GM 39070

THE GRENVILLE RECONNAISSANCE PROJECT, A COMPILATION AND PROPOSAL

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A COMPILATION AND PROPOSAL

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SUMMARY

A compilation of the Eastern Grenville has shown that there exist large areas of favourable geology with anomalous geochemical values, that have received little or no attention from exploration companies. Further, additional areas of favourable geology have sparce geochemical coverage. With the exception of uranium, and iron-titanium exploration, there has been little other activity.

A two-part programme is proposed after an initial orientation survey around known occurrences. Each part facilitates an evaluation of accessible and non-accessible parts of the Eastern Grenville.

It is recommended that the orientation survey and part 1 of this programme be commenced in early 1977. Estimated cost for 1977 is $24,000.00.

INTRODUCTION

After visiting the deposits of the Edwards-Balmat area of New York, the Grenville Project was conceived by Shell Canada Resources personnel. At that time, it was felt that there exists discovery potential of Balmat-type deposits in the Grenville area of Canada. Several known occurrences and 3 past producers certainly lend some strength to this fact. Further, it was felt that the Eastern Grenville may have not received as much attention in the past, as other regions such as the Laurentian and Hastings highlands of Quebec and Ontario.

The Eastern Grenville is that region of Quebec that is east of an arbitrary line drawn from Quebec City to Chibougamau. Within this region, an assessment work compilation was completed. The amount of information available to the public is very meager. One can only conclude that there has been very little exploration for base metals in the eastern Grenville. This is partially substantiated by the small number of showings. However, it must be remembered that the very same area is under consideration by numerous exploration companies for its uranium potential.

OBJECTIVE

(1) The objective of the Grenville reconnaissance project is to seek our potential areas suitable for detailed exploration in the search for Balmat-type Zn-Pb deposits. This report presents the findings of a compilation of geochemical sampling, geological mapping and public assessment file information. Based on the information presented, areas for field examination are recommended.

LOCATION

Prior to commencing the compilation study, the eastern Grenville region was considered to be of higher priority than the western Grenville, due to: a lack of comprehensive exploration in the past; and assumed greater topographic relief, hopefully rendering stream sediment sampling more effective (Hodge 1976). An arbitrary line was projected from Quebec City to Chibougamau, and the region east of this line was designated the eastern Grenville (Fig. 1).

The eastern Grenville region encompases some 220,000 Km^2 (85,000 Mi^2), and has been the subject of a comprehensive mapping project by the Quebec Ministry of Natural Resources. This study is known as the Grenville project. Much of the Grenville geology is of little interest to this report. It is only those rocks and formations of the Grenville Group to which attention has been directed. The distribution of the Grenville Group of formations is depicted on Figure 1, and have been subdivided into areas of interest. (1c)

ACCESS

Access to the different areas outlined on Figure 1 is available. For example, to get to the Sheldrake area, one must rely on float planes from Sept-Iles or Havre St. Pierre; while portions of the Manicouagan-Sept-Iles and Lac Berte areas are accessible from the Gangon-Sept-Iles Railway. The other parts of the aforementioned areas are accessible by float plane. Areas along the north shore of the St. Lawrence River are accessible from Highway 15 and connecting secondary and timber roads.

TOPOGRAPH Y AND DRAINAGE

The topography of the eastern Grenville area is variable. Much of the north western portions of Figure 1 is underlaid n by extensive areas of gneisses, etc. ~~Evaluation~~ elevations usually lie between 500 to 1,000 ft. above sea level. In contrast, the southern parts, along the North Shore, possess quite a rugged topography in areas occupied by anothosites and manganites. Local reliefs of 1,000 ft are common with maximum reaching 3,800 ft. in place. The height-of-land cuts across the north western portion of Figure 1, all drainage southeast of this line ultimately drains into the St. Lawrence.

The reader is referred to the Barringer Report for a detailed discussion of the drainage and its suitability for geochemistry

GEOLOGY

The Metasedimentary Rocks of the Grenville Group

The geographic distribution of the Grenville Group is shown on Figure 1, and lithological distributions are illustrated on Figure 2. Recent geological mapping at a scale of 1 inch to 4 miles, has been conducted over much of the eastern Grenville. Much of this recent information is incorporated in this section.

Lithologies

The various rock types belonging to the Grenville Group consist of metasedimentary rocks; quartzites, mixed paragneisses, crystalline limestone, skarn and amphibolite. All units may occur interlayered or as separate mappable units. This point is important when viewing large scale maps of the eastern Grenville region.

The following description of the lithologies of the Grenville group of sediments is from Sharma and Laurin 1975.

1 Quartzite

"The quartzite is a well bedded, homogeneous to heterogeneous rock, white to grey in colour, composed of glassy quartz with varying amounts of feldspar, mica, hornblende, pyroxene, garnet, magnetite, etc. Graphite has been frequently seen associated with quartzite. The pure varieties of quartzite generally contain more than 80% quartz. Good cross-bedding has been observed in many outcrops. The quartzite does not form bands of sufficient thickness to be mapped at the present scale of mapping. The bands are generally interlayered with the mixed paragneisses.

3 types ① northern part of area - with limestone
② north shore of St Lau. - no limestone
③ Gagnon Gp. no interest

(2) Mixed Paragneisses

The mixed paragneisses are generally very well layered because of variations in the percentage of micaceous minerals in different layers. The layering is supposed to be a relic of the original sedimentary bedding; it is rather continuous and varies in thickness from a fraction in an inch to several feet. The paragneisses are characterized by the presence of pale violet to red garnet porphyroblasts. The mineralogy is extremely varied. Quartz occurs throughout and, together with plagiosclase, constitute the chief leucocratic minerals. The other minerals are biotite, hornblende, and sillimanite. Graphite is frequently observed.

Quite often these rocks show a typical rusty weathered surface and the quartzofeldspathic layers stand higher in relief than the biotite-rich layers. The foliation is nearly always parallel to the layering. The gneisses often possess good mineral lineation and microcorrugation lineations on the foliation plane. Minor folds and gentle warps are also present. In the case of minor folds, the foliation is bedding-plane foliation. Thin bands of quartzite, cal-silicate rock, crystalline limestone, and amphibolite are associated with these gneisses.

The paragneisses have been migmatized to varying degrees as evidenced by numerous thin quartz and granite-pegmatite veins, either parallel to the layering or cutting it in various directions. Ptygmatic folding is commonly seen. Even where the rock is highly migmatized, the original paragneisses can still be seen in minor amounts as bands and patches. Usually it is the biotite-rich bands of the paragneisses that survived migmatization.

NB In the Lac Berte-Mancouagan-Sept-Iles area, the paragneisses differ from those along the north shore of the St. Lawrence. They are distinguished by a much greater heterogeneity at the outcrop scale; a well-developed and ever-present bedding; the presence of rock types of undoubted sedimentary origin, such as beds of quartzite and crystalline limestone; and, lastly, by a special mineralogy characterized by the presence of graphite and alumino-silicates. Sharma et al 1975.

NB They outcrop mostly in the northern part of the area in the neighbourhood of the gabbro instrusion of Little Manicouagan lake and the anorthosites of Berte and Telepisca lakes. Elsewhere, they are found in small discontinuous zones, particularly along the Sainte-Marguerite river, northwest of Sept-Iles; near the shore of the St. Lawrence River between Franquelin and Pointe-des-monts; and north of Baie-Comeau. The southern outcrops are south of Labrieville and in the region of Grandes-Bergeronnes where they form circular structures which are quite evident on air-photos. ? where?

Within this group of paragneisses, we have distinguised three principal rock-types, after their mineralogical composition and lithological characteristics."

(a) The first type comprises all the paragneisses outcropping in the northern part of the area, as well as the majority of the isolated zones found in the area of grey gneisses. These paragneisses posses characteristics which are quite close to those of the rocks of the Grenville Group. However, crystalline limestone is quite rare here as compared to the amount outcropping in the southwestern part of the Grenville. The crystalline limestone found in the area are not of much help in stratigraphic correlation because of their limited thickness and extension along strike.

The most common variety of this type consist of a biotite gneiss, with or without garnet, sillimanite, and graphite. It is fine to medium-grained and layered. The weathered surface is characteristically rusty and the colour of the fresh rock is light to dark grey. The heterogeneity of this rock-type is shown by the presence of units of variable composition which are responsible for the bedded nature of these paragneisses, more precisely due to the alternance of bands of very different mineralogical composition parallel to the foliation. Associated with the biotite, garnet, and sillimanite-bearing gneisses there are zones of light coloured quartzofeldspathic gneisses containing less than 10% biotite, zones of mafic gneisses rich in amphibole, zones of garnetiferous quartzite, crystalline limestone and calc-silicate rocks.

The crystalline limestones show a granoblastic texture, composed of cystals of calcite with small amounts of biotite, graphite, phlogopite, diopside, not exceeding 10%. These limestones occur in large bands, associated with the paragneisses outcropping near the Daniel Johnson dam. In other places they occur only in thin discontinuous lenses which can be observed north of Chute-aux-Outar-des, on the lumber-hauling road along the lower course of Tremblay river.

The calc-silicate rocks occur in the form of lenses and nodules. These rocks have a rugged, weathered surface caused by leaching away of calcite and the remaining, more resistant, greenish diopside standing in relief. On a fresh surface the rock has a greenish colour due to the abundance of diopside. Sometimes these rocks possess a zoned structure, shown by the concentration of calcite, pyroxene and scapolite in distinct bands."

(b) The second type of paragneiss outcrops between Grandes-Bergeronnes and Sault-au-Mouton. Several characteristics distinguish it from the preceding type. It is much darker in colour due to a high content of biotite and amphibole. Garnet and sillimanite are practically absent and were only observed in rare cases. It is fine-grained and possesses good bedding which gives the rock a stratiform feature. It does not contain crystalline limestone. The quartzites are present in bands thick enough to mapped; they are relatively pure, possess a good sedimentary bedding and at places show cross-bedding. The quartzites observed near Grandes-Bergeronnes contain a high percentage of biotite, muscovite, garnet and are thinly resemble highly folded schists. The amphibolitic bands associated with them may represent the metamorphic equivalent of ancient lava; these amphibolites possess a homogeneous texture, in places show igneous characteristics, and do not show any banding. Near Saint-Paul-du-Nord, a variety of the paragneisses contains diopside-rich zones interlayered with the bands of quartzite and biotite gneiss; they have been folded into a series of similar folds showing a well-developed, axial-plane cleavage.

where is this ?

NB

(c) The third type corresponds to the metasedimentary formations belonging to the Gagnon Group. They are confined to an area northwest of Little Manicouagan lake and outcrop in the form of narrow, north-west-trending structures. They are of no interest to this report.

NB (3) Marble

The marble, or crystalline limestone, is a white, friable rock composed predominantly of calcite. The rock weathers easily. It forms bands that are only a few feet in thickness and are interlayered with the mixed paragneisses. In a few places it is thick enough to be mapped at the scale of mapping. Graphite is commonly present. Other minerals occurring in small amounts are tremolite, actinolite, diopside, scapolite, feldspar, quartz, pyrite, sphalerite, magnetite, phlogopite, muscovite, biotite. The bands of crystalline limestone behaved rather imcompetently during deformation and show thinning and thickening of calcite-rich layers.

