A COMPILATION OF GRAPHITIC OCCURRENCES IN THE ARCHAEAN OF PART OF NORTHWESTERN QUEBEC

by

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A Thesis Submitted to the Faculty of Graduate
Studies and Research of McGill University in
Partial Fulfillment of the Requirements
for the Degree of Master of Science

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August, 1969

Mise en garde

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CHAPTER I

INTRODUCTION

GENERAL STATEMENT

During the past fifty years, numerous studies have been published on the geology of the Rouyn-Val d'Or area, and on the geology of the numerous precious and base metal deposits occurring in the above mining district.

The present project has been undertaken as a reconnaissance study into the nature of the graphitic occurrences of this area, which in the past have been little mentioned. It is hoped that this study may:

1) Contribute to the knowledge of Precambrian geology;

2) Aid in the structural interpretation of this area, and of other areas in which graphite is widespread;

3) Lead to the discrimination between the "barren" graphitic occurrences, and those graphitic occurrences which are associated with economic base metal deposits;

4) Provide a useful compilation of the geophysical (electro-magnetic) work, and of the graphitic occurrences contained within this area;

5) Elucidate the nature and the origin of the graphitic occurrences.

This study has been made possible as a result of intense exploration by the mining industry within the area. Many companies have surveyed large tracts of the Rouyn-Val d'Or area, first by airborne electromagnetic methods, and then by a variety of ground electromagnetic surveys. Drilling of the geophysical anomalies has revealed the presence of immense volumes of graphitic rocks, which are otherwise little exposed. Large quantities of information have been made available to the public by way of assessment work, which is filed in accordance with the Quebec mining regulations. This information has provided the bulk of the data compiled in the present study.

This study has been divided into four parts:

1) Detailed descriptions of carbon and sulphide-bearing schists, on the basis of megascopic and microscopic investigations;

2) A limited study of the geochemistry of the graphitic occurrences, with emphasis being placed on significant differences between the sampled rocks of the study area, and those associated with economic base metal deposits from other regions;

3) The structural significance of the compiled geophysical and geological information;

4) Brief discussions bearing on the origin of the carbon and the sulphides found in the occurrences sampled and the possible relationship of the carbon-bearing units to economic base metal deposits.

AREA STUDIED

The area under discussion is contained within the Rouyn-Val d'Or mining districts in the Province of Quebec, within the map quadrangles 32D and C of the National Topographic System. The south boundary is delineated approximately by the 48th parallel. The northern limit has been arbitrarily defined by the 49th parallel. To the west, the area is bounded by the Quebec-Ontario border, and to the east by longitude 76° 40'. The northern and western boundaries are defined in part by limited accessibility, and the southern boundary by geological considerations.

Seventy-nine twps. are included in the area studied, which covers approximately 70,000 square miles. The twps. of Holmes, Robin,Augier, Martin and Boisseau in the east are not included in the study. This omission is based on geological considerations and on lack of accessibility. Rouyn and Dufresnoy twps. to the southwest have not been investigated due to time-limit considerations.

The centre of the area, approximately at the City of Amos, lies some 380 miles northwest of Montreal.

REASONS FOR THE SELECTION OF THE AREA OF STUDY

The area was chosen for study for the following principal reasons:

1) Availability of graphitic occurrences--the graphitic rocks are available predominately in the form of drill cores;

2) Ready access--Provincial highways, from Montreal and Toronto, converge on Val d'Or and Rouyn respectively. A C.N.R. main line passes through Amos, and Air Canada has flights twice daily into the two cities. Paved highways provide a circle route through Val d'Or-Noranda-Macamic-Amos-Senneterre-Val d'Or. A well developed system of secondary all-weather gravel roads branches off the highways. These, in turn, pass into gravelled colonization roads. In general, no point within the study area is over five miles from some form of road;

3) Availability of data: As a result of the mineral potential in the Rouyn-Val d'Or area, a large amount of geological and geophysical information has been assembled by governmental and private agencies. The government work is available to the public in the form of published maps and reports, whereas only a small portion of the material accumulated by private industry is available to the public. The information which has been compiled in the present study deals with only a fraction of that which industry may have on file (or even of that which they may have discarded);

4) The number of economic deposits abounding in the area offers the possibility that an association between the graphitic units may be postulated.

