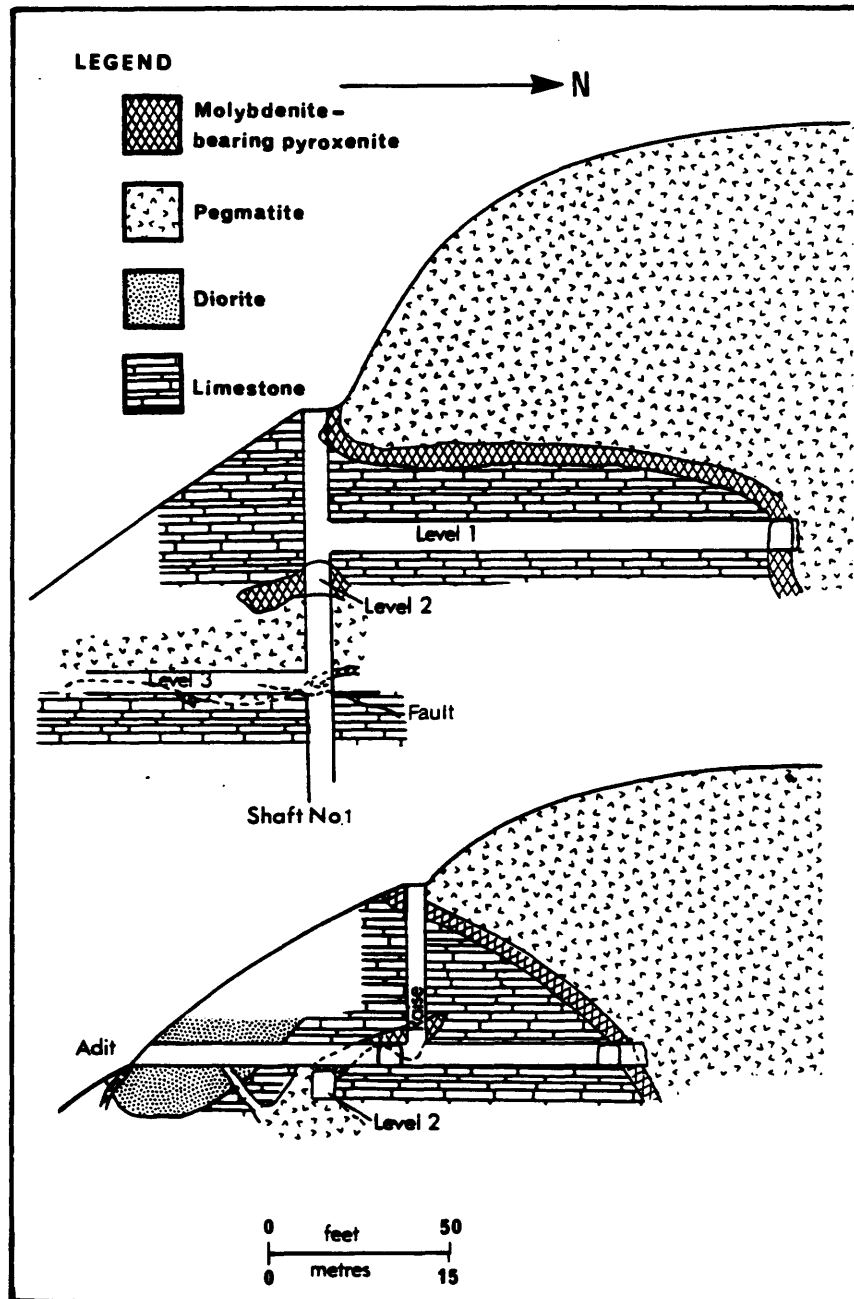


Figure 46: — North-south cross-sections showing contact relationships of molybdenum ore-bodies at the Hunt mine. Adapted from Wilson (1921, p.38).

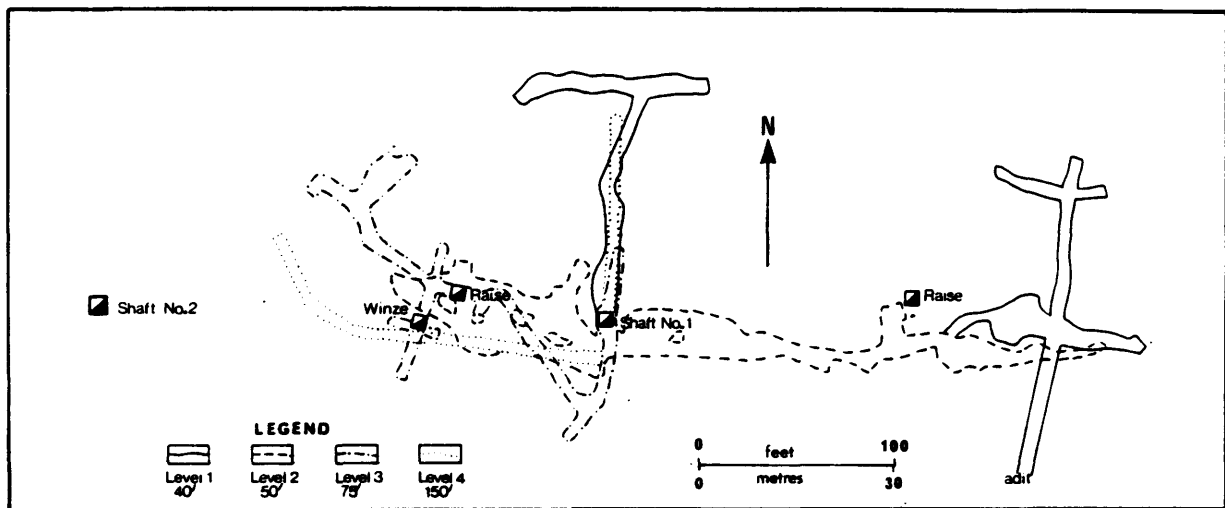


Figure 47 - Plan of underground workings, Hunt molybdenum mine. Adapted from Wilson (1921, p.40).

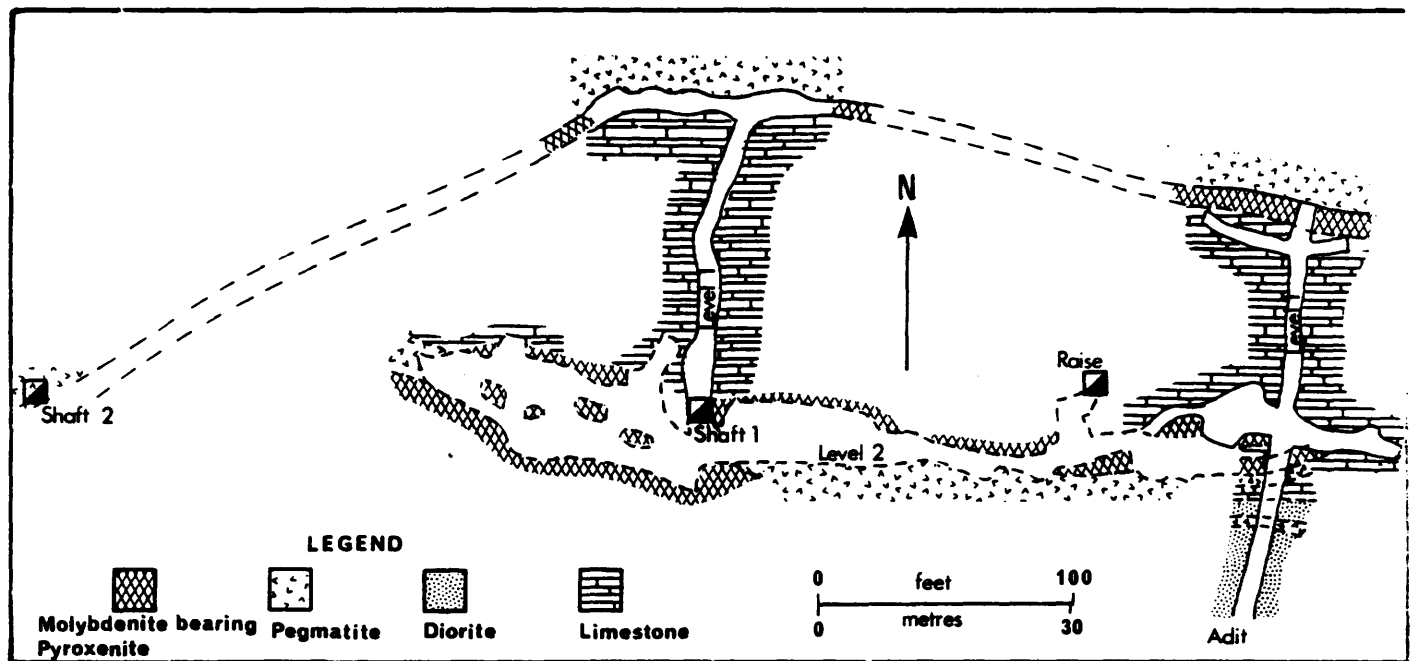


Figure 48 — Plan of No.1 and No.2 levels of the Hunt molybdenum mine. Adapted from Wilson (1921, p.39).

Pyroxenite skarn zones containing disseminated molybdenite, pyrite, and pyrrhotite are developed in the marble along the contact with the pegmatite and a few metres away from the contact (Figs.45 and 46).

Rock types exposed in the vicinity of the deposit include calcitic and dolomitic marble, pegmatite, paragneiss (biotite gneiss, amphibole gneiss, hedenbergite gneiss), and pyroxenite skarn. The marbles are coarse-grained white rocks composed essentially of calcite and/or dolomite with variable amounts of white mica, quartz, and diopside. The pegmatite is a massive, coarse-grained, (3 mm), pink rock composed of a mixture of quartz, microcline, plagioclase, and minor magnetite. The biotite gneiss is a strongly foliated rock composed of fine-grained biotite, quartz and feldspar. The amphibole gneiss is similar, except for the presence of amphibole. Hedenbergite gneiss is reported to be exposed on top of the ridge and is "well-foliated, medium-to-fine-grained, dark green rock which consists entirely of scapolite (mizzonite) and hedenbergite, with only small amounts of sphene, pyrrhotite, and apatite", (Karvinen 1973). The pyroxenite skarn is a massive, coarse-grained, dark green rock that consists essentially of diopside and minor scapolite, tremolite, and microcline, and locally abundant pyrite and pyrrhotite.

Karvinen (1973) prepared several thin sections from samples collected at the former mine-site. Modal analyses of some of these sections are presented in Table 31.

History of Development

- before 1912: Cornelius Hunt discovered molybdenite on the farm of Daniel Hunt, his father. The property was optioned to some American businessmen but was soon dropped.
- 1912-1914: Property optioned by F.R. Aufhammer in late 1912 who sold the option to Algonican Development Company, a Belgian syndicate. After some diamond drilling and development work, the company closed down due to the outbreak of war.
- 1915-1918: Renfrew Molybdenum Mines Limited was formed in about 1915 and operated the property as a mine from 1915 to 1918. The work done consisted of approximately 1,800 to 2,000 feet of cross-cuts and drifts on four levels between depths of 10 and 150 feet, connected by about 230 feet of raises and shafts. In addition, about 400 feet of drifts were widened into stopes from 20 to 25 feet wide. Total production amounted to

TABLE 31: Modal analyses of some thin sections of selected rock types. Taken from Karvinen, 1973, Table AIII.