(4) Calc-Silicate Rocks and Skarn

Calc-silicate rocks and skarn are rather rare in the map area and are seen mostly as thin layers interbedded with the mixed paragneisses and marble. They are composed of varying proportions of calcite, diopside, scapolite, biotite, sphene, feldspar, etc. Figure 2 shows layers of calc-silicate material and marble interbedded with the mixed paragneisses.

(5) Amphibolite

Bands of amphibolite are frequently observed interlayered with the paragneisses. They may result as a consequence of enrichment in mafics of some of the bands or by metamorphism of sills of diabase and gabbro. In general they are fine to medium grained, equigranular, well foliated rocks. They are dark greenish to black in colour and are composed essentially of amphibole and plagioclase in nearly equal proportions or with amphibole in excess of plagioclase. Biotite is usually a minor constituent." (Sharma et al 1975)

Economic Geology

There is a pronounced lack of base metal showings in the eastern Grenville region, yet a few hundred miles to the southwest are the Edwards-Balmot deposits in northeastern New York State. These large, rich deposits are found in interbedded marbles and paragneisses of Paleohelikian age, and are approximate time-equivalents of the Grenville Group. The reader is referred to Appendix 1 for detailed descriptions of these deposits and of those found at Calumet and Montauban in Quebec.

Base Metal Occurrences in the Eastern Grenville

The following is a summary of showings and known occurrences of base metal sulphides that are found in the eastern Grenville.

(1) 45 claims were staked in the vicinity of Blough lake by Prosper Exploration Limited. The mineralization consists of a zone of massive sulphides, vertically traversing the limestone a few hundred feet from the south shore of Blough lake. This mineralized zone extends for more than 7,000 feet and is 100 to 200 feet in width. To the specular hematite, signs of zinc and nickel are also present. ?

where? when?

(2) Pyrrhotite mineralization is reported from the extreme southwestern part of Range A, Rouleau township, Lake-Saint-Jean county. A 20-foot thick mineralized zone occurs in coarse-grained noritic anothosite and is traceable for 300 feet. The sulphides occur as small disseminated patches to small massive bodies, and sometimes enclose the pyroxene and the plagioclase crystals of the anothosite. Results of assays indicate from 0.1 to 0.2% Ni and 0.1 to 0.3% Cu.

(3) Interesting mineralization of disseminated chalcopyrite and other sulphides found in the anorthositic rocks north of Nepton river (east of Lake Chibougamau) has been reported by Pouliot (1963). Representative samples from two important locations gave the following results:

Chibougamau type?
No interest

A	(Cu......................0.41% (Ag......................0.092 once/ton (No gold
B	(Cu......................0.40% and 0.23% (No Gold or silver

In addition, several other occurrences of disseminated pyrite were reported from the Keewatin-type rocks of the area.

(4) A sulphide prospect (Berrange, 1959) is located at the intersection of the lines between lots 11 and 12, and ranges II and III in La Trappe township. Anorthosite and gabbroic anorthosite are traversed by granite-pegmatite veins. Sparingly disseminated pyrite and pyrrhotite with minor chalcopyrite occur in the gabbroic anorthosite. Selected grab samples, by Berrange, assayed as follows:

	Cu	Ni	Co
Lot 11	0.20%	0.31%	0.02%
Lot 12	0.40%	0.08%	0.05%" (Sharma et al 1975)

Mount Murray Seigneury

Smell !!

(5) "Half way between St. Simeon and Port au Persil, a calcite vein occupying a fissure in granite contains segregations of sphalerite and galena." (Faessler, 1929, p. 181)

Murray Bay Seigneury
Nairn Falls, Malbaie River, St. Etienne de la Malbaie Parish Smell!

(6) "Small fissures filled with calcite, zeolites, and a little galena are found near the dam. All these veins are very short and irregular. In places they widen up to 1 foot and contain, where wide, a large proportion of green fluorite." (Faessler, 1929, p. 181)

Cote De Beaupre Seigneury
Baie St. Paul Parish, Lot 1197

(7) "A carbonate-bearing vein which cuts the granite in the Tremblay quarry contains a small amount of galena and sphalerite." (Osborne, 1934, p. 54)

Kentucky type?
Miss. V.
Smell?

Riviere du Moulin, Baie St. Paul Parish

(8) "Veins of calcite containing much green fluorite and galena outcrop at the surface in the contact zone between the granite and Palaeozoic rocks. The veins measure up to 1 1/2 feet in width and can be followed along the width of the river canyon about 80 feet." (Faessler, 1929, p. 180)

Des Plaines Seigneury
Bois Franc de l'Ail Range, Lot 104

(9) "The mineralization consists mostly of pyrite, and sulphides of copper associated with stringers of quartz which occur in shear zones in a dense fine-grained amygdaloidal rock. Representative samples from the 50-foot level average 0.13 per cent copper, 0.02 per cent zinc, 0.04 per cent nickel and traces of silver." (Que. Dept. Mines, P.R. No. 330, p.96)

Bergeronnes Township
Range 1 Anse a la Cave

Smell ?

(10) "Galena occurs with fluorspar in a small calcite vein at Anse a la Cave. The vein cuts paragneiss of the Grenville system; it is not more than 50-feet long and 1-foot wide." (Faessler, 1930, p. 87)

Previous Work

The available public information from the Assessment Work Files of the Quebec Ministry of Natural Resources is summarized here according to the areas as per Figures 1 and 2. The numbers prefixed by GM beside each township refer to the actual file number in Quebec City.

Sheldrake Area
Twp. 1364 GM 2247

meta volc.? ?

This is the only twp in which assessment work has been recorded. In approximately 1953-54, the Iron Ore Company of Canada investigated a magnetite occurrence in a hornblende gneiss located at Gad Lake, southwest of Manitou Lake.

Baie Comeau Area
Laflecke Twp GM 10368

A high-grade quartzite occurrence was examined around 1967 for the Quebec North Shore Paper Company. In the vicinity of Lac Malfait, quartzite grading 98.5% SiO_2 is interbedded with other metasediments of the Grenville Group which have been highly migmatized. Considerable tonnage has yet to be proven.

Forestville-Tadoussac Area
Bergerrones Twp GM 2322B

Strategic Minerals, in conjunction with a couple of other junior mining companies, conducted an exploration programme for uranium in this twp. Drilling (9 holes) appears to be centered on pegmatites which intrude quartzites and paragneisses. No further information is available.

Labrieville Area

No records of any work

Manicouagan - Sept-Iles Area

Probably a good job of prospecting was done.

NB In 1944, the Mining Corporation of Canada conducted a primary prospecting programme. No mineralization was encountered during the course of traversing, however, quartzites with interbedded metaliferrous metavolcanics were found on the west side of Mouchalagan gorge.

Lac Berte Area

No records of any work

Chicoutimi Area
Bagot Twp GM 23601

Soquem, the Quebec government mining exploration company, conducted a uranium exploration programme in an area underlying predominantly by granite. Work consisted of a radiometric survey along side roads and geological mapping.

Otis Twp. GM 5415 A & B 7582

In lots 5, 6 and 7, of ranges 4, 5 and 6, Basnov Mining Co. conducted a uranium exploration programme in this twp. High thorium with minor uranium mineralization was encountered in 5 drill holes.

Garreau Twp. GM 13400

Bersimus Mining Company put and drill holes down on a titaniferrous magnetite occurrence in an anorthositic complex.

St. Paul - Saquenay Area
Callieres Twp. GM 4333B

Consolidated St. Simon Mining Co. did a preliminary study on radioactive pegmatites in the area.

GM 2719 A & B

St. Simon Uranium Corp. conducted a survey confined to pegmatites and skarns in Granville Group metasediments. Considerable trenching by buldozing was done. A weighted bulk sample gave 0.16% U_3O_8 or $24.00 ore at $7.50/lb. ($192.00 ore @ $20.00/lb.) (See Figure 3 and 4).

GM 21710 GM 23954 and GM 21858

Goldrim Mining Corp. and Richore Gold Mines Ltd. all under the same author, conducted a preliminary geological reconnaissance survey. Based on the results of adjoining companies (St. Simon Uranium Company) further work was recommended.

Sagard Twp. GM 24633

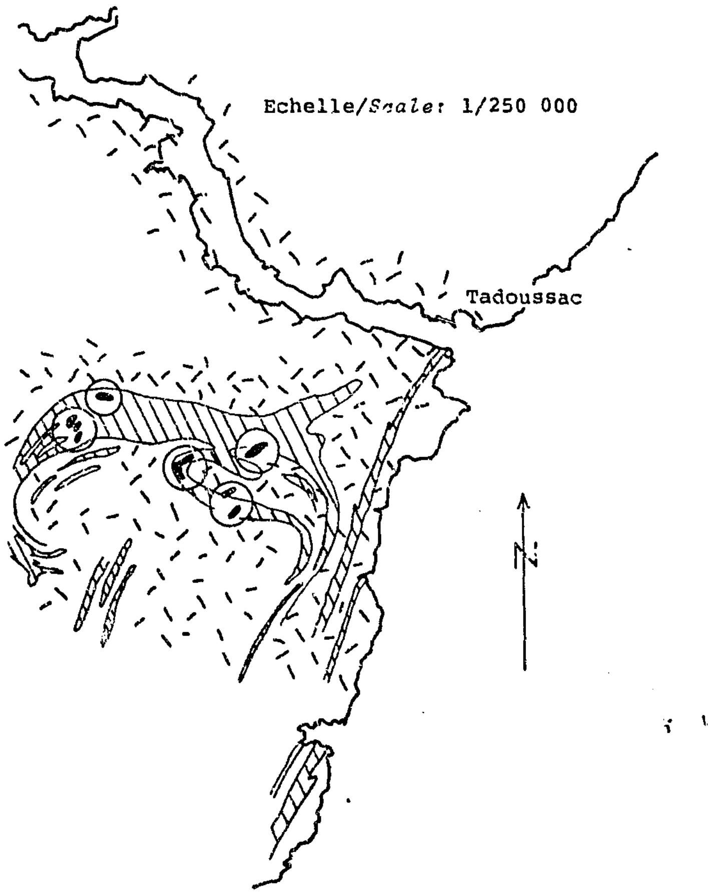
Quebec Mattagami Minerals was unsuccessful in delineating economic concentrations of uranium in pegmatites.

Saguenay Twp. GM21784 21780

United Obalski Mining Co. reported the occurrence of a magnetite - uranium association in a pegmatite. This occurrence is reported to have a highgrade zone of 1.30 lbs./ton U_3O_8 (Tonnage?) and a low grade zone of 0.45 lbs./ton U_3O_8 (Tonnage?) The outcrop area is 1,200' x 500' with a reported 31,000 tons/vertical foot; minable by open pit. The ore to waste ratio is 1:1.85. There are minor accessory minerals of Thorium, Ytterium and Zirconium.

Charlevoix (3) - unsurveyed GM 1249 7678 7679 & 13222

NB Murray Bay Mines Ltd. and Mountain Crest Mines Ltd. report a Tin-Irridum occurrence in Grenville rocks of the Grenville Group cut by aphenitic to pegmatitic dikes. Assays of 0.23 - 2.14% Tin and 0.29 - 1.16 oz Ir/ton were reported. The approximate location of the mineralization is outlined on the accompanying map. A supplementary memo will accompany this report on this occurrence.