METHOD OF STUDY

The information bearing on this study has been gathered in a three-fold manner:

1) Published geological reports by Provincial and Federal agencies, university theses, and from professional papers in various geological publications. Of particular importance to this thesis is the special report compiled and published by The Quebec Department of Natural Resources (Q.D.N.R.-Grenier, 1967), an annotated bibliography on the metallic mineralization in the regions of Noranda, Val d'Or, Mattagami and Chibaugamau). This report has provided the necessary geological framework within which to place the compiled data;

2) Unpublished reports: These take the form of reports, filed by individuals and companies, for assessment purposes. These reports include geological drill hole and surface information, geophysical maps and cost estimates of the work done. The reports are filed with The Mining Recorder and, while the property is in good standing, the information is kept in a confidential file. When the property is allowed to lapse, the material is transferred to a public file. The Q.D.N.R. have made both the confidential and public files available for the purpose of this study. Confidential information has been used only with the permission of the individual or company concerned. Appendix 1 lists the public data as filed by Q.D.N.R. These files have provided the bulk of the information used in the compilation map (back pocket). The above-mentioned material is filed at Quebec City and at the offices of the Resident Geologists at Val d'Or and Rouyn;

3) A lesser, but significant amount of material was obtained directly from individuals and company personnel operating within the area. These are listed in the acknowledgements.

Field Work

Six weeks were allotted to perform the necessary field work. This included the collection of drill hole and electromagnetic data available, as well as the limited sampling required to initiate a pilot study on the geochemistry of the graphitic rocks.

One month was spent within the map area, during which time all the drill hole information on file showing graphitic intersections was compiled. At the same time, various individuals and company personnel were contacted regarding samples of graphitic core. As a result of overburden cover, few graphite bearing outcrops were accessible to sampling, so that drill core provided the principal source of samples. The collection of samples is, therefore, mainly dependent on the goodwill of the mining community.

A final two weeks were spent at Quebec City, during which time all available electromagnetically indicated conductors were compiled. This information was derived from the assessment files of the Mineral Deposits Branch of the Q.D.N.R.

Sampling

It had been hoped that a systematic grid-type of sampling might be completed for the area. Scarcity of sample sites made this impossible and, as a result, a random selection was imposed. A variety of graphitic and pyritic samples were obtained (see page 21).

Composite graphitic samples were taken at each drill hole, in order to obtain an average estimate of the geochemical values in any one section.

Samples E-6 to E-21 represent the continuous sampling of one drill hole (in Desboues Twp.), which was so sampled in order to study geochemical and mineralogical changes throughout a graphitic unit. These samples have been taken on the basis of significant changes, either in the graphitic and/or sulphide content and/or in lithology.

Finally, in the scheme of sampling, was the desire to compare the geochemistry of the graphitic rocks, as seen in the map area, to that of graphitic rocks lying in intimate association with economic deposits. These are represented by samples from the Kidd Creek ore deposit, Ontario, the Caribou ore deposit, New Brunswick, and the Cuprus Mine, Manitoba.

Laboratory Studies

Laboratory studies on the graphitic samples have been performed in a three-fold manner:

1) Geochemical analyses for twenty-four oxides and elements have been carried out by the Q.D.N.R. geochemical laboratories;

2) Petrographic studies in thin section and hand-specimen have been performed in order to detail the occurrences with respect to mineralogy, metamorphism, fabric and structure;

3) Mineralographic studies, in polished section and handspecimen, have been performed in order to determine the characteristics of sulphides, their mineralogy, modes of origin and to explain (a) the occurrence of some of the elements as determined by analysis, and (b) the relationship of the sulphides to the graphite.

Limited X-ray defractometer studies were made to amplify parts 2 and 3 above.

Thin and polished sections were provided by the Q.D.N.R.

Map Preparation

A map scale of 1" = 3 miles was chosen for two principal reasons:

1) The Quebec Department of Lands and Forests have a topographic map at this scale, which shows surveyed lots and ranges in many of the twps. The compiled information could thus be accurately located;

2) The scale is large enough to show the geophysical data in moderate detail (in the form of electromagnetically indicated conductor traces), so that they appear as more than mere dots (1/16" = 990'), yet small enough so that, in view of the large area involved, the map sheet would be of manageable proportions.

Data, as taken from the previously mentioned sources, was first transferred to 1" = ½ mile claim maps, the material being transferred having been recorded on maps ranging in scale from 1" = 100' to 1" = ½ mile. This data was then transferred to the present map.

The graphitic occurrences, primarily determined by drilling, are shown by the drill hole location (small circle) and the appropriate lithological symbol. The thickness and the lithology of a section of graphitic material is indicated as follows: 10 S4g (10 feet of graphitic greywacke). The thickness given is an approximation, based on the fact that the majority of drill holes were inclined at -55°, and on the assumption that bedding attitudes are dipping at 90°. In view of the large number of drill hole logs filed, in which no core angles were noted, this procedure is adopted so as to arrive at an approximation for the thickness involved. The lithology of the units, excluding the graphite-bearing horizon, are not given except in those instances where the association is thought to be atypical (e.g. where peridotite encloses a section of graphitic rock--indicated as 3E,10g,3E).

Geochemical analyses are tabulated and shown on the map sheet.

Typically, the electromagnetically indicated conductors are of adequate length, so that it is possible to indicate this length. In the occasional instance where the trace is too short to be shown in its true length, its existence is demonstrated by a circle in the appropriate colour. Airborne electromagnetically indicated (AEM) anomalies, where they are interpreted as being continuous, are so indicated. Isolated AEM anomalies are shown as a circle in the appropriate colour.