Skarn			Hedenbergite gneiss		
	<u>3-3-10</u>	<u>3-3-20</u>		<u>3-3-56</u>	<u>3-3-57</u>
diopside	92	38	hedenbergite	50	50
scapolite	3	45	scapolite	38	43
tremolite	tr	0	calcite	4	1
po-py	4	1	hornblende	0	3
microcline	0	15	sphene	2	3
phlogopite	tr	0	microcline	4	0
calcite	1	0	chlorite	1/2	0
sphene	tr	1/2	quartz	0	0
chlorite	1	0	apatite	tr	tr
			po-py	1	tr
Pegmatite			Marble		
	<u>3-3-17</u>		<u>3-3-80</u>	<u>3-3</u>	
quartz	40		calcite	7	87 1/2
microcline	35		dolomite	92	10
plagioclase (An ₂₃)	25		muscovite	1	tr
magnetite	tr		quartz	0	2
			graphite	tr	1/2
			pyrite	tr	0

96,660 pounds of concentrates, 85 percent of which averaged about 95 percent MoS_2 . All the ore, except 55 tons sent to Ottawa, was treated in a 30 ton per day concentrator at the site.

1965: Self-potential survey by New Far North Exploration Ltd.

References:

- Carter et al (1980, p.144-149)
- Eardley-Wilmot (1925, p.89-94)
- Freeman (1946, p.14)
- Johnston (1968, p.58)
- Karvinen (1973)
- MacKenzie et al. (1916, p.89,90,114,115)
- Meyn and Howarth (1977)
- Parsons (1917, p.291-292)
- Quinn (1952, p.61-62)
- Satterly (1946b, p.79)
- Sutherland et al. (1915, p.156)
- Timm (1914, p.69-71)
- Vokes (1963, p.145-150)
- Walker (1911, p.47)
- Wilson (1921, p.36-41)

SPAIN MOLYBDENUM MINE (PAST PRODUCER)Location and Access

The Spain molybdenum deposit is located about 10 km by road northeast of the village of Griffith, about 200 metres east of Highway 41 (Fig.49). It lies within lot 31, Con.IV, Griffith Township, in NTS quadrant 31F/6 at UTM co-ordinates 5016455N, 337450E.

Economic Features

The property was operated as a mine intermittently from 1915 till 1919 by W.J. Spain (1915-1918) and the Steel Alloys Corp. (1918-1919). Total production amounted to 8,067 pounds of pure MoS_2 , 600 pounds of concentrates of unknown grade, and about 5 tons of picked flake (about 90% MoS_2). A summary of production from 1916 to 1918 is presented in Table 32.

Most of the ore was mined from a small open pit which at the time of closing measured 23 by 37 metres and was about 15 metres deep. There are at least two other small pits on the property, a small shaft near the pit reported to be about 15 metres deep (Eardly-Wilmot, 1925), a system of trenches, and a small test shaft (Fig.49,50).

At the time of closing of the mine it was reported that "a wide pocket of high-grade and more concentrated ore was

TABLE 32: Molybdenum ore shipments from the Spain molybdenum mine to the Mines Branch, Ottawa (Eardley-Wilmot, 1925,p.102)

<u>Year</u>	<u>Pounds of ore</u>	<u>MoS₂ (percent)</u>
1916	61,198	1.09
	1,638	11.13
	7,151	84.20 (hand-picked flake, not treated)
1918	66,390	2.10

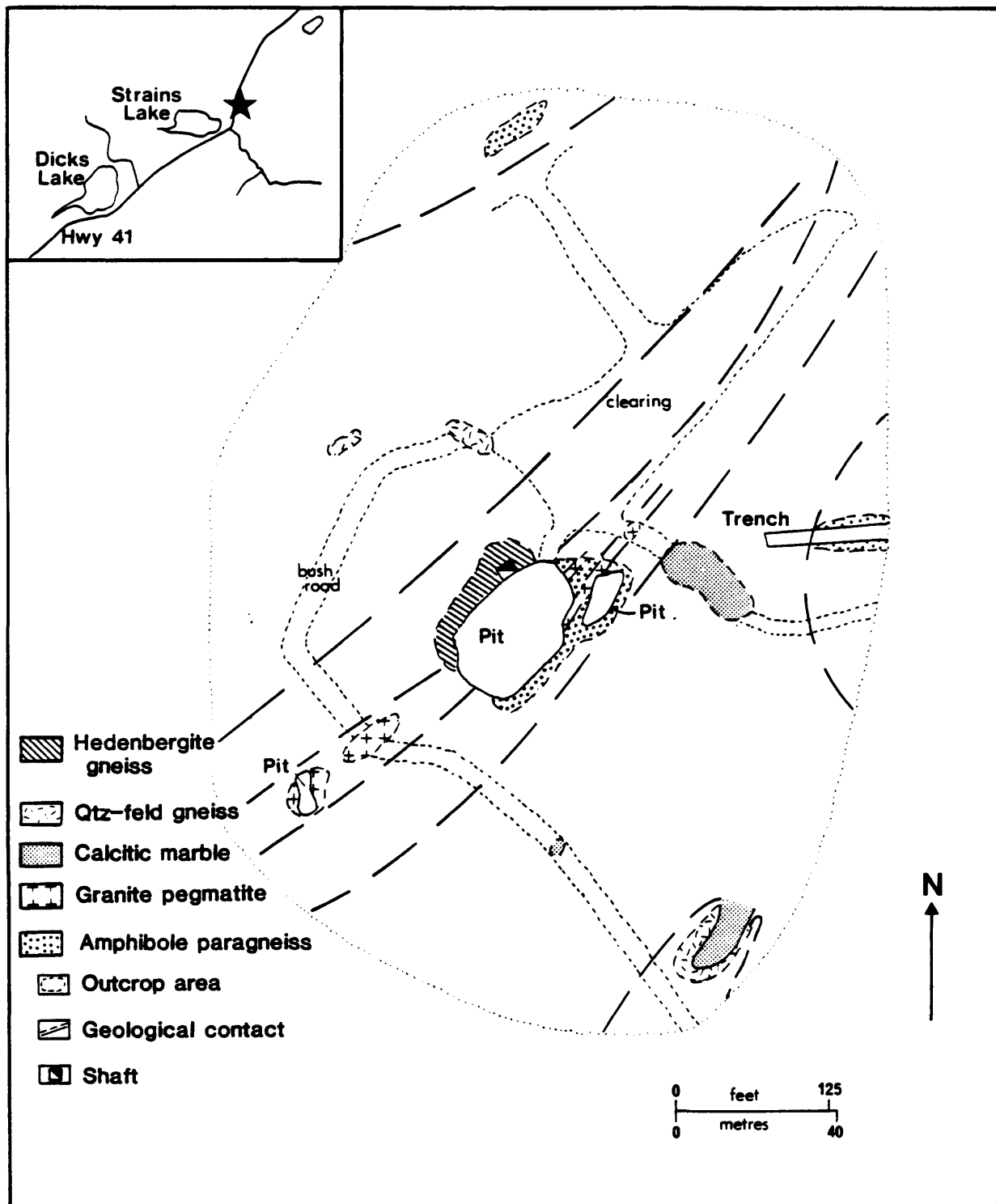


Figure 49: Geology of the Spain molybdenum deposit. Geology by T. Carter 1977.

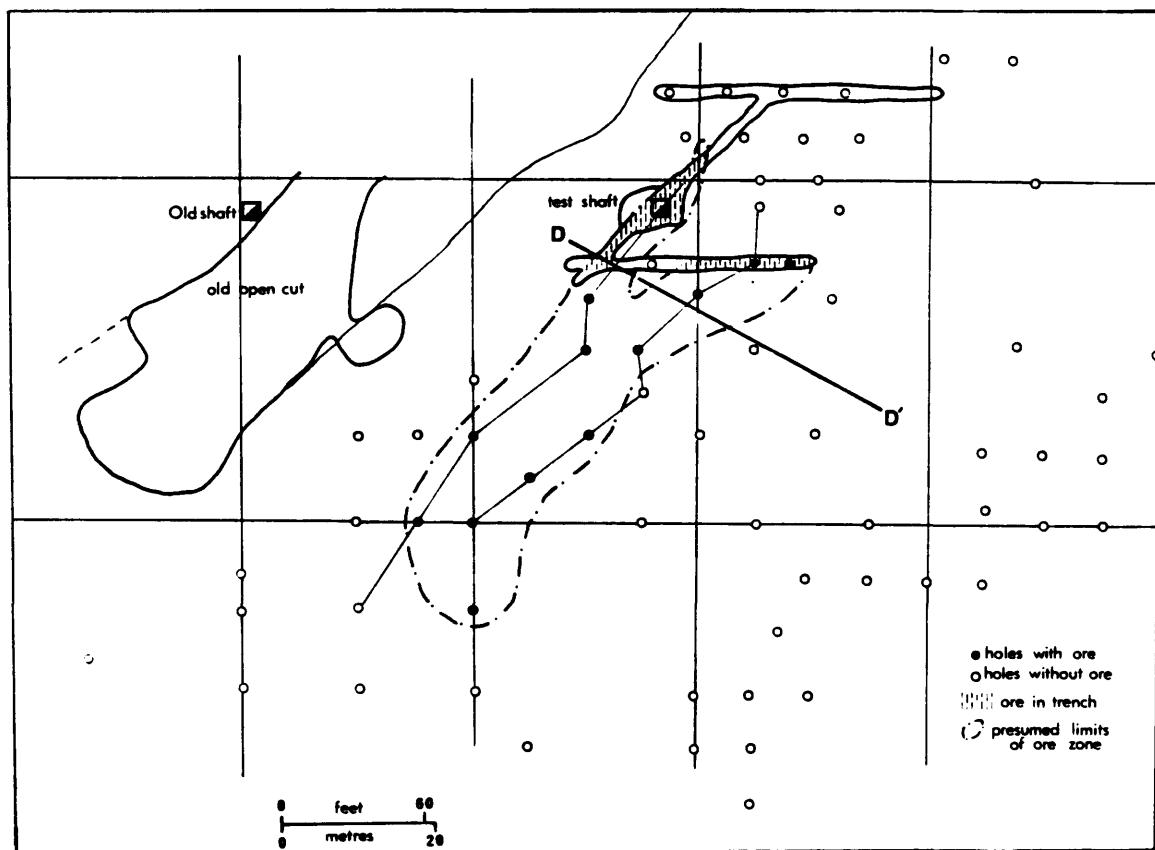


Figure 50: Location of mineralized zinc indicated by diamond drilling by North American Molybdenite Corporation Limited from a map by Horwood (1940)

encountered at the bottom of the northwest face" of the main pit (Eardly^e-Wilmot, 1925). The size and grade of the mineralization was not determined. A separate, parallel zone of mineralization was discovered east of the Spain workings by North American Molybdenite Corp. Ltd. in 1939-1940 (Fig. 50). According to Horwood (1940) this mineralized zone forms a stratabound lens within "pyroxene limestone" that measures 61 by 17 metres with an average thickness of 1.5 metres. Diamond drilling indicates the lens contains approximately 5200 tons of material, of unspecified grade.

Geology

The Spain molybdenum deposit occurs within a northeast trending sequence of interlayered marble and siliceous and calcareous gneisses near the eastern margin of a large granitic intrusion. The stratified rocks generally dip shallowly to the southeast.