Anomalies de la région/*Anomalies in the region*

Granite à biotite/*Biotite-granite*

Gneiss et schistes à hornblende/*Hornblende schists and gneisses*

(Géologie d'après/*Geology after* M.L. Miller 1951)

FIGURE 4 - Principales anomalies uranifères dans le canton de Saguenay.
Principal uraniferous anomalies in Saguenay township.

Charlevoix (1) - unsurveyed CM 16075

Leeds Metals investigated a high grade quartzite occurrence (98.5% SiO_2) in Grenville sediments, however, marble or crystalline limestones were not mentioned.

Lac St. Jean Area

Girard Twp. GM 6307 A & B

On claims owned by Chretien et al, drilling in a granodiorite discovered a pegmatite.

Baudit Twp. GM 5616 A & B

Three diamond drill holes less than 200 ft. each were drilled on a columbium-uranium prospect. One grab sample assayed 0.36% U_3O_8. Some marble with disseminated vermiculate was mentioned in one drill hole. The logs are very lean on detail.

Hermen Twp. GM 27157

A $CaCO_3$ prospect which is very pure (97.39 - 97.82% $CaCO_3$) was examined by Mines D'Iberville Ltee. There was no further information available.

Pelletier Twp. GM 23164

Pegmatites that crosscut crystalline limestone and paragneiss located on Lots 32 - 36 of Range 4, were found to contain traces of chalcopyrite and bornite.

GM 4805

On claims owned by Raphael et al minor sulphides consisting of chalcopyrite, pyrite and pyrrhotite were found in crystalline limestone cut by pegmatite dikes. Reported assays are 1.37%/2.5' and 2.03%/0.9'. copper?

Lyonne Twp. GM 6445

Robervale Mining reported a proven reserves of 38 million tons of titaniferrous magnetite. There is a possible 124 million tons of ore.

Discussion

It can be seen from the foregoing that there is an interesting lack of base metal occurrences in the eastern Grenville. Further, there has been little in the way of detailed base metal exploration that has been submitted for assessment credit. Does this situation exist because of a lack of exploration or a lack of results? The writer feels the answer is because of a lack of exploration. In the past, there has always been "greener pastures" for exploration dollars, though there has been considerable expenditure for uranium and iron-titanium in this region.

Within the eastern Grenville, we find small accumulations of what was once a continuous blanket of Grenville group metasediments. Some areas are small and almost insignificant, while others are quite large, in terms of size and geographic extent. Within this patchwork of metasediments, a crude carbonate facies appears to exist. Sharma et al 1975, point this out by stating that paragneisses in the northern part of the area, i.e., in the vicinity of Lac Manicouagan etc., is lacking in crystalline limestone compared to the amount outcropping in the southwestern part of the Grenville. Further, paragneisses in the Forestville-Tadoussac area are lacking in marble.

The presence or lack of marble or cystalline limestone is significant when one considers that in the Edwards-Balmat district, sulphide mineralization is found throughout 1,800 ft. of stratigraphy which consists of alternations of pure dolomite and strongly silicated units. Further the ore-bearing marbles or crystalline limestone have the following accessory minerals, diaspore, serpentine-talc, graphite, anhydrite, halite and phlogopite. The ore horizons are fetted with methane. These features should serve as a guide to ranking the favourable areas in the future.

However, within the Lac Berte and Macauagan - Sept-Iles areas crystalline limestone occures in varying degrees and has been subject to variable deformation. Where present, it is interbedded with paragneisses and/or is massive. It contains graphite philogopite and diopside. Thus it would appear that all the paragneiss belts in the eastern Grenville appear to be favourable.

Some other criteria will have to be used to assign priority to paragneiss belts. It would appear that geochemical stream sampling may serve this end.

The study of the metallogeny of the Grenville province would not be completed without considering the Laurentian-Hastings highlands to the southwest of the Quebec/Chiboagamau line. In the southwest Grenville there is an extensive accumulation of Grenville Group metasediments, further in these areas there are numerous showings known tonnage reserves and a history of past production. A compilation of this region is considered necessary at some time in the near future.

GEOCHEMISTRY

Consultants Report

Barringer Research Ltd. was commissioned by Shell Canada Resources Limited to provide information regarding the applicability and usefulness of geochemical sampling to supplement base metal exploration in the Grenville. It was hoped that Barringer would provide some case histories from their own experience in the Grenville, however, these were not forthcomming. The Barringer Report can be summarized by the following quote:

> "There are a number of potential complicating factors in the application of geochemistry. Nevertheless, it is considered reasonable to propose that the models originally developed by Bradshaw (1975) for the Cordillera and model B1 (Shield) could be readily applied to the Grenville of Quebec and that models A2 (Cordillera) and B1 (Shield) Figs. 5 and 6 should form the basis for initial reconnaissance studies." Barringer Research Ltd. 1977.

Q.M.N.A. Geochemistry

During the mapping of the eastern Grenville by the Quebec Ministry of Natural Resources, stream sediment samples were collected. The analysis were presented on coloured geological maps in Geological Reports 161, 162 163. The samples were analized for copper, lead, zinc, uranium, molybedium, silver, iron, and manganese.

When examining these maps one striking feature becomes apparent. That is, the variation in sample density. This ranges from one sample per twenty square miles in some areas to three samples per square mile in others. Caution is required when interpreting the data since the analysis were done using methods that are less accurate than those currently used.

What were they?

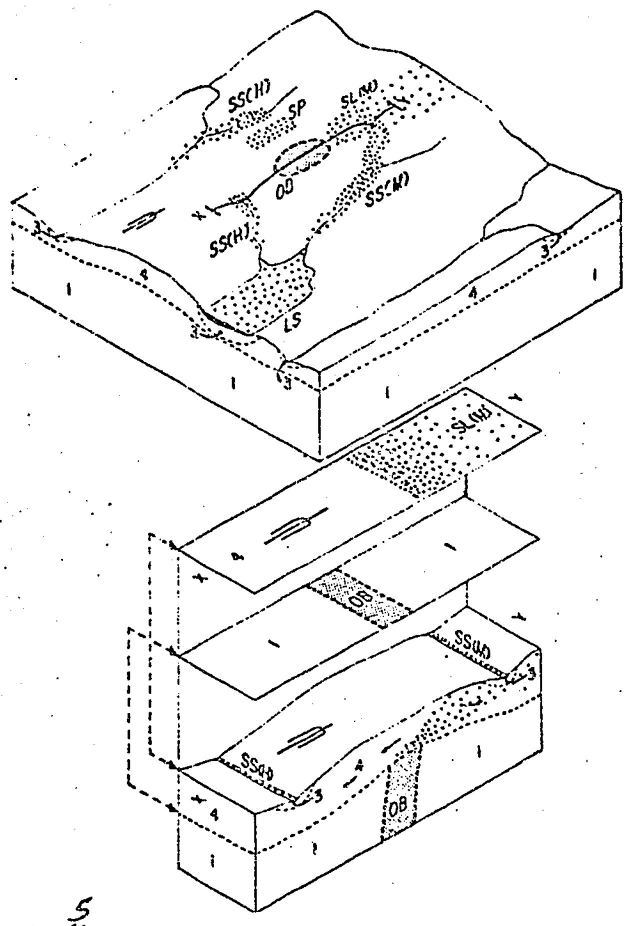


Fig. 5. Model A1 (Shield). Idealized models for geochemical dispersion of mobile elements in areas of thin lodgement till.

Anomaly types: SL(M) = soil anomaly derived by mechanical means, SL(H) = soil anomaly derived by hydromorphic means, SS(M) = stream sediment anomaly derived by mechanical means, SS(H) = stream sediment anomaly derived by hydromorphic means, LS = lake sediment anomaly, SP = seepage anomaly, BG = bog anomaly.

Overburden types: 1 = bedrock, 2 = residual soil, 3 = recent alluvium, 4 = till, 7 = transported overburden of remote rigin.

Others: OB = orebody, : : : = the density of dots is proportional to anomaly strength.

(From Bradshaw, 1975)

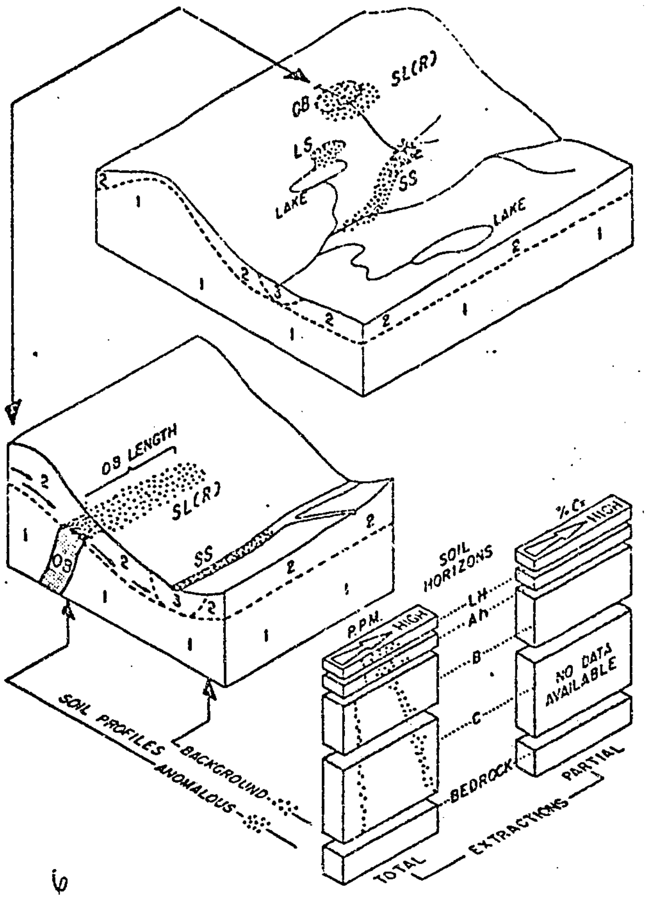


Fig. 6. Model A1 (Cordillera). Idealized models for geochemical dispersion of mobile elements in well-drained residual soil.

Anomaly types: SL(R) = residual soil anomaly, SL(M) = mechanically smeared soil anomaly (by glacial action), SS = stream sediment anomaly, LS = lake sediment anomaly, SP = seepage anomaly, BG = bog anomaly.

Overburden types: 1 = bedrock, 2 = residual soil, 3 = recent alluvium, 4 = till, 5 = overburden of remote origin.

Others: OB = orebody, : : : : = the density of dots indicates anomaly strength.

From Bradshaw, 1975.

Discussion of Q.M.N.R. Geochemical Results

Figure 7 shows the distribution of geochemically anomalous areas within the region mapped by the Ministry of Natural Resources. The number beside the anomalous area identifies the bedrock-type beneath the sample site. Those geochemical anomalous that are associated with Grenville Group paragneisses are illustrated on Figure 2.

It would appear that there is only one area of Grenville Group metasediments that appears to have a favourable geochemical background and that the Grenville Group as a whole is unattractive from a base metal point of view. However, this is more apparent than real for areas such as Baie Comeau, Labrieville, Forestville-Tadoussac and St. Paul Saguenay have received only minimal, at best, coverage. The base metal potential of these areas can be judged only when a uniform and consistent survey has been completed.