In most cases, the interpretation of the geophysics, as filed, has been accepted.

The geology of the area has been taken from Map No. 5 in the Q.D.N.R. Annotated Bibliography, etc. (1967). Topography and geology are largely schematic in this map; as such, the compiled geological and geophysical data are located accurately only with respect to the twp. boundaries.

PREVIOUS STUDIES

To date, no research has been conducted within the map area specifically studying the graphitic occurrences.

The Amos-Barraute Area Report (Webber and La Tulip, 1964) is the first report to include graphitic rocks as distinct lithological units.

Boyle (1968^b) has briefly studied the occurrence of graphite and associated sulphides, as found throughout the Canadian Precambrian Shield. He has also investigated the occurrence of lead, silver, zinc and gold as related to carbonaceous rocks (1968^a).

Bauman (personal communication), conducting post-doctoral studies at the Geological Survey of Canada, is currently engaged in a study of the graphitic schists of the Precambrian in Canada, dealing specifically with their geochemical characteristics.

In Europe, Petola (1960, 1968), Gammon (1966) have been, and are, continuing studies on the nature of these occurrences, particularly in the Precambrian of Finland and Sweden.

Barghoorn (1965, etc.), Hoering (1964-65), Cloud (1965), and others, have made considerable advances in attempting to establish the presence of life in the Precambrian.

A number of other research workers have studied modern day euxinic and sapropelic environments and sedimentation, thus providing data for comparative studies of the carbonaceous and graphitic occurrences of the past.

ACKNOWLEDGMENT

The writer acknowledges the great assistance, and encouraging criticisms, of Professor P. R. Eakins, of McGill University, and the assistance and financial aid of the Quebec Department of Natural Resources. Mr. W. Roscoe and other fellow students have provided stimulating discussions. Professor E. H. Kranck has been very generous with his advice and expertise throughout the petrographic studies. I wish to acknowledge both the aid provided by the following companies and personnel in obtaining portions of the data contained within this thesis, and the interest that the mining industry has displayed in the study:

Anaconda American Brass Limited; Dr. H. Squair; Falconbridge Mines Limited; Mr. G. Dumont; Mr. A. Pelette, Dome Exploration; Mr. J. Bergman; The Freeport Sulphur Company; Mr. E. MacVeigh; Mr. D. Hendrick, Kerr Addison; The Keevil Mining Group; SOQUEM; Dr. W. Hogg, Noranda Mines Limited; J. Honsberger; Bigtown Copper Mines Limited; Mr. D. Agar; Naganta Mines Limited; Canadian

Johns-Manville Company Limited; Consolidated Ribago Mines Limited; The Coniagas Mines Limited; Dumagami Mines Limited; Dasson Copper Company; Destorbelle Mines Limited; Ecstall Mining Company Limited; Hudson Bay Mining and Smelting Company Limited; Hydra Explorations Limited; Canadian Javelin Limited; Kennco Explorations (Canada) Limited; Lido Minerals Limited; St. Lawrence Columbium and Metals Corporation; Merril Island Mining Corporation; North Bordulac Mines Limited; Newconex Canadian Exploration Limited; Acme Mines Limited; New Algar Mines Limited; White Star Copper Mines Limited; Dr. A. Bauman and Dr. R. W. Boyle of the Geological Survey of Canada.

Last, but not least, I acknowledge the help and encouragement so generously given by Cham. S. H. Faron.

CHAPTER II

REGIONAL SETTING

PHYSIOGRAPHY

The Rouyn-Val d'Or area was almost totally inundated by glacial Lake Barlow-Ojibway, which had been formed during the melting of the last continental ice sheet (Dresser and Dennis, 1944). The area has as a result been partially covered by lacustrine sands and clays, as well as by the glacial debris characteristic of continental glaciation. The lacustrine clays have given rise to the "clay-belt" of northern Quebec and Ontario.

On the basis of occasional outcropping masses, the rugged outcropping terrain about Noranda, and the varying depth of the overburden throughout the area (0 - 150' as determined by drilling), it is considered probable that the preglacial topography was moderately rugged. The various effects of glaciation have largely served to eradicate the preglacial topographic expression, and with the exception of the terrain around Noranda, which shows elevations to 1,700 feet, the topography is typically flat to rolling, with local relief of 100 to 200 feet and a mean elevation of 900 - 1000 feet. The rolling character imparted to the topography is probably due to the preglacial topography. This feature is in part amplified by differential compaction of the glacial sediments.

The drainage is characteristic of that for glaciated regions (i.e. frequently disrupted river beds, with extensive swampy sections, and lakes being developed). A few of the major rivers have probably re-established their preglacial courses.

Major drainage is provided by the following rivers: The Kinojevis, draining the western portion of the area, and emptying southward into the

Ottawa River; the Bell, Laflamme and Harricana rivers draining the eastern portion of the area, and emptying northward into James Bay. The height of land passes through the south third of the area.