Calcitic marble, quartz-feldspar gneiss (sandstone?), amphibole paragneiss (mudstone?), hedenbergite paragneiss (calcareous mudstone?), and granite pegmatite are exposed in the vicinity of the former mine workings (Fig. 49). The quartz-feldspar paragneiss is the lowermost unit and is a well-foliated rock composed essentially of quartz, feldspar and biotite that contains minor interlayers of pegmatitic

granite. It grades into the overlying hedenbergite gneiss which is a well-foliated, medium-grained, homogeneous rock composed essentially of hedenbergite, microcline, oligoclase, and quartz (Karvinen 1973). Amphibole paragneiss overlies the hedenbergite gneiss and is a black, fine-grained, massive rock composed essentially of hornblende and plagioclase. The marble is the uppermost unit and contains coarse-grained white to pink calcite and less abundant dolomite with minor diopside and phlogopite. Pegmatite dikes are abundant in the vicinity of the main pit and vary from a few centimetres to a couple of metres in width. Two types are distinguished by Karvinen (1973). Unmineralized pegmatites are white to pink, very coarse-grained rocks composed of smoky quartz, microcline, and plagioclase. Some pegmatites contain disseminated molybdenite, pyrite, and pyrrhotite and are generally rusty-weathering rocks composed of smoky quartz, microcline, plagioclase, and hedenbergite. These mineralized pegmatites occur only in hedenbergite gneiss (Karvinen 1973).

A slightly different stratified succession is indicated by diamond drilling around the second mineralized zone (Fig. 51). According to Horwood "injected biotite gneiss" is the lowermost unit, overlain by pyroxene limestone, with "Grenville limestone" forming the top of the sequence. The units are intruded by masses of pegmatite. The biotite

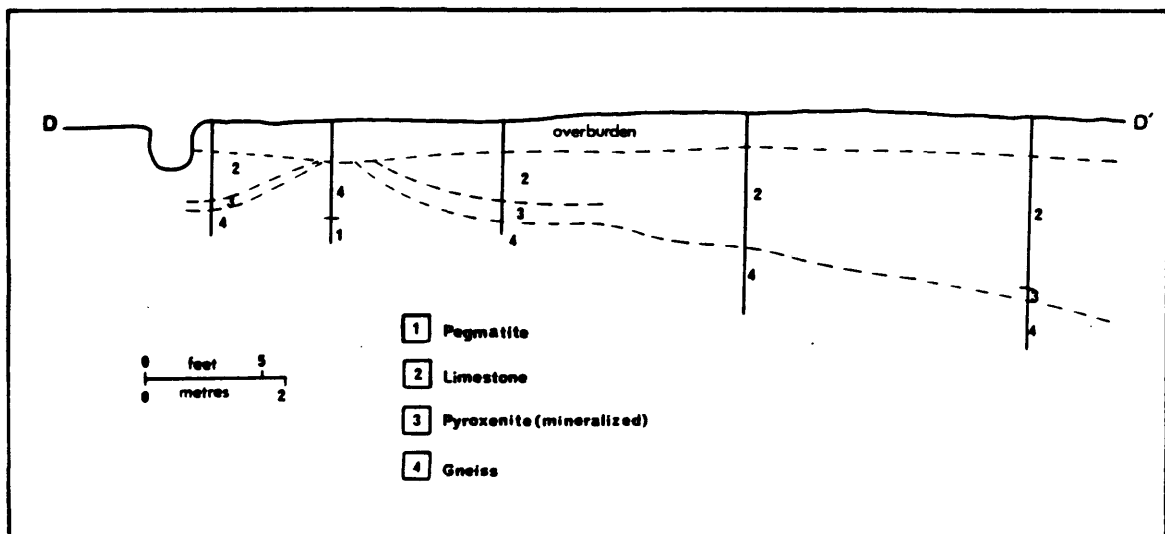


Figure 51: Geological cross-section through the North American Molybdenite mineralized zone at the Spain molybdenum deposit. Adapted from Horwood (1940).

gneiss and pyroxene limestone are probably correlative with the amphibole and hedenbergite paragneisses mapped by Karvinen (1973) and the author near the mine workings.

Mineralization: Mineralization consists of erratically distributed coarse flakes of molybdenite, generally associated with disseminated and massive pyrite and pyrrhotite. The mineralization occurs within hedenbergite gneiss and pegmatite dikes cutting the mineralized gneiss in the vicinity of the mine workings, and within 'pyroxene limestone' in the mineralized zone outlined by North American Molybdenite Corp. According to Wilson (1921) and Eardley-Wilmot (1925) the sulphide mineralization in the Spain mine was confined to narrow veins and joints in the host rocks, especially in the pegmatite dikes. Volkes (1963) described a strong northeast-striking joint set cutting the gneisses that hosts narrow pegmatite veins. Some of the pegmatite veins are reported to contain masses of pyrite, pyrrhotite, and molybdenite along central openings in the veins, interstitial to the silicates. The mineralized veins are erratically distributed and widely spaced, making accurate estimates of average grade nearly impossible.

Microscopy: Modal analyses by Karvinen (1973) of thin sections of hedenbergite gneiss (sections 3-1-11, 3-1-24)

and amphibole paragneiss (3-1-16) are presented in Table 33. The hedenbergite gneiss "consists predominantly of zoned oligoclase ($An_{27}-An_{17}$), hedenbergite, microcline and quartz with lesser amounts of sphene, calcite, hornblende, scapolite, apatite, epidote, chlorite, pyrite, and pyrrhotite. The oligoclase grains commonly contain cores of scapolite (mizzonite) which also occurs along feldspar grain boundaries. Microcline is present only in layers containing quartz, and textures seen in thin sections suggest that the microcline has partly replaced plagioclase where it occurs near quartz grains. The thin layers in the gneiss consist mainly of microcline-quartz-oligoclase-hedenbergite and of oligoclase-hedenbergite-scapolite. The hedenbergite is normally partly altered to a pleochroic (pale to dark green-brown) hornblende. Pyrite and pyrrhotite occur as small, rounded grains disseminated throughout the gneiss".

The amphibole gneiss, according to Karvinen, "consists mainly of hornblende and zoned oligoclase ($An_{30}-An_{25}$) with small amounts of scapolite, biotite, sphene, chlorite and pyrrhotite. The hornblende is pleochroic from pale green-brown to dark green-brown, and is optically identical to the hornblende which rims the hedenbergite in the hedenbergite gneiss. The oligoclase is slightly altered; small irregular grains of scapolite (mizzonite) occur

TABLE 33: Estimated modal compositions (in percent) of some thin sections of hedenbergite paragneiss (3-1-11, 3-1-24) and amphibole paragneiss (3-1-16)

	<u>3-1-11</u>	<u>3-1-24</u>	<u>3-1-16</u>
plagioclase	52	30	53
microcline	5	40	-
hedenbergite	22	10	-
quartz	17	15	-
sphene	1	1	-
calcite	1	1	-
hornblende	0	2	40
scapolite	2	0	2
apatite	0.5	0.5	-
pyrrhorite (py)	tr	tr	0.5
biotite	-	-	0.5
chlorite	-	-	3

interstitial to the plagioclase. Quartz and microcline are absent".

History of Development

1912-1915: The mine was opened by Mr. Joseph Legree. No production is reported (Eardley-Wilmot, 1925).

1915-1919: The property was acquired by W.J. Spain in 1915 who excavated a large open pit about 23 metres wide, 37 metres long, and from 3 to 8 metres deep, a shaft measuring about 2 x 3 metres and 15 metres deep, and several small pits. In 1916, Mr. Spain built a 50 ton capacity mill which operated intermittently for about 2 1/2 months. Approximately 5 tons of picked flake containing about 90 percent MoS_2 , was reported to have been shipped to the United States in 1915. In 1918 the mine was taken over by the Steel Alloys Corporation. During 1916 and 1919 approximately 68 tons of ore were shipped to the Mines Branch, Ottawa, from which 8,067 pounds of pure MoS_2 were obtained (see Table 1). In 1919 about 40 tons of ore were treated in the Spain mill and 600 pounds of

concentrates were produced and sent to the Tivani Steel Works. Mining operations ceased in December, 1919 (Eardley-Wilmot, 1925).

- 1939-1940: Second mineralized zone outlined as a result of stripping, trenching, and diamond drilling by North American Molybdenite Corp. Ltd. (Horwood, 1940).
- 1965: Self potential survey completed by New Far North Exploration Ltd. (Assessment Files Research Office, Tech. File No. 63-1555).

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- Carter et al.(1980, p.159-164)
 Eardley-Wilmot(1925, p.101-103)
 Horwood(1940)
 Johnston (1968, p.61)
 Karvinen(1973)
 Mackenzie et al.(1916, p.116-117)
 Meyn and Howarth (1977)
 Parsons(1917, p.297)
 Satterly(1945, p.83)
 Themistocleous(1980, p.55-59)
 Vokes(1963, p.155-158)
 Wilson(1921, p.41-43)

MADAWASKA URANIUM MINE

by

Ralph Alexander
Madawaska Mines Ltd
Bancroft, Ontario

Location and Access

The Madawaska uranium mine, formerly owned and operated by Madawaska Mines Ltd., is located about 8 km west of the town of Bancroft, about 1 km north of Highway 28 (Fig. 52). The mine workings and plant are situated in the north parts of lots 16 and 17, Con. 11, Faraday Township, approximately at UTM coordinates 4989200N, 269600E, in NTS quadrant 31F/4. The company owns the mineral rights to 2982 acres of land surrounding the mine site.

Economic Features

The Madawaska uranium mine has been the object of two mining programs since the first discovery of mineralization at this location in 1949. Between 1957 and 1964 Faraday Uranium Mines Ltd. recovered 6,155,505 pounds of U_3O_8 from 2,856,587 short tons of ore milled for a recovered grade of 0.108 percent U_3O_8 , or 2.15 pounds U_3O_8 per ton. From 1976 to July, 1982, Madawaska Mines Ltd. recovered 3,342,863