RECOMMENDATIONS

Large areas of favourable geology with known geochemical anomalies and drainage systems suitable for regional sampling programmes are spaced throughout the eastern Grenville region. Most of the areas such as St. Paul-Saguenay, Labrieville, Baie Comeau are easily accessible by road, while others such as Lac Berte and Manicouagan-Sept-Iles areas are partially accessble by road and rail. Those areas not accessible by this means can be reached by float plane.

A two-part programme that takes advantage of the differing accessibility is presented. The two parts can be run concurrently, contiguously or separately, depending on administrative conditions present at the time of mobilization.

Recommended Programme

(1) Orientation Survey

An orientation survey should be conducted over known occurrences of Zn mineralization in Grenville Limestones. It would prove useful to cover, not only, past producing areas such as Long Lake, Ontario, and Calumet, Quebec, but to cover areas where there are known Zn occurrences such as Wakefield, Quebec., etc. This would give an impression of the types of geochemical signature of various types and styles of Zn mineralization.

Appendix 3 lists some suggested areas.

(2) Part 1

This portion of the regional survey covers the following areas; St. Paul-Saguenay, Lac St. Jean, Chicoutimi-St. Jean, Forestville-Tadoussac, Labrieville and Baie Comeau. The locations of Grenville Group metasediments are easily accessible in these areas. Thus, sampling at intervals of 1,500 - 2,000 ft. along major streams and above confluances of all tributaries should provide geochemical information on a detailed scale not provided by the Quebec Ministry of Natural Resources. Further, while sampling is taking place, reconnaissance mapping along the river flanks should take place. The results should yield enough high quality data to fully evaluate the base metal potential of a given paragneiss belt.

(3) Part 2

Part 2 is a recommended reconnaissance stream sediment sampling campaign over the least accessible Lac Berté and Mancouagan-Sept-Iles areas. The phase would draw on the experiences gained from Part 1 as far as sampling technique and spacing. For the time being, it is estimated that a sample interval of 2,000 - 2,500 ft. along major streams and their tributaries above the influences. This phase of the programme may be supplemented by mineral rich lake margin sediments. Thus a float equipped helicopter may serve this end. Reconnaissance mapping and sampling of anomalous areas should be considered as a follow up.

CONCLUSIONS

There exists in the eastern Grenville substantial areas of, as yet, unexplored Grenville Group metasediments (Figures 1 and 2). These areas have varying amounts of, paragneiss, quartzite, marble or crystalline limestone and amphibolite lithologies. The Grenville Group metasediments have been subjected to varying degrees of structural deformation, migmatization and intrusion. To the southwest of the eastern Grenville region, these lithologies are host to zinc sulphide deposits of high grade and large tonnage.

Examination and compilation of public assessment work files indicates that there has not been any detailed exploration that warranted claim staking in the eastern Grenville region. However, this does not preclude regional reconnaissance programs that have not been reported. For example, it is known to the writer that in 1976, Soquem Ltee conducted a regional reconnaissance geological-geochemical program in the Forestville-Tadoussac Area.

A two-part programme has been recommended that offers Shell Canada Resources Limited a flexible means of examining the eastern Grenville at times, and under conditions, suitable to the company. This programme should commence as soon as possible in the 1977 field season. The programme should begin with an orientation survey around known occurrences of Zinc mineralization in the western Grenville region and be followed by as much coverage of the areas outlined under Part 1 as possible. The information and experience acquired will aid in continuing onto Part 2.

APPENDIX 1

The Geologic Model - The type of exploration target

The following is a brief description of the type of exploration target which an exploration program in the Grenville should aim for. This presentation is made only for familiarization and the reader is referred to the original work for details.

2. Zinc Deposits of the Balmat-Edwards District, New York

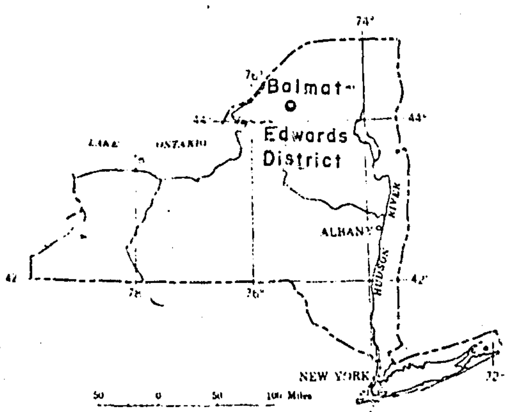
EDGAR R. LEA,* DAVID B. DILL, JR.*

Contents

Illustrations

* St. Joseph Lead Company, Edwards Division, Balmat, New York.

Tables



ABSTRACT

The zinc deposits of the Balmat-Edwards Division of the St. Joseph Lead Company in northern New York State provide some 10 per cent of the domestic zinc produced annually within the United States. These complex ore deposits are contained within marbles of the Precambrian Grenville series, in a repetitive sequence of dolomites and silicated units. The Balmat ore bodies are localized at various intervals throughout some 1800 feet of the stratigraphic column on the northwest side of a band of gneiss that has continuity to the Edwards area, some 10 miles to the northeast. The Edwards ore bodies are located to the southeast of this gneiss. The marble formations are thought to have included repetitive intervals of marine sedimentation that provided mineralized source "beds" and were subsequently folded, flooded, and injected with melts at great depth and were sheared, recrystallized, and reconstituted.

Detailed structural and stratigraphic studies throughout the northwestern Adirondacks in the Balmat-Edwards district, and at each mine in particular indicate the close dependence of the ore deposits on the enveloping structure whether it be local, district-wide, or regional in scope. Primary folding has developed a northeast regional trend with northwest dips. Secondary folding has been developed by an almost horizontal northeast-southwest-oriented shear couple in the plane of the regional trend. The secondary folding has produced crossfolds that intersect the regional northeast trend and plunge north to northwest at various angles.

The ore bodies are found within certain stratigraphic horizons where repeated alternation of competent and incompetent beds encouraged unusually complex folding. Analysis of individual mine structures indicates that the location of each deposit is controlled by structural crossing of primary and secondary folding. The ore bodies, which are tabular, lenticular, or pod-like in form, have features that suggest parallelism to true bedding or modified flow banding, developed by northeast-southwest shearing stresses related to the development of the crossfolds. The ore deposits in general follow both structural and recrystallization trends within the wall rocks.

Mobilization of the pre-metamorphic ore minerals is believed to have involved a combination of plastic flow under stress and solution of the sphalerite, minor galena, and pyrite. The ore fluids are thought to have been guided by secondary shearing and microbrecciation into structurally prepared areas where reprecipitation took place. The presumed pre-metamorphic mineralization now exhibits epigenetic high-temperature features related to late-stage metamorphism.

INTRODUCTION

The Balmat-Edwards zinc district is situated a few miles southeast of Gouverneur, St. Lawrence County, New York, within the St. Lawrence River Valley and adjacent to the northwestern slopes of the Adirondack Mountains (Figure 1). The district extends for 10 miles from Sylvia Lake and Balmat northeasterly to the village of Edwards. Active metal mining is limited to the operations of the Edwards Division of the St. Joseph Lead Company.

The writers have conducted joint studies within the Balmat-Edwards district since 1957.

Engel and Engel (18, p. 1385) confirmed Brown's (9, p. 254) reasoning by concluding that the paragenesis of the metamorphic minerals in the marbles was diopside, tremolite, anthophyllite, serpentine, and then talc, with the sulfides introduced during the anthophyllite stage of retrograde metamorphism.

Brown and Kulp (19, p. 138) on the basis of lead-isotope studies calculated the age of mineralization to be 1050 ± 100 m.y. This gave good agreement with the metamorphism of the Grenville Series as determined by Aldrich, *et. al.* (16, p. 105–108) for K/Ar, Rb/Sr, and Pb isotopes.

Doe (20, p. 37) derived an age of 1050 ± 100 m.y. both for the most recent metamorphism within the Grenville series and for the introduction of the sulfides.

Brown (26, p. 45) questioned the validity of an age of 1050 ± 100 m.y. for both metamorphism around Balmat and the assumed late stage introduction of sulfides, on the basis of his study of isotopic data on the Balmat-Edwards district lead mineralization and elsewhere, indicating that regional metamorphism resulted in homogenization of the originally varied isotopes. On the basis of this conclusion Brown (30, p. 66) has revised his earlier concepts and now believes that the Balmat-Edwards ores were not only present before, but took a complete part in, the Grenville metamorphism, thus explaining their present high-temperature characteristics.

Solomon (27, p. 154) advances the coarseness of the sulfides and gangue textures, the intense folding and microbrecciation of the Balmat ore body, and the confused paragenesis, together with the unique type of distribution of the sulfur isotopes, in support of premetamorphic sulfide mineralization.

Engel and Engel (12, p. 1044) assume an average age of 1100 m.y. for the culmination of the Grenville orogeny. They speculate that the inception of the Grenville sedimentation might have been as early as 1500 m.y. ago and probably exceeded 1200 m.y. If this speculation is valid, the age of the assumed premetamorphic sulfide mineralization would fall somewhere within these limits.

ECONOMIC GEOLOGY-PRIMARY ORE

Forms of the Ore Bodies

In general, the ore bodies can be defined as usually conformable, with cross-sectional areas of rather moderate size but characteristically with a large, often extremely large, down-plunge dimension. It is somewhat difficult to give dimensions to particular ore shoots because of their general habit of continually changing in details of form as they proceed down plunge. This feature, of course, is a direct result of the intimate relationship of the complexly folded enclosing rock formations with the ore shoots. Because of these varied characteristics of ore shoots in dimension and form, the reader is referred to particular plans (Figures 8, 9) and sections (Figures 5, 6, 7) for details within the particular mines.

The dimensions of individual mineable ore shoots for all mines within the district range as follows:

Thickness: 2 to 50 feet;

Horizontally along the strike: 50 to 800 feet;

Down plunge: Various, often according to the size of the particular ore shoot, but may be up to thousands of feet with downward limits now unknown;

Shape: Lenticular, pod-shaped, or tabular.

There are long, thin, tabular bodies in the less-folded areas. These usually strike northeast-southwest, consistent with the trend of primary folding, and progressively become thinner in their extensions until the mineralization is only faintly visible.

Elsewhere the ore bodies may become lenticular or pod-like as they pass into more intensely refolded areas or bulge out into greatly thickened masses reflecting the form of the folds. Some of these fold forms may be recumbent, doubled, and mashed together synclines and anticlines or troughs and crests. All orientations of strike and dip occur within the ore shoots, but, in all places, they faithfully conform to the direction and angle of plunge of the controlling crossfold structure. Within some ore shoots, remnants of diopside and in some cases carbonate show flexures and rock type characteristics similar to those present in the enveloping country rock. These remnants are preserved by surrounding high-grade sphalerite at many locations.