The presence of the clay cover presents problems with regard to electrical prospecting in the map area. These problems are brought about by:

1) The fact that the clay mantle may be moderately conductive;

2) This conductivity may effectively mask underlying conductive bedrock features.

It is perhaps no accident that the major base metal discoveries in the area, predominately about Noranda, are associated with a relative lack of overburden cover.

Extensive farming in the area has resulted in large tracts of land being stripped of their original forest cover.

REGIONAL GEOLOGY

The Rouyn-Val d'Or area is contained within an Archaean greenstone belt, within the Superior Province of the Precambrian Shield. The rocks within the area consist predominately of basaltic to intermediate flows and tuffaceous units. Lesser, but significant amounts of rhyolitic and dacitic flows and tuffs are frequently interbedded with the more basic units. Sedimentary units --argillites, shales, and quartzites--are intercalated with the volcanic sequences. These sedimentary units are shown by Dugas and La Tulip (1967) as being four and five miles wide, and are frequently interpreted as extending across the map sheet.

Intrusive rock types are widespread, and vary in composition from salic to ultramafic. The salic intrusives are prevalent as extensive batholithic bodies, which in part show diapiric outlines.

Metamorphism of the Archaean rocks is typically within the greenschist facies. The intrusion of the granitic masses has resulted in negligible contact metamorphism (Weber and La Tulip, 1964).

The rocks of the Rouyn-Val d'Or area have undergone severe deformation resulting in the production of a series of vertical isoclinal folds whose axial plane traces trend in an east to southeast direction. These folds have been further dragfolded and faulted.

A more detailed account of the geology of this region is provided by the following authors: Dresser and Dennis, (1944); Weber and La Tulip, (1964); Wilson, (1965); and Eakins, (1962).

THE OCCURRENCE OF GRAPHITE IN RELATION TO THE REGIONAL GEOLOGY

A study of the graphitic occurrences as compiled (see map-back pocket), which are largely extrapolated on the basis of their geophysical expression, reveals that over half of the occurrences lie within the mafic volcanic units; the bulk of the remainder lie within sedimentary units. Twenty-five per cent of these, furthermore, lie in close proximity to the rhyolitic units. A remaining one to two per cent of the electromagnetically-indicated conductors lie within ultramafic assemblages.

Fig. 1 to 3 show histograms which are designed to illustrate:

1) The nomenclature commonly applied to the graphitic rocks (fig. 1);

2) The associations of the graphitic units, (fig. 2);

3) The variable thicknesses of the graphitic units (fig. 3).

These graphs are based on drill logs filed for assessment purposes.

The drill hole information, as plotted in the above-mentioned histograms, indicates:

1) That the graphitic units are logged as being:

    (a) sedimentary--53 per cent

    (b) volcanic--34 per cent

    (c) metamorphic--12 per cent

2) That the sedimentary units are most commonly associated with:

    (a) volcanic units--56 per cent

    (b) sedimentary units--27 per cent

    (c) metamorphic units--10 per cent

    (d) intrusive units--7 per cent

3) That greater than 50 per cent of the graphitic units are 15 feet thick or less, but may attain thicknesses of up to, and greater than, 300 feet.

Thin section studies (Chapter III) indicate that the graphitic units are of sedimentary origin (shales and siltstones); no evidence was found for a possible tuffaceous origin.

The graphitic occurrences, as determined through drilling, and extrapolated by the use of geophysical data, are grouped into nine distinct belts. These belts extend across the map sheet. It has been suggested that these postulated belts may be related in the form of large scale fold structures (Chapter V).