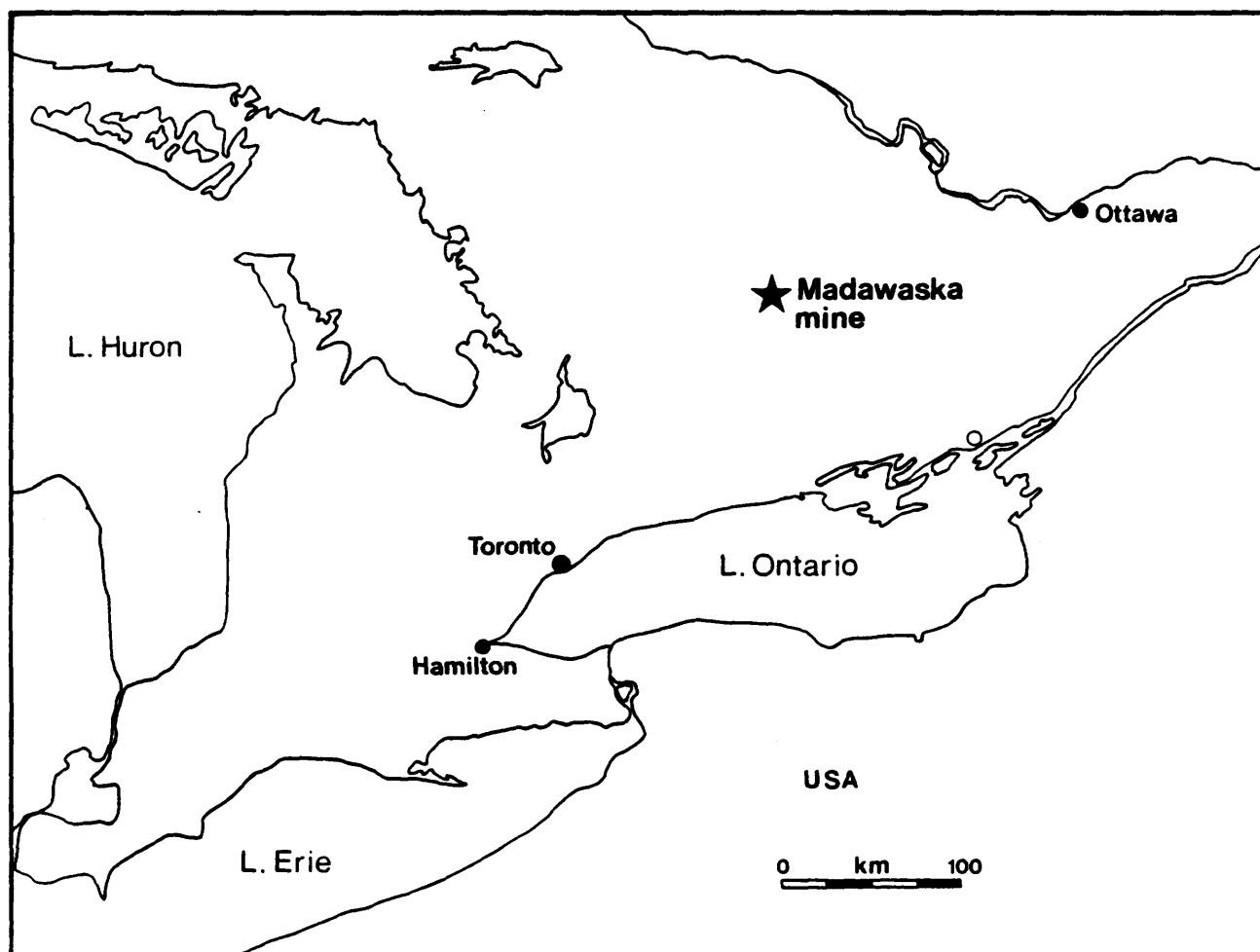


Figure 52: Location of the Madawaska uranium mine.

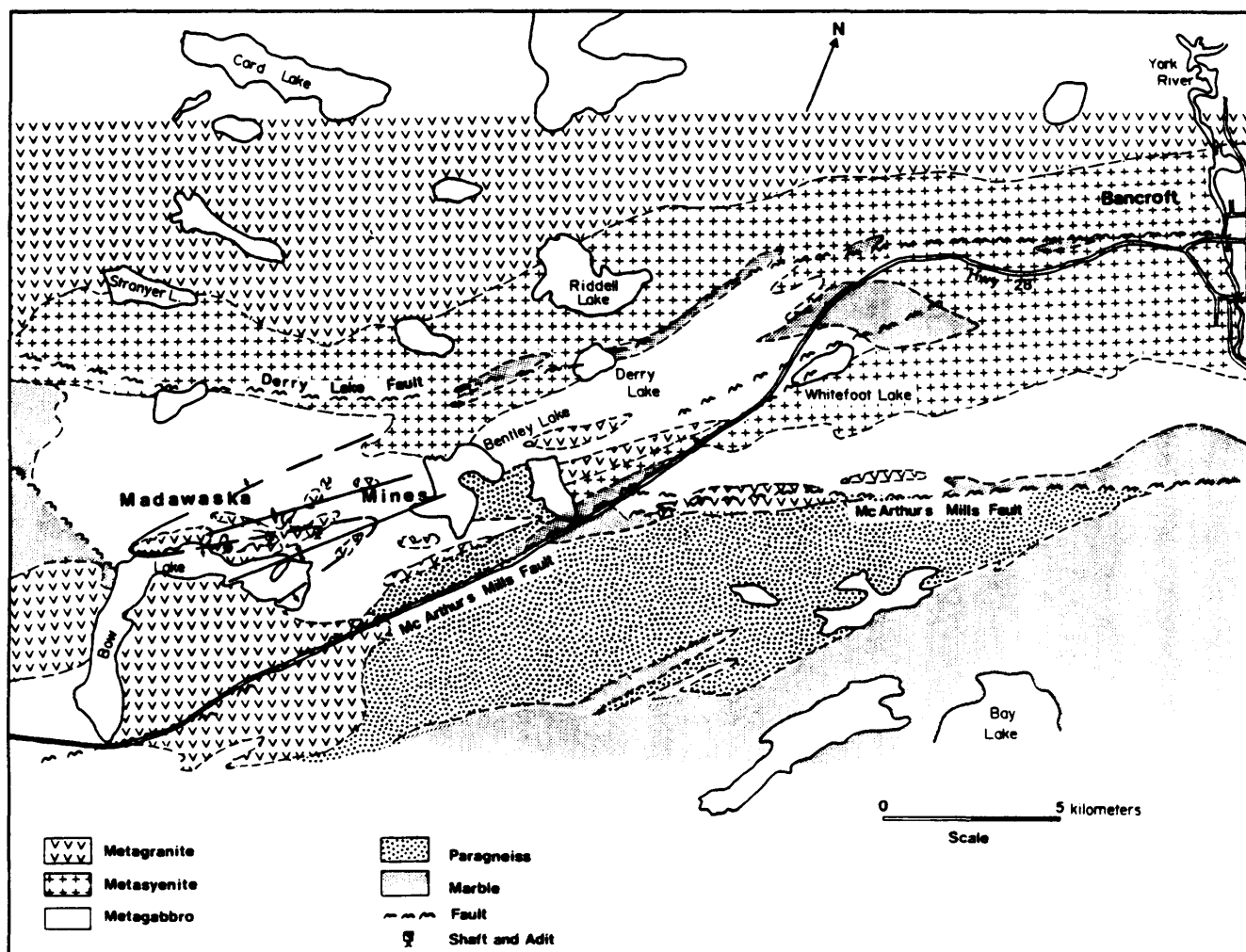


Figure 53: General geology around the Madawaska uranium mine (adapted from Hewitt 1957).

pounds of U_3O_8 from 2,152,548 short tons of ore milled for a recovered grade of 0.078 percent U_3O_8 , or 1.55 pounds U_3O_8 per ton. Total production between 1957 and 1982 amounts to 9,492,171 pounds of U_3O_8 from 5,009,135 short tons of ore milled for a recovered grade of 0.095 percent U_3O_8 or 1.89 pounds U_3O_8 per ton.

In the first period of production, ore was mined principally from the upper five levels; during the second period, ore was derived mainly from the lower five levels. Cut off grade during the first production period was 0.07 percent U_3O_8 . During the second production period cut-off grades were 0.04 percent (1976-77), 0.05 percent (1978), 0.06 percent (1979), 0.07 percent (1980), and 0.08 percent (1981-82). The increase in cut-off grades during this period were a direct result of inflation and rising costs. Mining was by cut and fill, long hole, open panel, or shrinkage, with emphasis on the first two methods.

The deposit was developed by a production shaft to a depth of 1651 feet, with drifting on 10 levels from adit level to the 1350 level. Underground development in drifts, cross-cuts, and raises, totalled 188,756.5 linear feet to May 31, 1982. Underground diamond drilling completed from 1954 to June 30, 1982 totalled 758,911 feet in 4,899 holes. An additional 309 diamond drill holes were

drilled from the surface for a total length of 134,580 feet.

Mineralization is contained within a complex network of pegmatite dikes which occupy a zone approximately 6000 feet long and 500 feet wide and extend to a depth of at least 1500 feet (Masson and Gordon, 1981). Ore shoots typically vary from 50 to 350 feet long, 5 to 250 feet wide, and 50 to 300 feet high. Grades are irregular over any distance greater than 6 feet. The largest ore zone mined was the 852 stope on the 1200 level which produced 208,787 tons of ore with an average grade of 0.103 percent U_3O_8 . The richest was the 407 stope which produced 22,632 tons of ore grading 0.272 percent U_3O_8 .

Mineral reserves at December 31, 1981 are presented in Table 34. The estimates are based on a cut-off grade of 0.08 percent U_3O_8 , tons in situ, no dilution factor applied, with a ten percent margin of error. Dilution during mining varied from 15 to 50 percent depending on the complexity of the ore shoot and method of mining employed.

Geology

The Madawaska uranium mine occurs along the northeastern margin of the Central Metasedimentary Belt in southeastern Ontario, within a zone of intense deformation parallelling the contact with the Ontario Gneiss Segment.

TABLE 34: Mineral Reserves at the Madawaska Uranium Mine
at December 31, 1981

	Short Tons	Percent U_3O_8	Lb. U_3O_8
Measured	385,193	0.143	1,098,283
Indicated	450,988	0.158	1,427,195
Total	836,181	0.151	2,525,478

Principal rock types include granitic and syenite gneiss, metagabbro, mafic paragneisses, marble and calc-silicate rocks, and pegmatite (Fig. 53). The rocks form a complex sequence with a dominant northeast trend and a regional lineation to the southeast (Bedell, 1981). Several major faults cut this sequence of rocks. The McArthurs Mills fault is a normal, south dipping fault zone which passes about 1 km south of the mine adit and has been traced for about 45 km. The Derry Lake fault lies about 1 km north of the mine and has been traced from Bancroft to a point 3 km northwest of Bow Lake where it encounters a third fault which has been traced for about 6 1/2 km north east of Bow Lake.

Gneissic granite and syenite form northeast trending belts north of the mine area, with minor bands of marble occurring within the syenite. Coarse-grained to pegmatitic granite, with minor gneiss, occurs to the south. The mine area itself is dominated by metagabbro with abundant mafic paragneisses and some lenticular areas of marble and quartzite. Pegmatites are common towards the southern margin of this central area. The paragneisses are variable in composition, composed essentially of plagioclase, mica, quartz, and hornblende. They are generally strongly foliated to schistose, sometimes with some banding apparent. Marble occurs mainly in the hanging-wall or southeast part of the mine, and the easterly nose of a

large synform. The marble varies from white to grey, medium to coarse-grained, and is impure, with dolomitic or siliceous portions containing diopside, tremolite, phlogopite, and minor serpentine. The marble and paragneisses are often interlayered in a lenticular, conformable manner. Quartzite is the least abundant rock in the mine area and generally occurs as small, discontinuous lenses within paragneiss.

The Madawaska mine occurs within the Faraday metagabbro complex. The metagabbro is foliated and varies from relatively fresh gabbro to hornblende/augite schist. It is generally a medium to coarse-grained hornblende-plagioclase schist. Accessory minerals present include quartz, scapolite, chlorite, mica, sphene, magnetite, pyrite, and ilmenite. The least altered portions of the intrusion are indicative of an anorthositic gabbro-diorite with alkalic pyroxene (Bedell and Schwerdtner, 1981).

Veins and fracture fillings of purple anhydrite, minor gypsum, pink calcite, augite, and minor pyrite, cut all other rock types in the mine. Little (1969) favoured their source to be late fractionation of primary magma that contained calcium sulphate.

Pegmatite: Pegmatite is a local name that refers to numerous dikes, lenses, and sills of syenite, granite, and

pegmatite nepheline syenite that occur in the mine. It is the most important rock type in the mine as it contains all the uranium except minor amounts in the first few inches to two feet of the country rock where the contact is not sharp. The pegmatite and metagabbro contacts are usually sharp with thin alteration rims. The pegmatite occurs as tabular and irregular masses that are widely variable in size. The larger masses can vary from 300 feet to several thousands of feet in length and 10 to 200 feet in width, while the vertical continuity has reached 1000 feet.

The granite pegmatite is composed of pink to red feldspars (microcline, microcline perthite, albite), pyroxene and amphiboles (2-40 percent), often altering to chlorite, and quartz (5-20 percent). The quartz is generally clear, but may be smoky or milky. Accessory minerals are magnetite, zircon, sphene, apatite, tourmaline, hematite, calcite, anhydrite, pyrite, marcasite, and the uranium minerals. The main uranium minerals are uraninite, uranothorite, thorite, allanite, and secondary uranophane. Hematite is the most important accessory mineral as it generally indicates the presence of uranium mineralization.