Mineralogy of the Deposits

The assemblage of ore minerals is simple. Pyrite and sphalerite are abundant, and galena, pyrrhotite, and chalcoprite are minor in amount. Marcasite has been reported but is not conspicuous. The arsenic minerals, jordanite and realgar, occur extremely rarely and are mere curiosities. Supergene minerals, present largely in Balmat No. 2 mine, consist of magnetite, hematite, and secondary forms

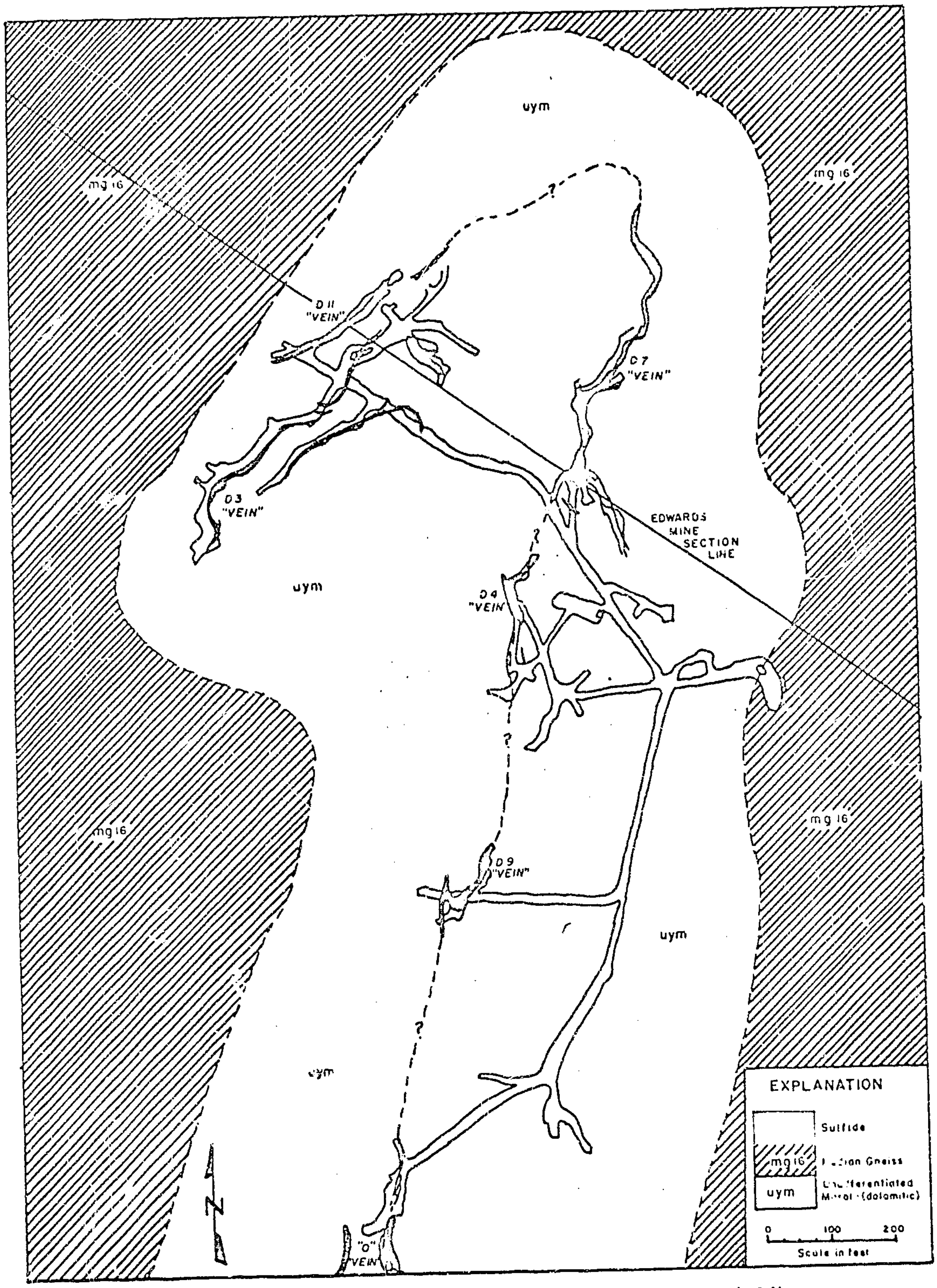


FIG. 8. *Geologic Map of the 1500-Foot Mining Level: Edwards Mine.*

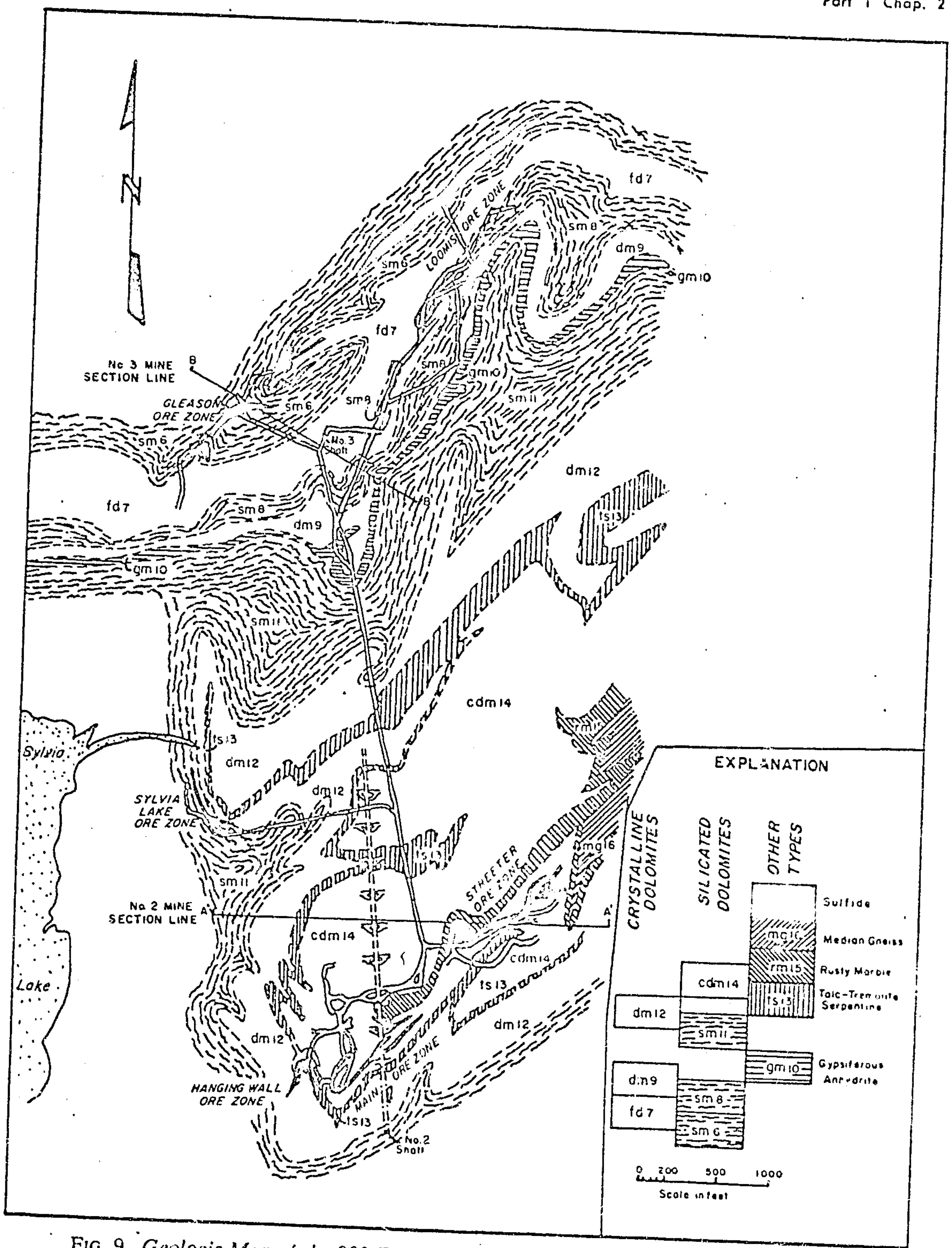


FIG. 9. *Geologic Map of the 900-Foot Mining Level: Balmat No. 2 and No. 3 Mines.*

of sphalerite, galena, chalcopyrite, bornite, and willemite.

Gangue minerals include quartz, diopside, tremolite, serpentine, talc, carbonate, barite, and anhydrite. In the supergene ores, chlorite is abundant, with minor ilvaite and garnet (grossularite). In most, if not all cases, the nonmetallic minerals found within the ores are either reworked fragments of adjacent wall rock or late products of retrograde metamorphism in the surrounding calcsilicate marbles.

Aside from a gradual diminishing of supergene effects with depth, there is no general change in mineralogy either laterally or in depth, in the sense of metal zoning or impoverishment in zinc. The tendency for pyrite to be segregated and for sphalerite to be disseminated leanly around the rims and extensions of individual ore bodies does not apply as a generalization to groups of ore zones. In comparing groups of ore zones, and also individual ore bodies within ore zones, fairly wide deviations in ore grade exist from high-grade, low-pyrite shoots to lean, weakly mineralized or highly pyritic bodies. These variations, however, occur in about the same proportion throughout the strike and plunge of the ore bodies and are a measure of structural control. The only possible exception to the foregoing statements is the habit of galena at Balmat No. 2 mine to accumulate, for reasons not yet understood, in footwall portions of the structure. In general, for each mine's composite production, there is a remarkable consistency in zinc-ore grade. For example, the ore grade at Edwards is essentially the same at the surface as at the 3100-foot level, nearly a mile down the plunge.

Wall rock alteration is virtually absent in the Balmat-Edwards district. Occasionally bleached rims measured in a few inches, may be observed in the more pure dolomites at ore contacts in the Balmat No. 2 and No. 3 mines, but these are exceptional.

There is a wide range of mineral association and texture. Macroscopically, most of the ores are massive to disseminated coarsely crystalline aggregates of sphalerite and pyrite in gangue of quartz, carbonate, and diopside. Where inclusions of wall-rock are abundant, the sulfide bodies have the aspect of ore breccias. Pyrite occurs with sphalerite either as cubes and pyritohedra in discrete subhedral or anhedral grains up to 10 cm, shattered and microbrecciated or in massive aggregates almost without sphalerite or gangue. Sphalerite usually is coarse-grained but ranges from .01 mm grains to subhedral crystals over 8 cm in length and has well-developed polysynthetic twinning. Color ranges from a light chocolate brown at Balmat No. 3 mine to dark chocolate-brown at Edwards and Balmat No. 2. The color is an index of the FeS content in the sphalerite. Doe (20, p. 75–82), in a study of the sphalerite geothermometer, determined the FeS content in pure sphalerite for 170 specimens from Balmat No. 2 mine and for 25 specimens from No. 3 mine. No valid temperature data could be determined, but the arithmetical average of analyses showed 9.6 weight per cent FeS for Balmat No. 2 and 3.1 weight per cent FeS for Balmat No. 3. Available data give about the same percentages for Edwards as for Balmat No. 2.

Galena very rarely appears within the pyrite-sphalerite ore except in footwall areas of Balmat No. 2 ore zones, where it occurs as discrete grains and fracture fillings in pyrite, sphalerite, and silicates. Commonly, at Edwards and Balmat No. 2 mines, galena is conspicuous as veinlets up to 3 cm in diopside rock. A little lead is recovered as a by-product at Balmat.

Chalcopyrite and pyrrhotite, as is true of galena, are most conspicuous as gash veins and disseminated blebs, often with minor sphalerite, in diopside rock at some distance from zinc ore bodies. Occurrences of chalcopyrite and pyrrhotite within ore bodies can be observed only in polished section. Chalcopyrite appears as fine blebs and chains within sphalerite and pyrrhotite, and pyrrhotite has complex relations with pyrite and sphalerite. There is no agreement on whether pyrrhotite is exsolved from sphalerite or replaces it.