Figure 1

Frequency chart showing names used to describe graphitic units

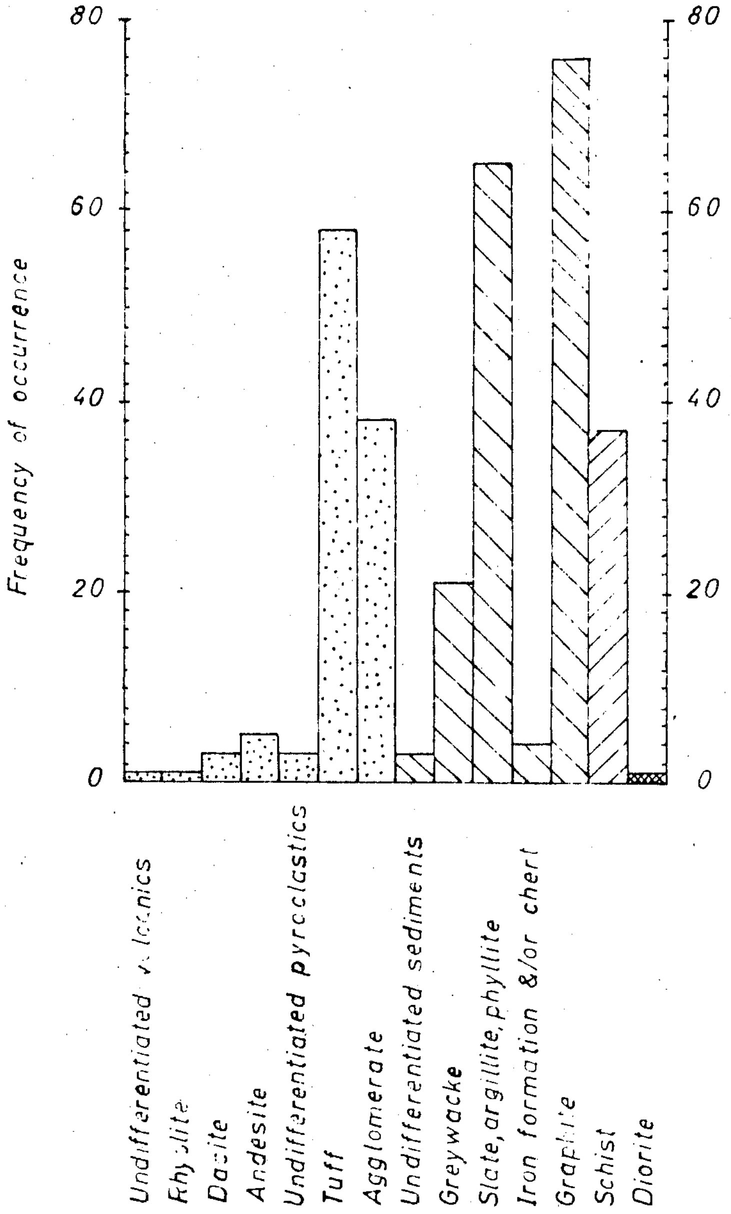
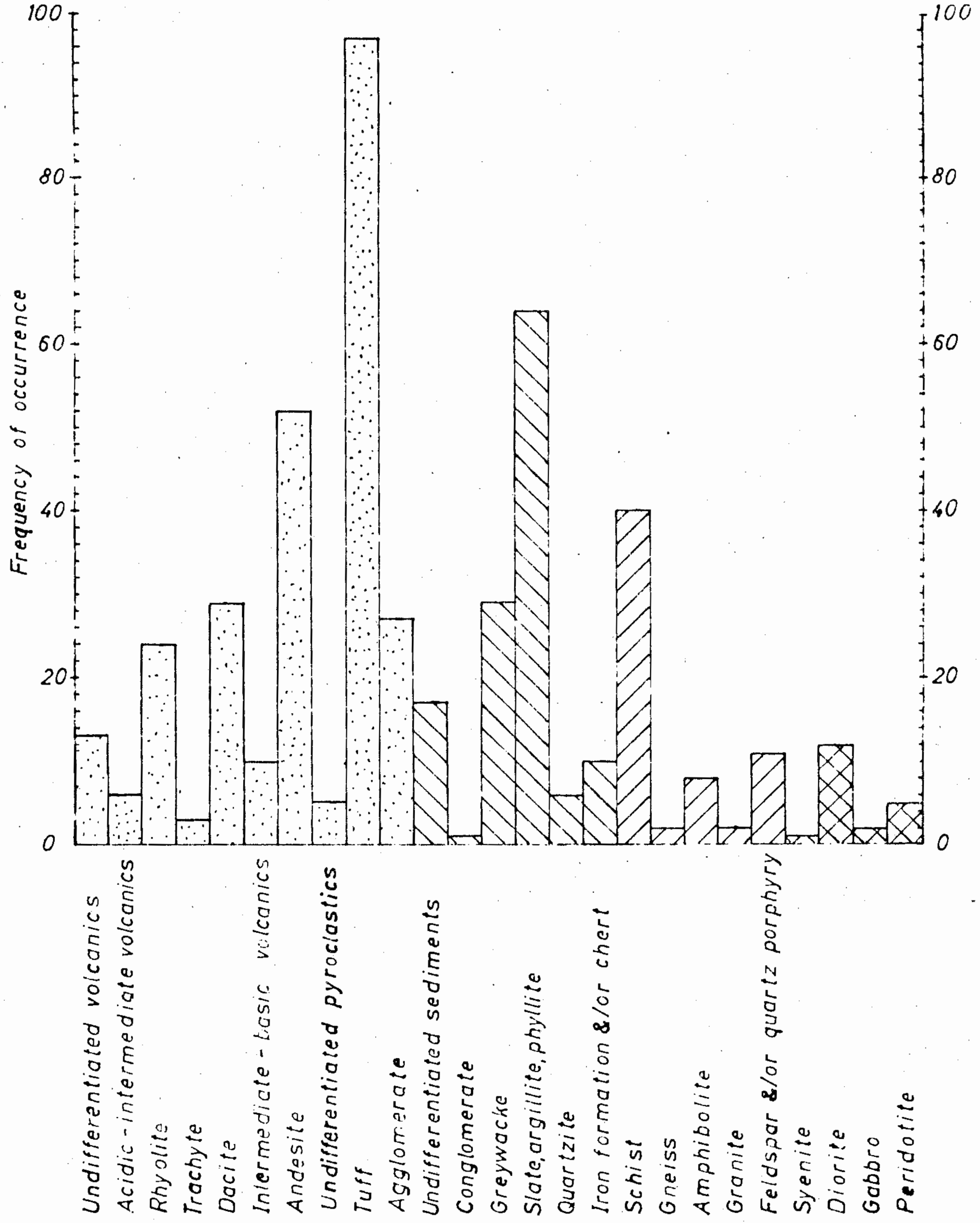