Ferromagnesian minerals are irregularly distributed in the pegmatites and often occur as concentrations, especially along contacts or near large inclusions of wall

rock. The ferromagnesian mineral content of the pegmatite is often an indication of the uranium content, although it is not as reliable as the hematite. The better grade ore usually contains ten percent or more ferro-magnesian minerals.

The pegmatites are fractured or jointed and locally are brecciated. Fracturing and shattering due to radioactivity is often observed in the richer ore. The better grade ore is often friable as a result.

Some of the larger pegmatite bodies have zones of vugs that are often lenticular parallel to the long axis of the body. The zone can range from a few inches to several feet wide and up to 70 feet long. The actual vugs are small, a fraction of an inch to several inches in diameter, but in exceptional cases are several feet wide and tens of feet long. Well formed crystals of calcite, gypsum, quartz, pyrite, goethite, limonite, hematite, fluorite, chalcopyrite, and uranophane often rim the voids. The pegmatite surrounding the vuggy zones often has little uranium but the zone may sometimes contain sufficient uranophane to make ore. The vugs are more common in the upper levels of the mine.

Structure: The distribution of the pegmatite indicates an overturned synform, plunging 50 degrees southwest and

flattening to 35 degrees at depth (Figs. 53,54,55). The synform is closed to the east and the axial plane strikes east-northeast and dips generally 45 to 50 degrees southeast. About 500 feet north of the north limb of the synform is a less well defined limb of an antiform dipping nearly vertically to 70 degrees northwest. The structure has been explored to the southwest for 3000 feet on the upper levels and decreasing lengths to 800 feet on the 1200 foot level. There are also subsidiary zones of pegmatite dikes and veins between the two main limbs of the synform.

The intensely metamorphosed sedimentary rocks generally strike east-northeast but the foliation and layering can be oriented in any direction on a local scale. The lenticular beds and possible plastic flow of the marble could account for the discontinuous lithology and lack of marker beds to support the synclinal structure.

According to Bedell (1981) the pegmatites intruded in and around the metagabbro late in the Grenville orogeny and generally followed the regional strain pattern. The pegmatites are usually foliated parallel to their strike. The south limb follows the south boundary of the metagabbro, which coincides with the regional foliation. No post pegmatite folding or faulting has been recognized in the mine.

Ore shoots: All of the ore occurs within pegmatite and

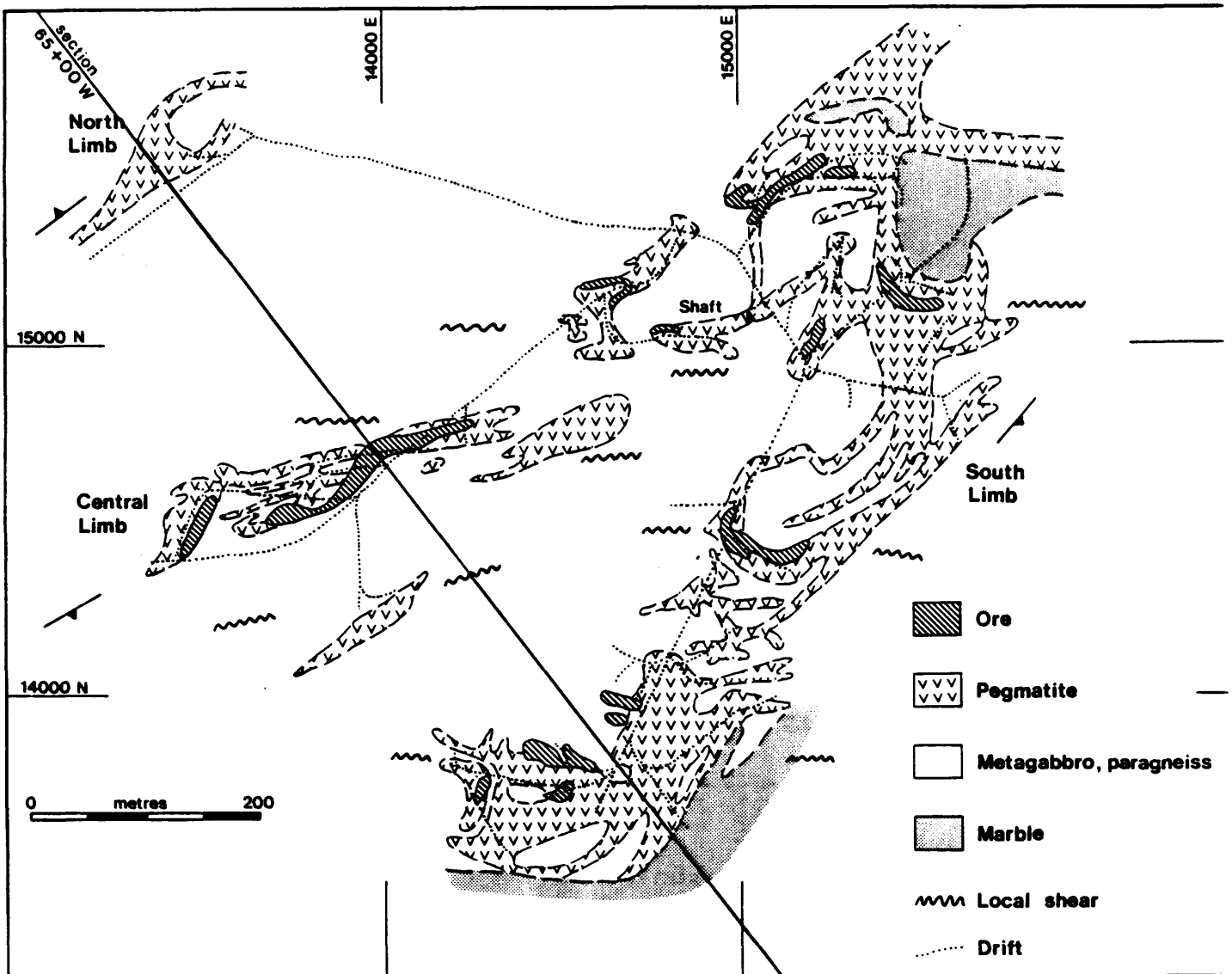


Figure 54: Geology of 450' of Madawaska Uranium mine

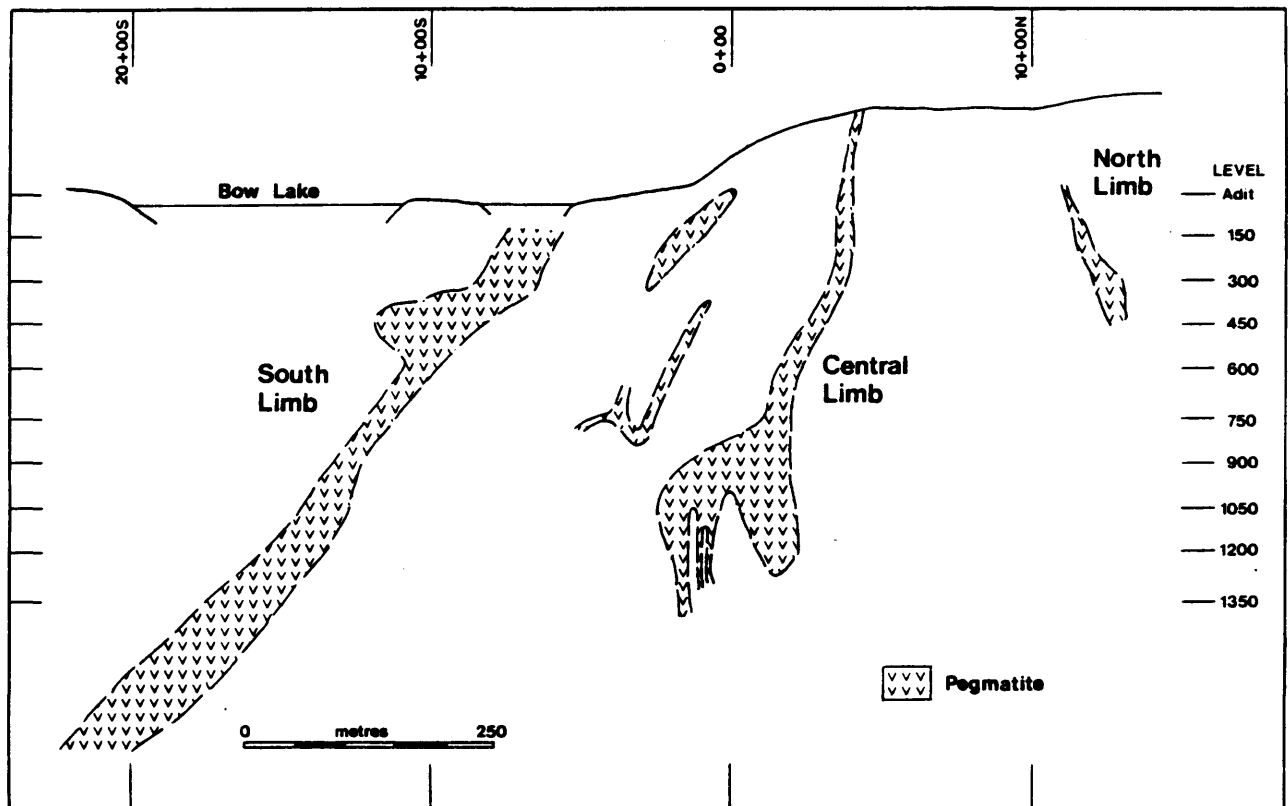


Figure 55: Schematic cross-section along 65+00 of the Madawaska Uranium Mine

consists of areas enriched with uranium. Most of the pegmatite contains uranium minerals but only parts constitute ore. Ore shoots are randomly located within the pegmatite and grades are generally irregular.

Concentrations of uranium in the larger pegmatites frequently occur along and parallel to the contacts, or are medially located. The medial ore shoots can have any shape and attitude, parallel or transverse to the strike and occasionally with a definite rake. The smaller pegmatites, a few inches to 6 feet wide, often give the highest assays for uranium. This trend is more prevalent below the 1050 level, nonetheless the largest stoping area is located on the 1200 level.

Satterly (1956) identified three classes of ore shoots; i) leucogranite, ii) pyroxene-granite or syenite granite, and iii) magnetite or magnetite-pyroxene lenses in the pegmatite. Most orebodies mined in the last production period were in the former two groups. The better grade ore shoots are usually indicated by increased amounts of hematite and increased frequency of mafic crystals or xenoliths. Other less reliable visual indications of increased uranium are abundant magnetite, red flecking or staining of quartz, friability, and granitic rather than pegmatitic texture.

History of Development

The late A.H. Shore found the showing which led to the mine in 1949 on lot 15, Con. A, Faraday Township, near Bentley Lake, about 1 km east of the present Madawaska Mines Ltd. shaft. The property was incorporated as Faraday Uranium Mines Ltd. in 1949 and until 1953 the exploration was limited to trenching and 25 diamond drill holes. Late in 1952 Newkirk Mining Corporation provided financing and technical services and subsequently an aerial scintillometer survey, ground scintillometer and resistivity surveys, and geological mapping were completed. Diamond drilling to this point indicated an ore structure with a length of 2500 feet and depth to 500 feet.