Gangue minerals may be nearly absent in some of the high-grade ores or may predominate in disseminated or weakly mineralized zones. Quartz is much more common than the microscopical studies would indicate. It is particularly abundant in the Upper Gleason, Streeter, and Main ore zones as partly rounded, semi-replaced inclusions. Rounded and subangular fragmental inclusions of diopside and tremolite are frequent, very often largely altered to serpentine and talc. Carbonate, usually calcite, may occur either as granular gangue or as unreplaced bands of wall-rock that are often distorted in complex folds. Barite is a rather common gangue mineral at Edwards and in the southwest portion of Balmat No. 2 mine; since it is not found in the wall-rock, it is presumed to be closely related to the ore minerals. Anhydrite previously reported as a gangue mineral and related to barite in some way, is probably unreplaced wall-rock.

Pyrite and sphalerite in some ore bodies may be evenly mixed, in others, they are nearly mutually exclusive, and in some cases may be segregated into fine-grained and coarse-grained alternating layers of pyrite-rich and sphalerite-rich sulfides that often exhibit flow banding. District-wide average composition of the ores is as follows: 10 to 30 per cent sphalerite, 0 to 80 per cent pyrite, and 5 to 80 per cent gangue.

Mineral paragenesis and texture has been studied in detail by Brown (9,10), Doe (20,22,23), and Solomon (27), and their reports have been freely used in the foregoing descriptions. Drawings of some recent polished-section work on ores from the various mines by G. Aletan are represented in Figure 10. Many conflicting observations in the published work emphasize the complexity of the mineral relationships, and, although many hundreds of polished sections have been examined, the interpretations unavoidably have been subjective and incomplete.

Only general statements can be made within the scope of this article. Mutual boundaries without obvious order of crystallization occur in the pairs sphalerite-pyrrhotite, sphalerite-carbonate, galena-sphalerite, galena-pyrite and galena-chalcopyrite, but many cross-cutting and reversible relationships also occur in these minerals. Pyrite has especially complex relations, but much of it is intensely microbrecciated and all other sulfides fill fractures in the pyrite and occur as grains within the pyrite crystals. Barite and quartz may be the only exotic nonmetallic minerals in the sulfides and appear to be closely related to the deposition of sulfides. Considering the ores in their present environment, serpentine and talc are definitely post-sulfide, and diopside-tremolite are pre-sulfide; these relationships assist in timing sulfide crystallization within Engel's series of retrograde metamorphism: Diopside-tremolite-anthophyllite-serpentine-talc. The preceding evidence strongly suggests to us that the primary ores in their present form were metamorphosed from previously existing sulfides.

Factors Controlling Form and Location of Ore Bodies

It has been indicated previously in this discussion that the Balmat-Edwards mines are located in silicated and dolomitic marbles within areas forming structural crossroads between northeast-trending, northwest-dipping (overturned) components of the primary or accordant folding and later development of north-northwest-plunging secondary cross folds.

Figure 8 of the Edwards mine at the 1500-foot mining level illustrates the relation of the siliceous, generally non-calcareous, and granitized median gneiss, as the more competent rock, to the less competent dolomitic marble series. The dolomites contain some silica as distinctly siliceous or quartzitic horizons, as banded quartz diopside, or as irregular disseminations within the dolomite. Some areas contain tremolite and diopside in association with their alteration products of talc and serpentine, and anhydrite, of probable sedimentary origin, is a mappable unit in certain areas of development.

Toward the close of all but the very last stage of major deformation and subsequent to silicate alteration within the dolomite, pegmatite dikes cut through the folded formations, and pegmatitic material soaked both the dolomites and the gneiss. Today, this granitic material shows up clearly within the gneiss as dikes, clots, and dissemination but loses its identity in the dolomites except where clear-cut pegmatite dikes have been intruded. The Edwards ore emplacement, at least in its present form of high-grade ore shoots, is post-pegmatite. At several locations, high-grade, coarse-grained sphalerite fills fractures and surrounds brecciated knots of pegmatite. In others, where pegmatite has become involved in a northeast-southwest-trending ore lens, brecciation of the pegmatite dike occurs along the strike of the ore lens in plan, and high-grade sphalerite ore surrounds and partially replaces the irregular pegmatite fragments. Definitely, some northeast-southwest shearing stresses are indicated as having been post-pegmatite but rior to the emplacement of ore shoots in their present form.

The effect of this shear couple acting on northeast-trending, northwest-dipping elements of the primary folding has been to rotate the gneisses around the dolomites to form Z-shaped folds, plunging to the northwest more or less down the regional dip. As seen in section and plan (Figures 5, 8) the rotation of the gneiss, enclosed and isoclinally rotated the marble and the mineralized horizon along which the major high-grade ore shoots were localized. Detailed mapping of these ore zones in most cases will give evidence of the same shearing stresses that developed the major controlling crossfold. For example, the D-9 'vein' (Figure 8) shows a well-developed Z-shaped fold, indicating that northeast-southwest shearing stresses have been important in controlling the form and location of the ore bodies. Else where the folding may be more obscure, but generally in detail, even in tabular ore bodies, microbrecciation and Z-shaped minor folds give evidence of northeast-southwest shearing stresses along the strike of the ore shoot. The ore shoots were developed along the strike to limits determined by the width and richness of ore considered as economic for mining. The sulfides do not terminate completely but continue beyond the limits of economic development, usually as pinched stringers of pyrite and minor sphalerite that, together with information from diamond drilling between ore shoot areas, suggest weak continuity of the mineralized beds. The form suggested is that of irregular or elongated beads on a string.

The lenticular ore shoots or the complexly folded irregular pod-like ore shoots take on the plunge of the major crossfold in the rotated gneiss. In vertical cross section, the dips change from steep to flat to steep. This feature has been shown to be indicative of changing plunges not only for the major cross fold, as indicated by the rotated gneiss, but also for individual ore shoots. Where the beds are steeper, ore shoots are more tabular and tend to straighten out, as is shown at the 1500-foot level and above. Where the beds dip more gently, generally there is a major development of Z-shaped minor crossfolds that, within the mineralized horizon, control the shape of fantastically complex pod-like ore shoots. These fold structures apparently were related in their development to shearing stresses along the fabric of bedded formations that had different degrees of competency within the zone of plastic flowage. The angle of plunge, whether steep or gentle in the ore bodies, is dependent upon, and consistent with, the plunge of the major crossfold in the gneiss for particular elevations within the mine.

The factors controlling the form and location of the Balmat No. 2 and No. 3 mine can best be considered by reference to Figure 9 of the 900-foot mining level and Figure 6 and Figure 7 illustrating vertical sections through each mine.

The geologic map of the 900-foot mining level, with its accompanying vertical section, illustrates the localization of the Balmat No. 2 mine with reference to the structural crossing previously indicated between the northeast trending, northwest-dipping beds of the primary folding and the north-northwest plunging elements of the secondary cross folding. As seen in east-west section (Figure 6), the dominant structure within the No. 2 mine is the north-northwest-plunging crossfold that caused extreme folding of the dolomites, silicated dolomites, tremolite, and other formations into an isoclinal syncline, overturned toward the southeast. The "rusty marble" formation (unit 15) is completely doubled by northeast-southwest shearing stresses that generated the secondary fold. The subunits of the No. 14 formation, which contains the ore bodies of the No. 2 mine, generally strike northeast and dip northwest in the Streeter ore zone on the footwall side of the Balmat trough, consistent with the trend and dip of the primary folding. At the keel of the synclinal crease formed by the rusty marble in vertical east-west section may be seen the complex configurations caused by plastic flow of both the enveloping rock formations and the enclosed ore horizon. The subunits of the No. 14 formation, in plan and section, indicate clockwise isoclinal rotation around the squeezed keel of rusty marble, thus causing footwall No. 14 formation to repeat itself within the Balmat No. 2 trough. The shearing has operated along the bedding planes of the northwest-dipping overturned limb of the accordant Sylvia Lake syncline. The Hanging Wall ore zone is composed essentially of high-grade coarse-grained sphalerite and very minor pyrite. The Main and Streeter ore zones are more pyritic, containing variable amounts of sphalerite, resulting in medium grades generally. Some of the northeast extensions of the Streeter ore zone may be unusually pyritic.

In contrast to the No. 2 mine, the dominating structure of the No. 3 mine is that formed by the accordant drag folds that plunge gently to the northeast and reverse themselves in the mine area.

In detail, the No. 3 mine may be separated into two parts, the Gleason area to the northwest and the Loomis area to the southeast. The Gleason ore bodies have been called the Upper, Middle, and Lower Gleason ore zones (Figure 7). These ore bodies are localized in the general area of intersection between northeast-trending, northwest-dipping beds and what is believed to be north-northwest extensions of the axis of the same crossfold structure which dominates the No. 2 mine some 5000 feet to the south-southeast. The Gleason ore bodies enlarge in the general area of the section used for illustration. The Upper Gleason ore body is localized within a crossfold structure plunging to the north-northwest at about

25° with a limited down-plunge extension to the northwest and south-southeast extensions up the plunge to surface. The ore horizon is a coarsely crystallized high-grade sphalerite and pyrite replacement of a brecciated gray-quartz lens, with minor diopside, that is enclosed within the No. 6 formation. The Middle and Lower Gleason ore zones lie within northeast-trending structures. The very irregular high-grade, coarse-grained sphalerite and generally minor pyrite replacements of fractured or brecciated gray quartz and silicated dolomite lend themselves to longhole-stope extraction.

It is interesting to note the presence of northeast-southwest-trending shear planes that dip steeply to the northwest and have large horizontal displacements and small vertical throws. These shears are believed to be expressions of the northeast-southwest-acting shearing stresses related to the development of crossfolds. Some slight post-ore movement may have occurred along these fault planes in the more competent silicated and quartzitic dolomites of the No. 6 formation. Within the dolomitic horizons, the shear planes have since healed or are difficult to see in these more plastic formations.

The northeast-southwest section shows Loomis A ore zone development on a small drag fold structure related to the overturned limb of the Sylvia Lake syncline. The ore body forms at the sheared contact between the plastically deformed No. 7 dolomite formation and the more competent No. 8 silicated dolomite. The Loomis B ore zone is weak on this section but blossoms within the No. 8 silicated dolomite and No. 9 dolomite to the northeast (Figures, 7, 9), where a north-northwest-plunging crossfold intersects the northeast trends of the Loomis A ore zone. Both the Loomis A and B horizons are characterized by ore formed of light-brown coarse-grained sphalerite containing less than 1 percent Fe and accompanied by very minor pyrite.

Lithology frequently controls the shape of the ore bodies, particularly with reference to their contacts. In the No. 2 mine for example, sharp contacts of massive sulfides are usually seen with the rusty marble, tremolite, calcitic marble, or dolomite. On the other hand, contacts with serpentinous or diopsidic marbles usually are vague and poorly defined, and disseminations of sulfides, discontinuous pods, bunches, horsetails, and stringers outward from the more massive ore suggest irregular migration of ore minerals into slightly crushed foot wall or hanging wall rocks. Ore bodies in diopside, quartz diopside, or quartz show contacts that are highly irregular and erratic, have complex patterns of penetration into the wall-rocks, and contain sulfide-filled gash veins.

Generally the thickest ore concentrations are found in synclinal or trough structures. Lesser thickening for some reason occurs at their crests. There is thinning along all flanks almost without exception. The favorable horizons are considered to be those in which base-metal sulfides were disseminated during the original deposition of the sediments, a process that was repeated at intervals during the development of the stratigraphic column.