Chart prepared from 249 assessment drill logs, listing 316 distinct graphitic units

Figure 2

Frequency chart of rock types immediately associated with graphitic units including lithology of the graphitic units*

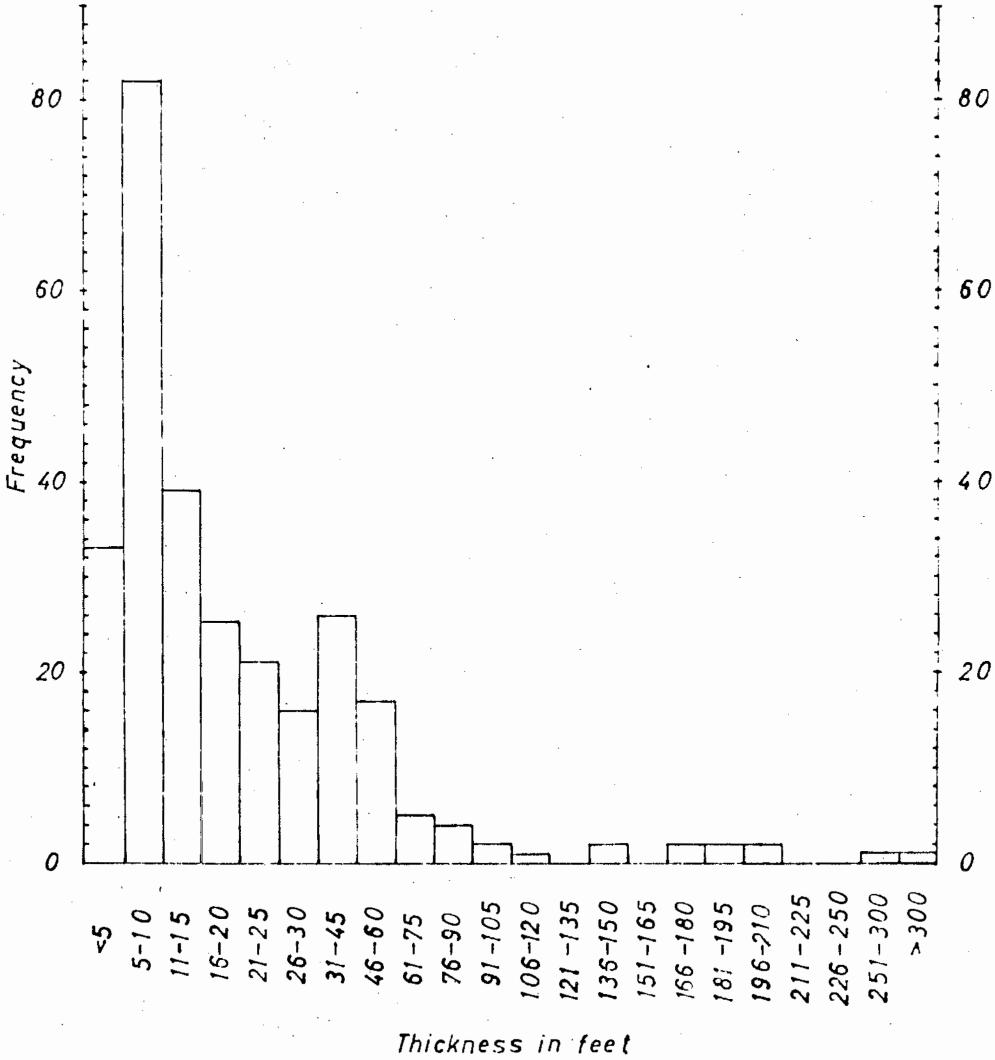


** i.e. foot & hangingwall lithologies*

Descriptions taken from 249 assessment drill logs

Figure 3

Distribution of 282 graphitic units



See text for explanation

CHAPTER III

GEOLOGY OF THE GRAPHITIC OCCURRENCES

INTRODUCTION

GENERAL STATEMENT

Twenty-two thin sections and 11 polished sections have been studied with regard to the mineralogy, tectonic fabric and metamorphism of the sampled graphitic occurrences. The sampled graphitic rocks were originally carbonaceous shales, with interlaminated, slightly carbonaceous siltstones. Pyrite is present in variable amounts and forms. Pyrrhotite, chalcopyrite and sphalerite occur in trace amounts, associated with the pyrite. The carbon, typically called graphite, is shown to be a crystallographic form of lower order than graphite, and may be in the form of schungite, as termed by Marmo (1953). The graphitic rocks of the Rouyn-Val d'Or, as sampled, show the low grade metamorphic characteristics of the lower greenschist facies; specifically, they are assigned to the quartz-albite-muscovite sub-facies, as defined by Turner and Verhoogen (1960). Deformation is locally intense. The graphitic layers, by virtue of their relative incompetence, show the effect of deformation most commonly, whereas the siliceous siltstones are relatively unaffected. The sampled rocks typically show a well-developed schistosity, apparently developed parallel to the original layering. Soft rock deformation is locally evident.

Two samples taken south of the main map area are shown to be equivalent rock types, but they show a higher degree of metamorphism.

Adequacy of Data

The samples studied represent 17 separate occurrences, 15 of which lie within the Rouyn-Val d'Or area; the remaining two lie to the south of the main area. These are considered to reflect the different forms as they are commonly observed in the field. They are not necessarily considered as representing a complete spectrum of graphitic occurrences. It is probable that a graphitic tuffaceous rock exists, in view of the commonly intercalated volcanic rocks. The existence of such a graphitic occurrence was not found.

GEOLOGY OF THE OCCURRENCES SAMPLED

Petrography and Mineralogy

The graphitic rocks, as sampled within the Rouyn-Val d'Or area, are metamorphosed carbonaceous shales and siltstones. (A detailed description of the graphitic rocks is given in Appredix 2).

Megascopically, four varieties of graphitic rock types were recognized:

1) A massive, frequently apparently structureless, richly graphitic variety;

2) A massive variety as above, but showing variable amounts of massive, disseminated and nodular pyrite;

3) A laminated "varved" variety, in which highly siliceous and graphite poor laminae alternate with relatively graphite-rich laminae;

4) A massively mineralized graphite rich variety.

These types may occur in various combinations in any one section of graphitic rock.

The graphitic rocks show grain sizes ranging from fine grained to almost cryptocrystalline. Graded bedding is occasionally observed, proceeding from very fine grained in the graphite rich laminae, to coarser grained in the graphite poor laminae. The graded bedding was observed both megascopically and microscopically.