Underground development commenced in September 1954 with the first adit collared into a steep hill on the south shore of Bow Lake, with two other adits started shortly after. During the summer of 1955 an exploration shaft was sunk to a depth of 210 feet from the middle adit to quickly explore the 150 foot level while a production shaft was sunk from the easterly adit. In September 1955 the underground development and diamond drilling had confirmed the presence of 1,660,980 short tons of ore grading 0.112 percent U_3O_8 . The production shaft was completed in October 1956 to a depth of 863 feet with five production levels established at 150, 300, 450, 600 and 750 feet below the adit elevation.

A contract for the delivery of uranium concentrates containing 2,920,000 pounds of U_3O_8 by March 31, 1962 was signed in January, 1956 with Eldorado Mining and Refining Limited (now Eldorado Nuclear Limited). The construction of the concentrator was started in March, 1956 and milling began in April, 1957. An agreement was reached to custom mill ore from the adjoining mine of Greyhawk Uranium Mines Limited which had received a contract to supply 1,500,000 pounds of uranium oxide to Eldorado Mining and Smelting Ltd. Unfortunately the Greyhawk mine ran out of ore by the end of 1958 after supplying only 108,332 pounds of U_3O_8 , and Faraday Uranium Mines Ltd. took over the contract. In 1958, and 1959, in order to fill both contracts, the production shaft was deepened to 1465 feet and four production levels were added. The mill was averaging 1450 tons per day by early 1959 and peaked at 1650 tons per day by January, 1960. In 1962 the mine received a small share of a new contract with the United Kingdom and later received a portion of the temporary stockpiling program initiated by the Canadian government. The mine closed on June 30, 1964.

Early financing of Faraday Uranium Mines Ltd gave control to Continental Mining Exploration Ltd; later interests brought control to Canadian Faraday Corporation Limited. In December 1963 the mine became Metal Mines Limited, Bancroft Division., In May 1967 Canadian

Consolidated Faraday Limited was formed by amalgamation of Augustus Exploration Limited and Metal Mines Limited. Late in 1966, Federal Resources Limited purchased an option to acquire 51 percent of the Faraday mine property and completed an underground development and drilling program by 1969. The property name was changed to Madawaska Mines Limited in 1975 and was made a joint venture in June 1980.

Early in 1976 a contract for six million pounds of uranium oxide concentrates was signed with Azienda Generale Italiani Petroli (AGIP). The production shaft was deepened to 1651 feet by June 1976 and the mill began production in August at a planned rate of 1500 tons per day for a five day week. Production ceased on July 9, 1982 due to a weak market and cancellation of the contract with AGIP.

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HOLLANDIA LEAD MINE (PAST PRODUCER)

Location and Access

The principal workings of the former Hollandia lead mine are located in lot A, concession VI, Madoc Township, at UTM co-ordinates 4949450 N, 298650 E, in NTS quadrant 31C/12. The deposit can be reached via a gravel road that extends northeast from Hwy 62 at a point approximately 0.9 km north of the village of Bannockburn (Fig.56). The workings are located northwest of the gravel road approximately 3 km from Hwy 62. A short dirt road leads to the main workings.

Economic Features

Mineralization at the deposit consists principally of erratically dispersed grains and elongate masses of galena contained in a calcite vein cutting Grenville country rocks. The vein has been traced over a strike length of about 175 metres by a series of pits and shafts and diamond drill holes. Uglow (1916) reports that the vein occurs discontinuously in outcrops over a strike length of about one mile but diamond drilling completed by Teck Exploration Ltd. indicates the vein terminates or continues only intermittently beyond the principal workings of the former mine. Exposed portions of the vein vary in width from

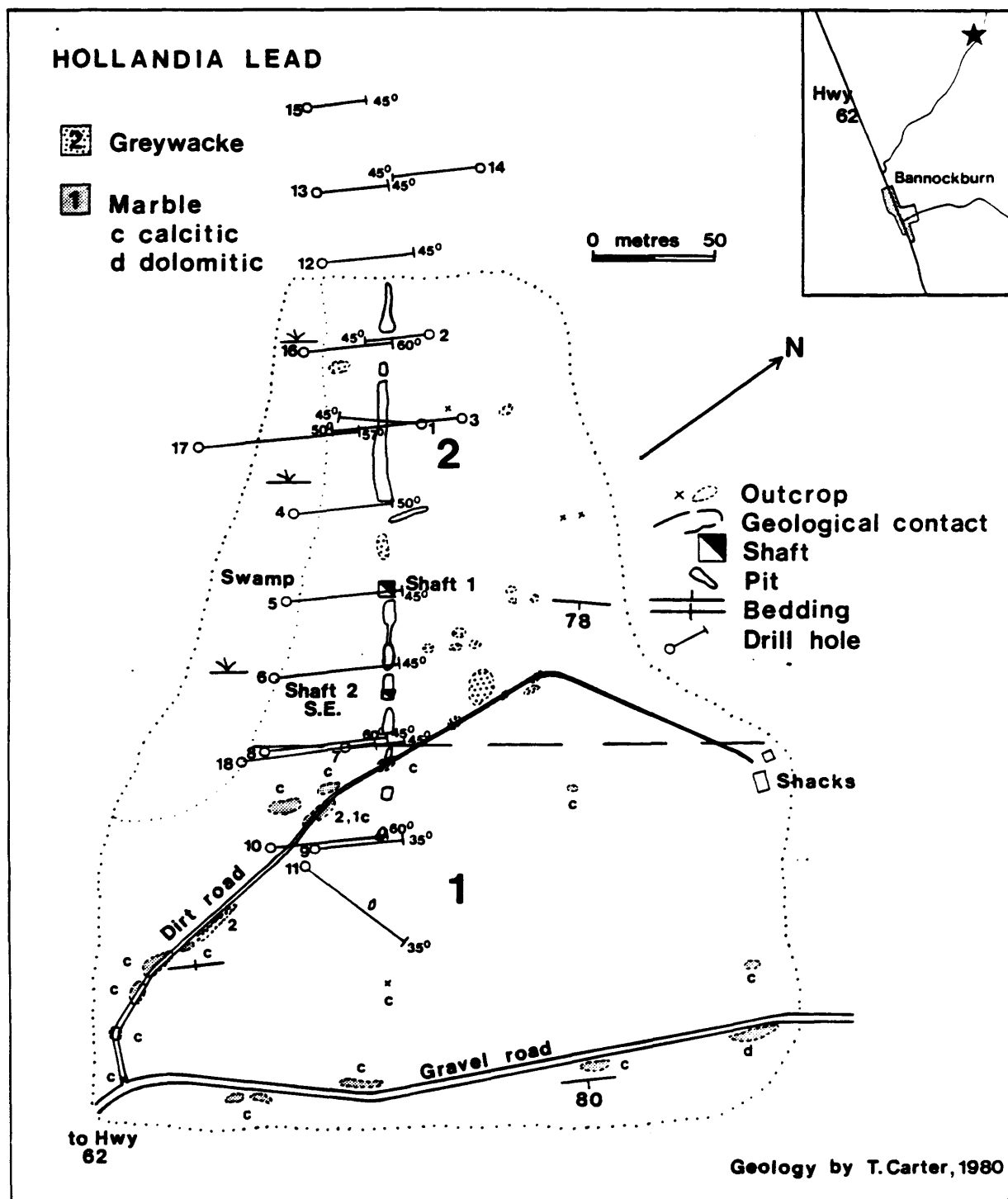


Figure 56: Geology, workings, and location of diamond drill holes at the Hollandia lead mine, Madoc Township.

10 cm to about 1 metre. Alcock (1930) reports the vein had an average width of 4 feet (1.2 m) and was up to 10 feet (3m) wide. The vein has been developed by underground workings to a depth of about 27 metres. According to Alcock (1930) the part of the vein between shaft number 2 southeast (Fig.56) and shaft number 2 northwest (not shown) has been stoped out to surface and high-grade ore was produced from the upper 20 to 40 feet (6-12 m). The lead content of samples taken along the drifts is reported to have varied from one to twelve percent (Alcock, 1930). The diamond drilling by Teck Explorations Ltd. indicates continuation of the vein to a depth of at least 60 metres and mineralized calcite vein material was intersected at a maximum vertical depth of approximately 90 metres in drill hole no. 17. The lead content of diamond drill vein intersections varies from nil to 31.76 percent, with minor amounts of silver (Table 35), illustrating the erratic distribution of mineralization.

Geology

The Hollandia lead deposit occupies a cross-cutting vein near the contact between sequences of marble and siliceous clastic sedimentary rocks. The two sequences are in sharp contact, striking northeasterly and dipping steeply (87 degrees) to the southeast. The metaclastic rocks are

TABLE 35: Mineralized diamond drill intersections,
Hollandia lead deposit. Results obtained
from unpublished files of Teck Explorations
Ltd.

<u>Drill-hole No.</u>	<u>Interval (Feet)</u>	<u>Length (Feet)</u>	<u>%Pb</u>	<u>oz Ag/ ton</u>
1	113 -119.4	6.4	31.76	0.62
2	37.4- 39	1.6	-	-
2	85.5- 87.2	1.7	3.32	-
3	237.4-243	5.6	0.91	trace
4	154 -156	2	2.04	trace
4	156 -158.4	2.4	0.05	trace
5	189.5-191.5	2.0	-	-
5	204.2-206.0	1.8	0.35	-
6	209.6-212.0	2.4	16.28	0.76
7	72.7-73.3	0.6	1.08	trace
8	193.9-194.4	0.5	0.21	trace
8	195.0-196.1	1.1	4.80	trace
17	357.5-360.7	3.2	0.29	-
17	360.7-363.3	2.6	1.16	-

light to dark grey, thinly layered (2 mm - 3 cm), and very fine-grained, and often are rusty-weathering due to the presence of fine-grained disseminated pyrite. They probably represent metamorphosed greywackes. The marbles are calcitic to locally dolomitic in composition and are grey in colour, aphanitic to very fine grained, and are usually well-layered. Thin interbeds of metaclastic rocks are common.

Mineralization is confined to a well-defined calcite vein which strikes northwest, approximately perpendicular to the strike of the country rocks, and dips vertically or steeply (85°) to the southwest. Exposed and mineralized portions of the vein are confined to the metaclastic rocks. Coarse-grained, pink to white calcite is the principal vein mineral with subordinate amounts of galena and rare barite, sphalerite, and pyrite. The galena occurs either as scattered grains or as thin (1-5 cm) massive layers conformable with the banding. According to Alcock (1930) large tabular masses of galena that were mined from the vein usually occurred near the footwall. Exposed portions of the vein exhibit a well-developed banding parallel to the contacts due to variations in grain size and zones of discoloration. Elongate, angular fragments of broken country rocks are common in the vein near the contacts.

Numerous relationships, including the cross-cutting nature of the vein, indicate it occupies a late fault zone. The calcite vein is bounded by micaceous schist and breccia zones in many of the diamond drill intersections and exposed portions of the vein are often bounded by a narrow, rusty zone of crushed rock. The breccia consists of angular fragments of country rock cemented by coarse-grained calcite. Uglow (1916) noted that the walls of the vein are often smooth and slickensided.

Principal exposures

The vein is well exposed between shaft no. 1 and No.2 SE by a series of pits or open stopes. The best exposure is in the stope beside shaft no. 2 SE. Two other shafts occur northwest of shaft no. 1 but these are caved and waterfilled and could not be positively identified by the author.

History of Development

1898: Twenty tons of hand cobbled ore were produced from open cuts by L. Meyer and R.C. Van der Meulen.