Certainly, with ore bodies spread throughout many different horizons within the some 1800 feet of the stratigraphic column in the Balmat area, it would be difficult to attribute the source of present ore bodies to migration from one single source bed as advocated by Knight (17). Wisps and disseminations of pyrite, sphalerite, and very minor galena are found extending beyond and between known ore-bearing areas underground. This provides forceful evidence, as do the mineral textures, lack of wall-rock alteration, largely poor definition of mineral contacts, and general lack of obvious channelways or conduits, for considering the possibility of pre-metamorphic mineralization.

Intense folding and metamorphism have caused almost total destruction of primary sedimentary structures. This prevents a complete understanding of the original petrology of the Grenville marbles. We can but surmise on how the ore bearing source beds acquired their sulfide minerals.

Solomon (27, p. 154–155) proposes the following sequence of events to account for the known concentrations.

"a) The periodic formation in a rather shallow carbonate-precipitating basin of localized bottom depressions in which there developed a physico-chemical environment amenable to the reduction of $SO_4^{=}$ to $S^{=}$ and its contemporaneous interaction with an abundant supply of Zn^{++}, and Fe^{++} and other metallic ions to form fine grained sulfide accumulations.

b) Subsequent compaction and incorporation of these sulfide concentrations into the sedimentary sequence.

c) Folding and metamorphism during which the ores were recrystallized, isotopically homogenized and locally concentrated to give their present distribution."

Effects of Metamorphism on the Ores and Their Immediate Environment

It is assumed, for purposes of discussion, that the so-called source beds containing disseminated pyrite, sphalerite, and minor galena were pre-metamorphic and took a complete part in the Grenville metamorphism. It is thought that this metamorphism took place at great depth within the zone of plastic flowage, resulting in recrystallization and reconstitution of both source beds and enclosing rock formations.

The dolomites, silicated dolomites, and gneisses became thoroughly recrystallized under pressure and heat. Engel and Engel (18, p. 1385) indicate that the regional metamorphism, which extends throughout and beyond the Balmat-Edwards district, evolved the assemblage diopside, dolomite, calcite, and quartz in the marble and that of quartz, biotite, plagioclase, and muscovite in the gneiss. Their paragenesis in the marble was diopside, tremolite, anthophyllite, serpentine, and talc with the appearance of clinozoisite, chlorite, sericite, and albite in parts of the gneiss. Two major deformations affected the marbles. It has been suggested that the earlier of the two occurred slightly before, and during, primary emplacement of the granites. The second major deformation is thought to have taken place during the culmination of the granitic intrusions (24, p. 223). During the latter stage, the gneiss was subject to a drenching by melts and injected with granite. Late stages of the granite intrusion have resulted in pegmatite dikes cutting the marbles.

The early major deformation developed northeast-striking, northwest-dipping structures. The later deformation resulted in northeast movements of formations relative to those to the southeast, in the plane of regional trend. These shearing stresses developed the cross folds that intersected the primary regional trend at different angles to form the major structural control within particular mine areas.

At certain locations, possibly dependent on the competency of wall-rocks relative to each other and on the distribution of the shearing stresses, minor shear zones or fold structures developed along the mineralized beds. The plunge of both shear zones and Z-type minor fold structures, were dependent upon and followed the major controlling crossfolds in both direction and angle of plunge. The disseminated pyrite, sphalerite, and minor galena at certain locations within the source beds flowed plastically, developing pinched limbs and thickened concentrations of sulfides at the crests and troughs of minor folds. Shearing stresses along the fabric of the bedding were important in the development of local microbrecciation and shearing or of well-developed minor crossfold structures, involving rocks of different competencies. In these areas, the disseminated sphalerite and pyrite are believed to have acted quite differently. It is suggested that the pyrite, under these particular conditions of directed stress causing shearing between beds of different competency, was largely segregated and stayed in place. Mobilization of the disseminated sphalerite and minor galena and pyrite may have resulted by these minerals having gone into solution and having been reprecipitated elsewhere in the system (27, p. 74). These solutions are believed to have flowed along planes of secondary shear that followed the sedimentary fabric of the previously mineralized beds and redeposited their load in structurally prepared areas, thus forming the present high-grade ore shoots.

Within particular ore shoots and surrounded by ore, remnants and fragments of silicate bands are found. These have been stretched and torn apart by the shearing stresses described. Similar silicate remnants and fragments enclosed by dolomites and serpentinous dolomites may be seen in the surrounding wall-rocks. They suggest an analogous origin, i.e., previous brecciation under conditions of plastic flow. As a result of this plastic flow, nearly all evidence of shearing, brecciation, or fracturing was healed, leaving a general lack of obvious channelways or conduits for transport of ore solutions.

The introduced high-grade sphalerite is very coarse, and this suggests that it filled open spaces within originally brecciated zones that were developed in rocks of differing competency such as dolomite and diopside or dolomite and quartz. The high-grade, light to dark chocolate-brown sphalerite exhibits cleavage faces of up to 8 cm in width. These cleavage planes provide mirror surfaces and return bright flashes of light from mine lamps thus giving the name "spangle" ore in mining parlance. Spangle ore is a characteristic of all the Balmat and Edwards mines and provides necessary "sweetener stopes," or permits the mining in certain stoping areas of lower-grade disseminated ores through which it cuts with sharp contacts.

The introduction of sulfides at a late stage in the metamorphism into structurally prepared areas, following the formation of silicates, would be consistent with Engel and

Engel's (18, p. 1385) paragenesis of the metamorphic minerals in the marbles of diopside, tremolite, anthophyllite, serpentine, and then talc, with the sulfides introduced during the anthophyllite stage of retrograde metamorphism.

Summary

In general, the authors would be sympathetic with Brown (30, p. 66) and Solomon (27, p. 154–155) in their interpretation of premetamorphic sulfide mineralization in explaining the sequence of geologic events required for the formation of primary ores.

Fetid dolomitic marbles, containing H_2S, and sedimentary anhydrite occur at a number of different horizons within the stratigraphic sequence. In addition, a repetitive sequence is indicated by alternating formations of dolomite and silicated dolomites of almost identical composition. This would suggest that similar conditions prevailed in the sedimentary environment at repeated intervals during deposition of the Grenville limestones in the Balmat-Edwards district.

It is conceivable that these repeated occurrences of similar conditions in the sedimentary environment explain the recurrence of disseminated base-metal sulfides at numerous calcareous horizons throughout much of the stratigraphic column.

It is thought that these mineralized beds were deeply buried, folded, and metamorphosed, during which events the disseminated base-metal sulfides were recrystallized and mobilized. The sphalerite, minor galena, and pyrite are presumed to have flowed either plastically under directed stress or in solution along planes of secondary shear; these solutions followed the sedimentary fabric of the previously mineralized beds and reprecipitated and concentrated the sulfides in structurally prepared areas. The pyrite was partially segregated. The sphalerite, minor galena, and pyrite may have behaved much like a distillate or as if they were filter-pressed from the disseminated sulfides within the carbonate rocks. Mobilization of the zinc and lead sulfides along the strike and dip of the mineralized beds has resulted in zones of concentration similar to irregular beads along a contorted string in plan and with continuity up and down the dip by virtue of their plunge (see Figures 8, 5). These concentrations of high-grade sphalerite formed as replacements of microbrecciated zones between rocks of different competency along planes of secondary shear or as replacements of all manner of complex crumple structures, related in their origin to secondary shearing and to the development of plunging crossfolds.

ECONOMIC GEOLOGY-SECONDARY ORE

To generalize, supergene processes have had but little effect upon the sulfide ores of the district. Thin limonitic gossan, often measured only in inches, caps the rather meager outcrops of the Edwards and many other ore bodies, giving way immediately below to fresh, unaltered sulfide. Cavities and vugs, lined with specularite, calcite, and other secondary minerals, are common in upper levels of the mines, but more often than not they are in the wall-rock rather than within the ore bodies. Hematite is widespread in the Balmat area, occurring occasionally as earthy and specular varieties filling fractures in both ore and wall-rock. In these instances of hematitization, the sulfides are unaffected, and the hematite, presumably derived from pyrite, has been transported. The notable exceptions are in the Upper Gleason ore body of Balmat No. 3 mine and the Hanging Wall ore zone of Balmat No. 2 mine. In the first instance, a very strong hematitization occurs only in the upper 50 feet of a thick massive sulfide lens. In the second, however, an intricately folded ore structure shows the effect of supergene activity to unusual depths.

The Hanging Wall zone is an uninterrupted complex of individual ore bodies following extremely tight, plunging keels, crests, and troughs. Concomitant with the tight folding, much brecciation and shearing were developed along contacts of rocks of dissimilar competency. It is in this environment that an unusual assemblage of supergene minerals has been developed; they are lacking in all other ore zones in the district.

The occurrence of secondary sphalerite, galena, and willemite was first described by Brown (10), who gave compelling evidence for the origin of these minerals by supergene process rather than by a second stage of primary mineralization. Cited as proof of deep oxidation by meteoric waters were the presence of solution cavities and of massive earthy hematite to considerable depths but in diminishing abundance as the structures were followed downward. It must be emphasized that the oxidation is by no means complete throughout the Hanging Wall ore zone at any elevation, but it is certainly more intense near the surface and gradually decreases with depth. Oxidation effects at 2000 feet below surface are very slight and localized, showing virtual disappear-

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Bryan H. Wilson

THE MONTAUBAN GOLD DEPOSITS

RELATED TO BASE-METAL MINERALIZATION

IN THE GRENVILLE PROVINCE

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ABSTRACT

The Montauban gold deposits are located some 50 miles west of Quebec City at the village of Montauban-les-Mines. The North Gold Zone is known from previous work and recent geophysical surveys to be at least 3000 feet long. Shallow drilling carried out to date along 1600 feet of this length has indicated an average grade of 0.255 ounces of gold per ton across 15 feet, or 0.15 oz/T across 32 feet. No recent drilling has been done on the South Gold Zone but previous work indicated a length of 1650 feet with an average grade of 0.19 oz T gold and 2.0 oz/T silver across 7 feet.

The gold is associated with small amounts of disseminated sulphides, mainly sphalerite, chalcopyrite, galena, pyrite and pyrrhotite, in cordierite-anthophyllite gneisses. The mineralized zone appears to be conformable with the enclosing rocks and is closely related spatially to base-metal deposits, also apparently conformable, from which 2.7 millions tons averaging 4.5% zinc and 1.5% lead were mined in previous operations, with known remaining reserves estimated at 761,934 tons of 3.5% zinc and 1.1% lead.

The deposits are of particular interest because they occur within the Grenville structural province of the Canadian Shield, which to date has not been noted for either gold or base-metal production. K-Ar and Sr-Rb dates indicate that the enclosing rocks were probably emplaced and metamorphosed 1.3 to 1.7 billion years ago and were subjected to a second metamorphism during the Grenville "thermal event" about 1 billion years ago.