A varved appearance is produced by the graded bedding described above, in which thin, fine grained, dark grey to black laminae grade into lighter grey and greenish thicker, coarse grained laminae.

Lamination of the graphitic rocks ranges from paper thin (less than 0.01 mm.) to beds two and three metres thick. Most commonly, the "varved" variety displays graphitic laminae ranging in thickness from 0.01 mm. to 30 cm. The intercalated graphite poor beds are somewhat thicker, and range from less than 1 mm. to several centimeters in thickness. Within the cryptocrystalline graphitic layers, a fine bedding may be distinguished by the presence of fine trains of pyrite, or by the not infrequent presence of quartz lenses. The coarser graphite free laminae show grain sizes ranging from 0.001 mm. to 0.3 mm.

Essentially, the mineral composition is the same throughout the different layers, the layers being defined by differences in grain size and by relative abundance of the minerals. Quartz and sericite(muscovite)are essential minerals, whereas graphite and pyrite are variably present. Geochemical analyses show the carbon (graphite) content to vary considerably, ranging from one to 17 per cent. The graphite occurs variously as very fine specks (less than 0.001 mm.) and occasionally as larger clots, and as compacted streaks, seams and lenses anastomosing about quartz-sericite grains.

The optical properties of the mineral, here termed graphite, do not correspond to those of true graphite. X-ray defraction determinations likewise did not indicate the presence of true graphite. The mineral present, called graphite--in keeping with common usage--should perhaps be named schungite, after the term applied by Marmo (1953) to a mineral showing similar properties.

The sericite is colourless to occasionally a very light pale green (phengite?), and the grains range in size from less than 0.001 mm. to 0.3 mm. It occurs in two distinct forms: as lepidoblastic laths and sheathes; and as post-kinematic, helicitic porphyroblasts. The last-mentioned are typically discordant. The sericite is widespread. The sericite occurs as extremely fine laths within the graphite rich layers and as moderately coarsely developed laths, etc., developed in the quartzitic laminae. Fine flecks of sericite occur as an alteration product of the feldspar.

The quartz is characteristically coarse and granular within the graphite poor layers, and in fine-grained to cryptocrystalline, within the graphite rich layers. Rounded to sub-rounded clastic grains occur in the coarser beds and, occasionally, as discrete grains within the cryptocrystalline portions. The quartz grains range from less than 0.001 mm. to 0.3 mm. in size. The quartz typically does not show undulatory extinction, but may be weakly recrystallized parallel to the foliation. A secondary, or mobilized and recrystallized form of quartz is frequently evident as equigranular aggregates in fractures, and filling dilatant zones. In these dilatant zones, commonly associated with fractured and deformed pyrite beds, the quartz frequently adopts a lamellar character, which shows well-developed undulatory extinction. This quartz is often found as "pressure shadows," which may, in some instances, surround a pyrite nodule, but normally forms a wedge shaped "tail."