1903-1906, 1916: Four shafts sunk to 90 feet (#1), 132 feet (#2 SE), 65 feet (#2 NW), and 40 ft (#3 NW). The no. 1 shaft was the main shaft, with drifts driven 181 feet east and 159 west from the bottom of the shaft. The part of the vein between #2 SE and #2

NW was stoped out to the surface. A total of 2,653,365 pounds of lead valued at \$111,097 were produced by the Ontario Mining and Smelting Co. (1903-1905) and Stanley Smelting Co. (Shklanka, 1969).

- 1956: Eighteen diamond drill holes totalling 3810 feet (1161 m) drilled by Teck Exploration Co. Ltd.
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- (1905, p.15,79)
- Hewitt (1968, p.24)
- Shklanka (1969, p.139)
- Uglow (1916b, p.23-24)

DOG LAKE HEMATITE PROSPECT

Location and Access

The Dog Lake hematite prospect is located on a narrow ridge of land separating Dog Lake from Crane Nest Lake to the north, about 8 km southwest of the village of Seeleys Bay, and 22 km northeast of the city of Kingston. It is accessible by car via a gravel road between Seeleys Bay and the village of Battersea (Fig. 57). The prospect occurs within lot 20, con. X, Storrington Township, at UTM coordinates 4922350N, 393450E, in NTS quadrant 31C/8.

The Dog Lake prospect was not visited by the author. The following description is taken from the quoted references.

Economic Features

Mineralization at the Dog Lake hematite prospect consists of disseminated to massive hematite contained within an outlier of Paleozoic sandstone. The mineralized zone is exposed by an open cut on the Crane Nest Lake side of the ridge, and is described by Ingall (1901, p.77) as "extending down about 30 feet from the top of the ridge; about 90 feet along its face, and 25 feet in from the edge." There is also a small shaft reported to be about 20 feet deep, on top of the ridge. The open cut and shaft are

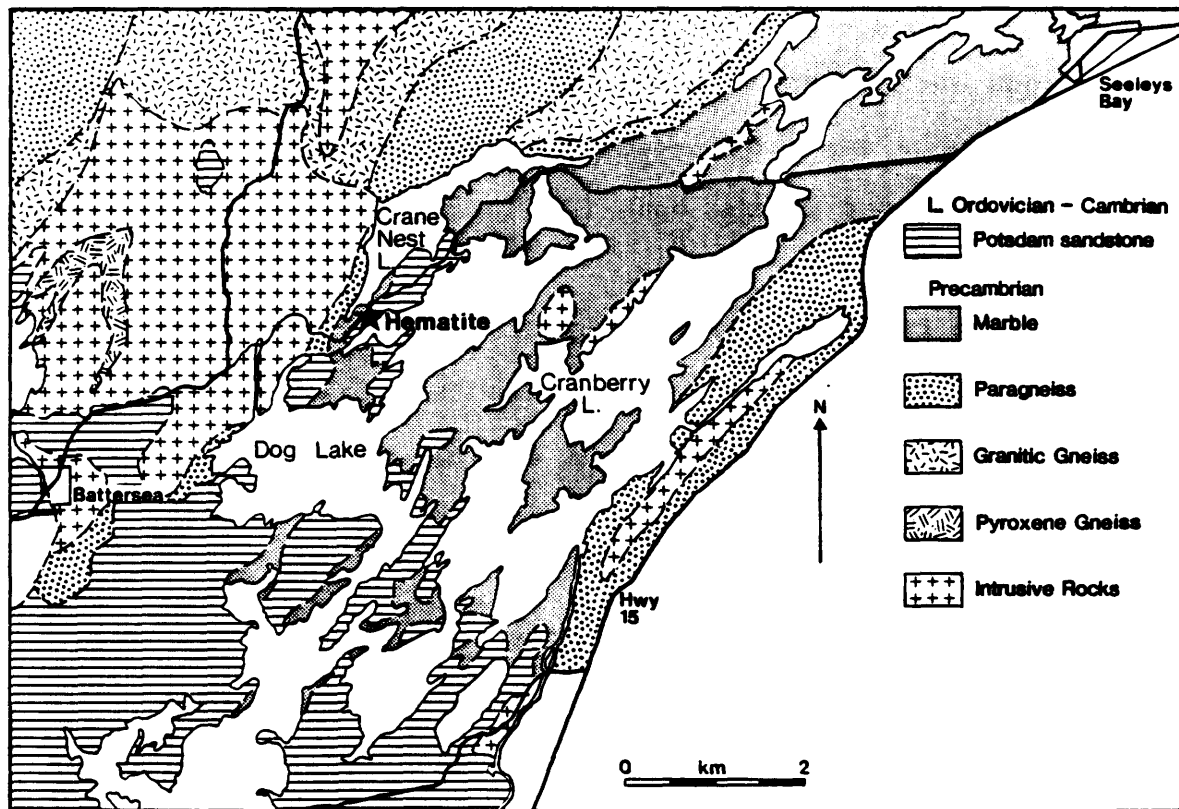


Figure 57: Geology in the vicinity of the Dog Lake hematite prospect, adapted from Wynne-Edwards (1962).

reported to be overgrown and covered with rubble, but good exposures can still be found (P. Kingston, Tweed Resident Geologist, personal communication, 1982).

Hematite mineralization, varying from disseminated to massive, occurs throughout the exposed thickness of sandstone in the open cut. Hematite-bearing rock fragments occur on a small dump near the shaft, located about 30 feet from the edge of the open cut. Hematite mineralization was also encountered at a depth of 90 feet in a diamond drill hole on the Dog Lake side of the ridge. Limits on the lateral extent of the mineralized zone have not been established and estimates of average grade are unavailable.

Geology

The Dog Lake hematite prospect occurs within an outlier of Lower Ordovician to Cambrian rocks of the Potsdam Formation on the neck of land separating Dog Lake and Crane Nest Lake. The rock forms a ridge about 30 metres in height above the lakes and consists of red sandstone unconformably overlying Precambrian marble at this point. Numerous other outliers of Potsdam sandstone occur in the vicinity, some containing disseminated hematite. The main Paleozoic sequence lies immediately to the south. The following description of the hematite prospect is taken largely from Ingall (1901).

Sandstone exposed in the open cut is quartz-rich and contains pebbles of varying size, occurring either singly or in layers. The rock is very porous and vuggy in places and in others is very compact. The vuggy portions often contain concentrations of hematite, sometimes in the form of specular hematite. In some of the cavities the remaining pore space is occupied by a white platy mineral with a somewhat radial habit, probably barite. Zones of massive blue-black hematite occur locally, sometimes exhibiting well developed botryoidal structure, cementing scattered glassy quartz grains. Elsewhere the sandstone may be hematite-free, or is simply stained yellow or red by disseminated hematite.

History of Development

1899-1900: In 1899 a company was formed which excavated an open cut, a shallow shaft, and completed one diamond drill hole for 90 feet. The open cut has a face about 9 metres high and is 27 metres long (Ingall, 1901; de Kalb, 1900)., According to Shklanka (1968) about 600 tons of iron ore was shipped in 1899..

References

de Kalb (1900, p.104)
Ingall (1901, p.76-78)
Shklanka (1968, p.144)
Wynne-Edwards (1962)

FAHEY HEMATITE PROSPECT

Location and Access

The Fahey hematite prospect is located 380 metres northeast of Eggshape Bay of White Lake, about 20 km southwest of the town of Arnprior. It is accessible by car and lies about 60 metres east of a private dirt road on the southern edge of a large clearing, at a point about 0.8 kilometres north from the gravel access road to Pickerel Bay of White Lake (Fig. 58). The prospect occurs within lot 26, con. XI, of Darling Township, at UTM co-ordinates 5015560N, 382360E, in NTS quadrant 31F/7.

Economic Features

The main mineralized zone at the Fahey hematite prospect consists of a lens of massive hematite reported to be about 15 feet wide (Frechette, 1910), which is exposed over a lateral extent of at least 200 feet. Workings consist of several small overgrown pits extending over a length of about 200 feet, and a water-filled shaft which was not located by the author but is reported by Frechette to be 20 feet deep. Disseminated to massive hematite is exposed in most of the pits. There are no outcrop exposures of mineralization.

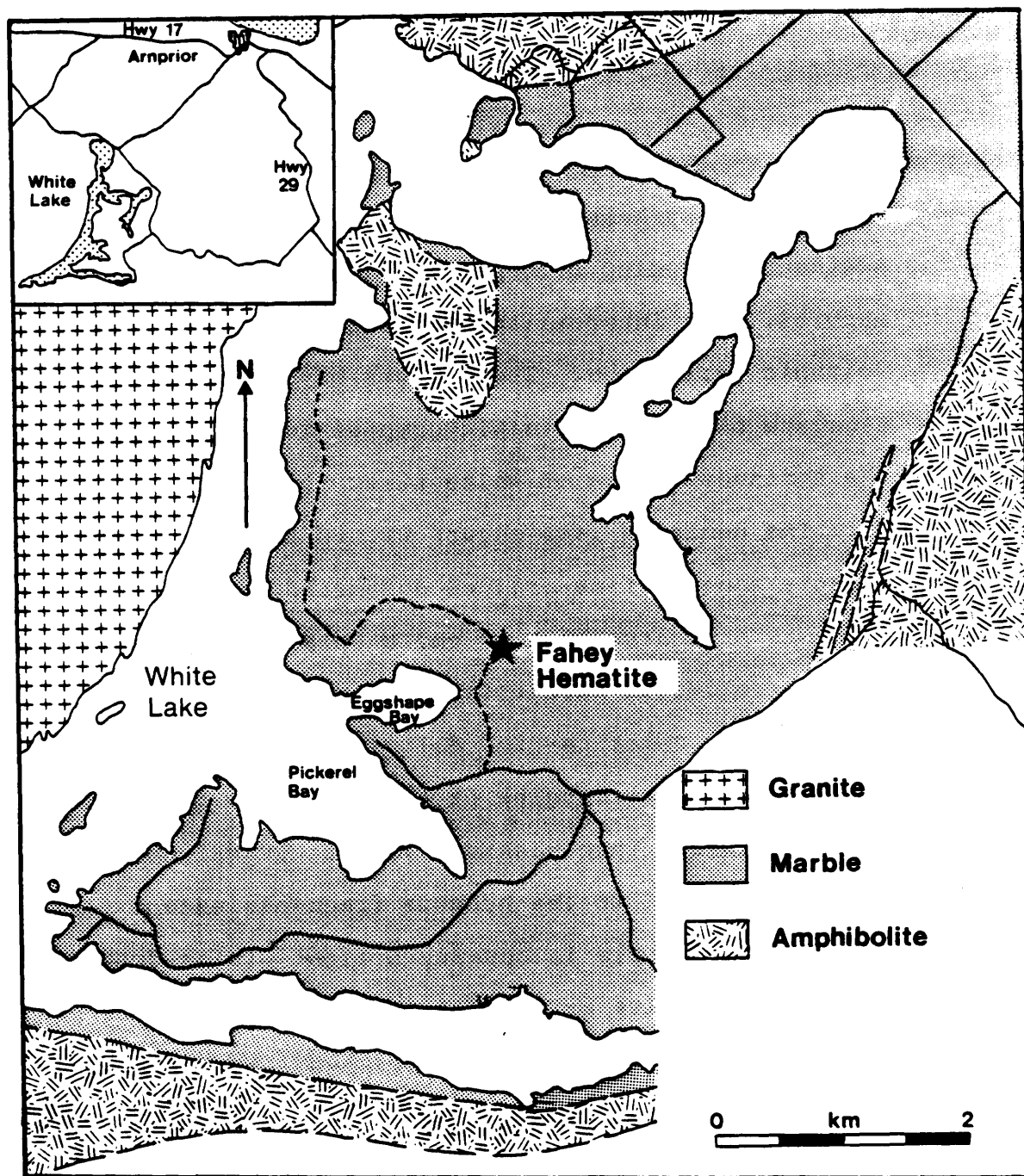


Figure 58: Geology in the vicinity of the Fahey hematite prospect, as adapted from Hill (1972) and Quinn (1952).