Formerly believed to be of contact-metamorphic origin related to nearby intrusives, the base and precious metal zones are now thought to be stratiform deposits formed by processes associated with volcanism. The metamorphic grade of the ore and of the wallrock is compatible with the idea that the deposits were formed in a volcanic environment and later deformed and subjected to regional metamorphism along with the enclosing rocks. In this model the thin beds of meta-limestone with which much of the zinc ore is associated are regarded as exhalite deposits; the surrounding gneisses and amphibotites are interpreted, from chemical and other evidence, as being metamorphosed equivalents of basic to felsic volcanic rocks, tuffs and associated sediments and possibly chloritic alteration pipes related to volcanogenic sulphide deposits.

The extent of the gold and base metal zones at Montauban is comparable to that of many such deposits in the Superior and Churchill provinces of the Canadian Shield. Their recognition as typical volcanogenic deposits should lead to a re-evaluation of the potential of the much-neglected Grenville province. In applying standard exploration concepts and criteria, however, it is necessary to look through the metamorphism to the original environment in which the ore minerals were deposited.

These events occurred while the Grenville Plate was still widely separated from the Pre-Grenville (or Interior Laurentia) Plate. Collision of the two plates was accompanied by general uplift, especially on the Grenville side, and resulted in deformation along northeast axes superimposed on the earlier north-south folding. This was accompanied by heating but temperatures reached were in many cases not high enough to re-set the Rb-Sr or hornblende K-Ar systems. The typically Grenville ages of about 950 m.y. are regarded as reflecting the stage of post-collision cooling at which temperature dropped below the critical level required to isolate the K-Ar system in feldspar and biotite.

Near the Grenville Front many of the oldest rocks have been recognized as reworked units of the Superior Province re-deformed and re-metamorphosed by the Grenville orogeny. Elsewhere in southern Quebec, eastern Ontario and northwestern New York State, the rocks that predate the anorthosite plutons are referred to as the Grenville Group. They comprise mainly quartzofeldspathic gneisses, amphibolites and marbles and are regarded as being of mixed sedimentary and volcanic origin. Thickness of between 5000 and 20,000 feet have been estimated for the Grenville Group in various areas but there is considerable uncertainty in these figures because of extensive folding and flowage.

It has been suggested that deposition of the Grenville Group may have occurred as early as the Aphebian (2,400 to 1,600 m.y. BP) while some workers consider a somewhat later, Palaeohelikian, age more likely.

GRENVILLE METALLOGENY

In comparison with such geological units as the Superior and Churchill Provinces or the Appalachian and Cordilleran Orogens the Grenville province has not been regarded as a major producer of precious or base metals. There has, however, been significant production from a few deposits which may be of considerable significance in assessing the metallogenic potential of the Grenville environment. Besides the Montauban property described in this paper, the principal multimetallic mines have been the Balmat and Edwards operations in New York State and the Calumet Mine in Quebec.

The Balmat-Edwards area provides some 10 percent of the domestic zinc produced annually in the United States. Production in the area since 1915 has totalled over 20 million tons of ore from five mines, with present reserves of approximately the same amount. The average grade mined to date is 10.1% zinc, and some lead was also produced at one mine. The orebodies are contained within Grenville marbles closely associated with quartz-feldspar gneisses. The orebodies are generally conformable and are lenticular, pod-shaped or tabular in form. The main ore minerals are pyrite and sphalerite, with minor galena, pyrrhotite and chalcopyrite.

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Early writers considered these deposits to be veins or replacements formed in pre-existing dolomitic limestones. However, recent isotopic and textural studies indicate that the ores were present before, and took a complete part in, the regional metamorphism (12). One writer has proposed the formation, in a rather shallow basin where carbonates were being precipitated, of periodic accumulations of fine-grained sulphides. Subsequent folding and metamorphism caused the sulphides to be recrystallized and locally concentrated to give their present distribution. Regional metamorphism evolved the assemblage diopside, dolomite, calcite and quartz in the marble and quartz, biotite, plagioclose and muscovite, in the gneiss.

The Calumet Mine operated from 1943 to 1968, during which period 3,763,345 tons of zinc-lead-gold-silver-copper ore were extracted. Recoveries averaged 5.9% zinc, 1.65% lead, 0.07% copper, 2.7 oz silver and 0.014 oz gold per ton. The orebodies were generally tabular and lay conformably within a sheet-like mass of biotite-hornblende gneiss. They comprised both massive sulphides and disseminated sulphides in a gangue of altered feldspar and pyroxene. A less common type of ore was a dark calcite-tremolite rock containing auriferous galena, and it is reported that native gold was found associated with all the sulphides and as minute grains in the gangue. It has been suggested that the ore-bearing gneiss horizon may be a bed of altered impure limestone; in any case it is underlain by migmatite with relict sedimentary structures and overlain by massive amphibolite. Most of the literature on this deposit dates from earlier periods when a post-metamorphic hydrothermal origin was favoured. More recently, it has been considered that the presence of gahnite implies that zinc was present before metamorphism.

In considering the origin of gold deposits in the Grenville, it is worth noting that scattered gold occurrences have been found in southeastern Ontario, northeast of Havelock. In a general way the area corresponds with the southern limit of a complex chain of small volcanic belts stretching across this part of the Grenville province. Only a few of the deposits are associated with the volcanics directly, although most occur in diorite that may in part be derived from volcanics.

GENERAL GEOLOGY

The Montauban area lies within that part of the Grenville Province in which the oldest recognized rocks are the metamorphosed sedimentaries and volcanics of the Grenville Group. Within the area, these are composed mainly of quartz-biotite-hornblende gneisses grading into hornblende gneisses and amphibolites, with some sillimanite, cordierite and garnet bearing members, intercalated quartzitic units and minor lenses of carbonate rocks. The gneisses have a general northerly trend and dip to the east. The most recent regional mapping, by D.R. Pyke, suggests that the area has been folded at least twice, first into open folds with generally north-south axes and later, after a period of intrusive activity, weak east-west cross-folds were developed.

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The regional metamorphism is of the amphibolite facies. Granitization and migmatization are common but not widespread. The Grenville Group has been intruded by a variety of igneous rocks, mainly granite and quartz diorite but also including diorite, gabbro, norite, peridotite and pegmatite. These intrusive rocks now underlie approximately one-half of the area (Fig. 4).

Only a few faults have been recognized in the area; the two most prominent lie ten miles northeast of the Montauban mineralized zone and strike north-northwesterly.

Pyke has mapped some well-preserved pillows in a band of basic metavolcanics, previously mapped as amphibolite, one mile west of the Montauban ore zone. This tends to confirm previous suggestions that the numerous amphibolitic rocks within the Grenville Group are of possible basic volcanic origin. On the basis of chemical studies of the Montauban quartz feldspathic gneisses and comparison with criteria developed for similar rocks elsewhere, K. St.-Seymour (25) concluded that the quartz biotite gneisses at Montauban comprise highly metamorphosed equivalents of intercalated acidic volcanics, tuffs and associated clastic sediments.

LOCAL GEOLOGY

The most abundant rocks in the vicinity of the Montauban deposits are quartzfeldspathic gneisses, composed mainly of plagioclase, quartz potassium feldspar and biotite. There are some minor discontinuous garnetiferous members, and a hornblende-bearing unit directly east of the ore zone, as well as a sillimanite gneiss near the ore zone.

The southern part of the lead-zinc zone is mainly enclosed in a calc-silicate band 3000 feet long and from a few feet to almost 200 feet wide. This unit consists mostly of tremolite and diopside, with some quartz and a mixture of recrystallized calcite and dolomite locally referred to as "fireite" because it gives a dull red phosphorescence when struck in the dark. The calc-silicate unit is succeeded to the north by a band from 25 to 200 feet wide of cordierite-anthophyllite gneiss. The northern ore zones, including the gold-mineralization, lie within this unit. Its characteristic mineral assemblage is cordierite-quartz-biotite-muscovite-garnet-anthophyllite-plagioclase-minor sillimanite; this is intercalated with bands consisting exclusively of anthophyllite in a groundmass of cordierite.

Bands of amphibolite are common in the area, and one such band, up to 60 feet wide, lies 200 feet west of and parallel to the mineralized zone. The main mineral is hornblende, with lesser plagioclase (andesine-bytownite) and the amphibolites can be classified according to the presence of other minerals such as biotite, quartz, clinopyroxene, garnet and opaque oxides. A much wider band of amphibolite occupies a ridge about one mile west of the ore zone and well-preserved pillows have been found in this band.

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All of the above rock units exhibit a general northerly strike, with an open arcuate form (concave eastwards) in the vicinity of the mine.

The ore zone is believed to lie on the east limb of an overturned syncline, for the following reasons: The ore zone dips to the east. From folds observed in the mine it is deduced that the east side has moved downwards relative to the west side. About 1.5 miles west of the mine the opposite sense of movement is observed, suggesting a synclinal axis somewhere between. The volcanic pillows observed one mile west of the mine indicate overturned bedding and the volcanic ridge on which they are exposed was interpreted by Pyke as occupying the axial portion of a syncline overturned to the west and plunging gently to the north.

The only intrusive rocks close to the ore are two large masses of pegmatite which lie just east of the southern zinc zone. In addition to microcline and quartz, these pegmatities contain abundant tourmaline and also biotite, muscovite, apatite and sphene. Other pegmatites and an aplite dike have been mapped cutting the gneisses in the general vicinity of the ore zone.

ZINC-LEAD DEPOSITS

The Montauban base metal zone has been traced on surface for a length of 8500 feet, in a general north-south direction. Its average width is approximately 80 feet. In the southern 2900 feet the mineralization occurs in a calc-silicate rock, characteristically diopside-tremolite, and extends into the gneisses in both walls. Carbonate is absent at surface in the northern 5600 feet of the zone, where the sulphides are found in the band of cordierite-anthorphyllite gneiss which succeeds the calc-silicate member to the north.

Deformation is prominent in the ore zone. The general attitude of the footwall and hanging wall gneisses is that of a warped surface dipping 20° to 50° east. In plan, the ore zone has the same arcuate form as the wall rock foliation. The carbonate member which hosts the southern part of the ore zone has been folded into Z-shaped folds, with thinning on the limbs apparently due to flowage of material to the noses of the folds.

Most of the ore mined in previous operations came from the calc-silicate member, with lesser amounts from the gneisses in either wall. Ore shoots were found along the east noses of minor folds, and in the limbs up dip from these noses. At least 5 base metal ore zones were mined in this southern part of the zone. Two other zinc-lead zones were outlined towards the north end, in the gneisses, but only limited mining has been done on these.

In the Province of Quebec, there are numerous occurrences of Pb-Zn in marbles. As part of the orientation survey, the reader should consider occurrences of Zn mineralization around Gracefield, Quebec along the Gatineau River. Details on these occurrences can be found in the Toronto office files under Property Submissions, in the Grenville Project files.

APPENDIX 3

COST ESTIMATE FOR GRENVILLE RECONNAISSANCE PROJECT

1977 FIELD SEASONS

Personnel Requirements:

1 - Project Geologist
1 - Senior Assistant
2 - Junior Assistants

Amount budgeted for 1977 field season		$25,000.00
Maintenance cost for a four-man party for 60 days @ $35.00/man-day	$10,000.00	
Truck rental, fuel, and servicing for 2 months	3,000.00	
Salaries for 3 temporary people 3 X $1,000.00 (avg. monthly wage) X 1.25*	3,750.00	
Assay of 1,000 samples for 4 elements 1,000 x 1.50 + .50 + .50	4,000.00	
	$20,750.00	
+15% Sundry	3,112.00	
Total	$23,862.00	

*Contingency benefits, etc.