A sample of massive hematite collected from a pit by the author contained 63.6 percent Fe, 0.04 percent TiO_2 , 0.32 percent P_2O_5 , 0.01 percent V, and 0.01 percent S.

Geology

The Fahey hematite prospect occurs within an extensive northeast-trending sequence of fine to medium-grained marbles, with intercalated amphibolites of probable volcanic derivation. These rocks have been intruded by an elongate pluton of granitic composition that outcrops along the northwest shore of White Lake.

The hematite lens occurs within a northeast-trending breccia zone in fine-grained dolomitic marble. The breccia consists of coarse (1 to 3 cm) angular fragments of white to pink dolomitic marble set in a red matrix of very fine-grained hematite-rich dolomite. This breccia occurs within and on the margins of the massive hematite lens, and grades outwards into massive, very fine-grained, dolomitic marble identical to the breccia fragments except for colour. The marble is usually a light bluish-grey colour that becomes white or reddish as the hematite lens and associated breccia zone is approached. Several narrow breccia 'veins' cutting the marble are exposed in outcrops in a clearing immediately to the north of the main mineralized zone.

The main hematite lens is a massive, aphanitic, dark bluish-grey rock that crushes to a bright red powder. Faint indistinct outlines of completely replaced marble fragments can often be seen in the rock upon close examination. These zones of replaced marble fragments sometimes grade into poorly defined lenses of marble breccia within the massive hematite. Hematite occurs as aphanitic grains disseminated throughout the matrix of the breccia. Occasional small pods of massive hematite also occur, often within vuggy zones in the breccia.

In polished thin sections of massive hematite examined by the author the hematite occurs as irregular, poorly defined, oval grains that generally have amorphous, poorly polished cores and well-polished crystalline rims. Scattered quartz grains and fine hematite occupy the interstices between grains.

History of Development

Several small trenches and a water-filled shaft 20 feet deep are reported by Frechette (1910) in 1909. There are no records of when or by whom the excavations were completed.

References

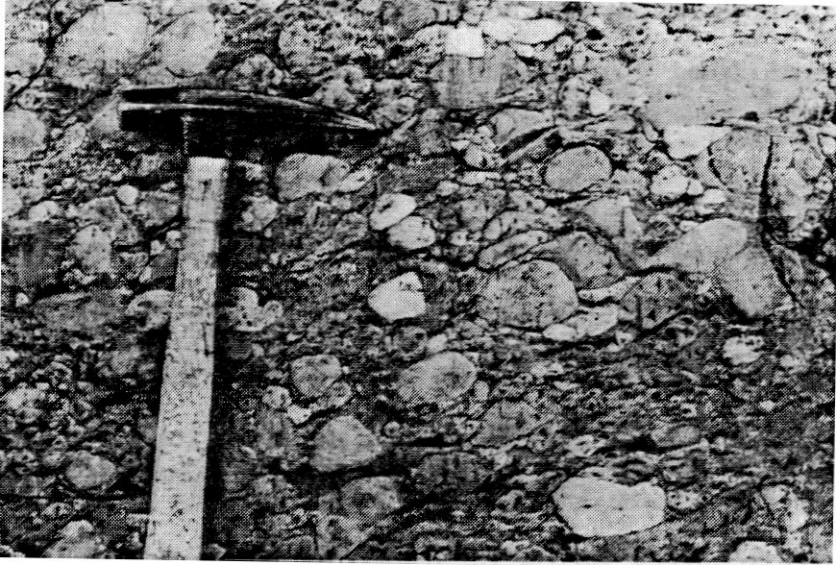
- Frechette (1910, p.82-83)
Hill (1972)
Peach (1958, p.55-56)
Quinn (1952, p.38)
Rose (1958, p.66)
Shklanka (1968, p.248)

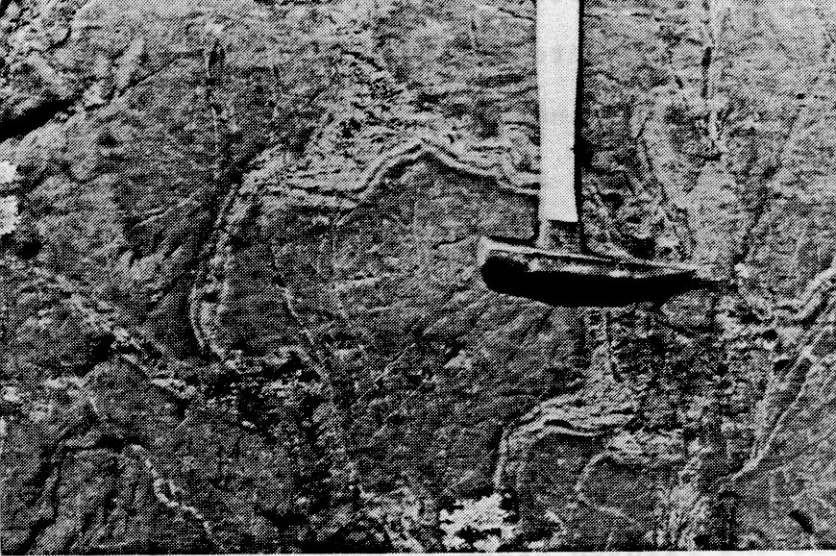


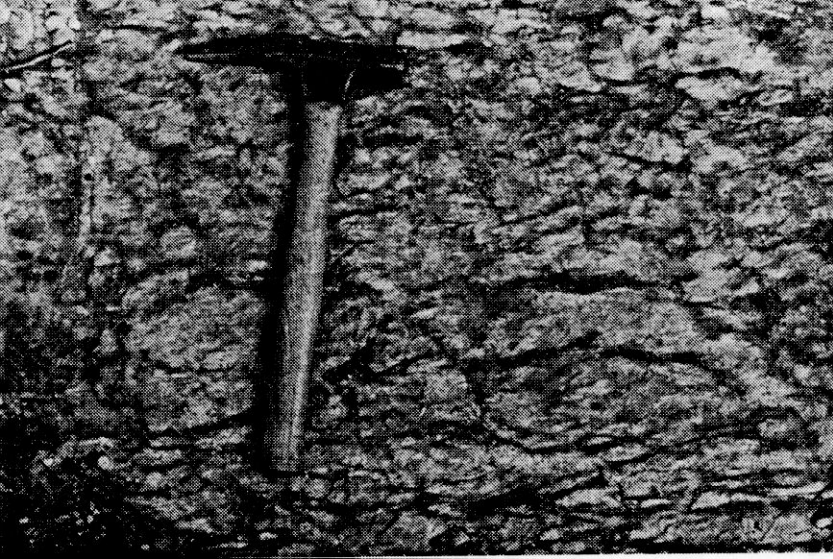


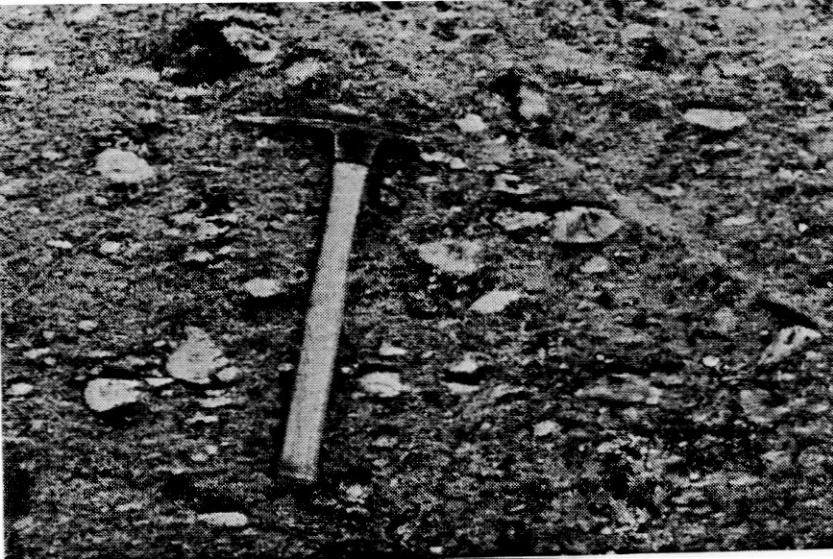
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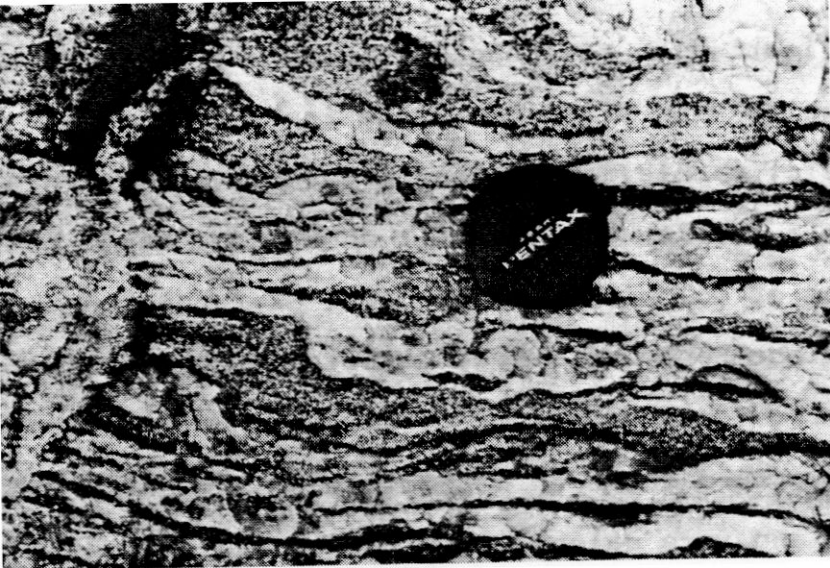


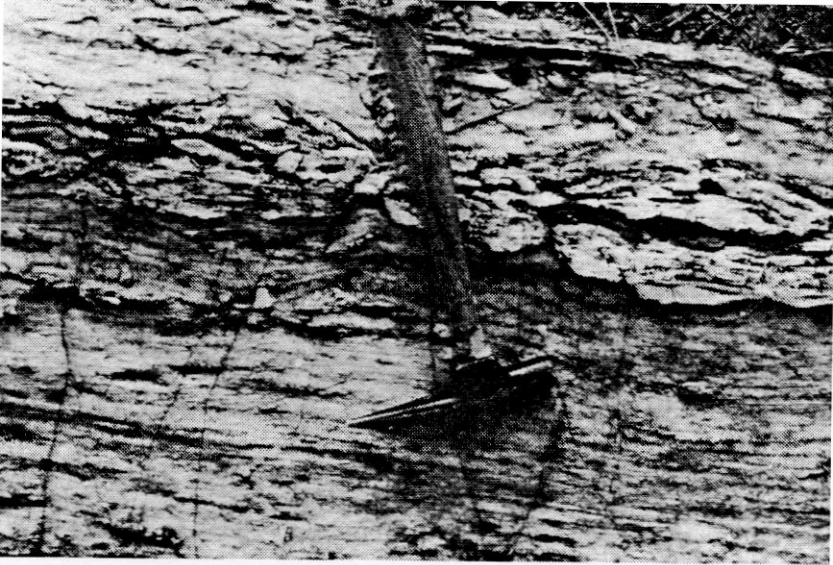


















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