Albite is present in the rocks sampled in limited amounts, as attested by X-ray analysis, and by the geochemical analyses showing up to four per cent Na_2O. The albite was not determined optically in the rocks of the Rouyn-Val d'Or area. Albite was, however, optically determined for the two specimens taken south of the main map area.

Potash feldspar was identified, in a few instances, as isolated grains, which have been partially sericitized.

Plagioclase, possibly other than albite, was identified only as clastic grains--a tentative optical identification determined these grains to be of an andesine composition.

Chlorite occurs in variable amounts, ranging from 0 to 5 per cent, typically growing in close association with sericite.

Sphene and epidote occur as discrete grains, 0.1 to 0.02 mm. in size.

Tremolite and biotite are present in significant amounts only in those rocks sampled south of the main map area. Both minerals occur as lepidoblasts and as post-kinematic porphyroblasts, which transect the foliation. Neither mineral was identified in the rocks of the Rouyn-Val d'Or area.

Calcite occurs in variable amounts. It frequently occurs as coarse crystals in fractures, and also in association with the mobilized quartz. Calcite occurs as very fine specks in some of the graphitic layers.

Mineralography of Sulphides Associated with the Graphitic Occurrences

Pyrite is the most commonly occurring sulphide in the graphitic rocks. It occurs in four commonly inter-related forms:

1) As massive layers, 3 to 90 mm. thick; these are typically in the graphite rich beds;

2) As massive, sheared, brecciated or foliated units, with graphite commonly associated. This pyrite is distinguished on the basis that it acts as a distinct unit under deformation;

3) As "nodules" ranging in size from less than one mm. to 60 mm. in diameter. These may or may not show a distinct core; they are typically inclusion rich. The nodules frequently are partially recrystallized;

4) As disseminated grains--dust size to aggregated grains, one to two mm. in diameter. These grains are typically lobate, suggesting the coalescence of two or more spherules of pyrite. Pyrrhotite, chalcopyrite, and sphalerite occur in trace amounts, either as inclusion-like blebs within the pyrite, or as blebs adjacent to pyrite crystal or grain boundaries. The

pyrrhotite and chalcopyrite occur only in trace amounts, whereas the sphalerite occurs in trace amounts and sometimes to one per cent of the total sulphide present.

Brecciated magnetite-hematite intergrowths occur in one instance, lying within a quartzitic unit.

Primary and Deformational Fabrics of the Graphitic Occurrences

The graphitic rocks show a primary compositional layering, on which has been superimposed a schistosity. This schistosity is expressed by the crystallographic alignment of the quartz grains, and by the lepidoblastic occurrence of the sericite. Graphite has, in places, been compacted within the foliation. The quartz, in the graphite poor laminae, generally shows little undulatory extinction (i.e. little or no strain effect), and only minor re-crystallization occurs within the quartzitic beds.

The graphite-and-pyrite-rich beds are typically deformed. The pyrite is brecciated, fractured and boudinaged; mobilization and re-crystallization of the quartz in the form of "pressure shadows" is an attendant feature. The graphitic folia about these pyrite beds show extreme plastic deformation, which dies away as the rock types become increasingly siliceous. Slips and slicken-sides are preferentially developed within the graphite rich layers.

The rocks sampled in Desboues twp. showed a feldspathic unit which had undergone brecciation. This brecciated layer shows graded bedding, the fragments decreasing in size upwards. The matrix is predominantly graphite.

A second breccia within these rocks is composed of highly angular fragments of magnetite-hematite intergrowths in a quartzitic matrix. This unit occurs as a lens warping about a pyrite nodule.

Textures and Fabric of the Sulphides Associated with Graphitic Occurrences

The massive sulphides show the results of the deformation undergone by the graphitic units, which typically includes brecciation, shearing and fracturing. The sulphide (pyrite) shows strong evidence of having attained a massive character because of the coalescence of large numbers of pyritic spherules. The spherules have coalesced with the inclusion of abundant quartz, sericite and graphite. The pyrite is typically inclusion choked. The inclusions in the pyritic nodules may define a core and rim effect. Very fine inclusions often outline inclusion-free spherules, and in some instances, define crystal zoning within the pyrite. The inclusions outline grain boundaries, which frequently show near 120° triple points. The disseminated grains are composed of two or more pyritic spherules. Crystals of pyrite commonly protrude from the nodules and pyritic aggregates. No euhedral crystals of pyrite were observed.

Pyrrhotite, sphalerite and chalcopyrite occur sporadically rimming the pyrite, or as exsolution-like blebs, either along the fracture in the pyrite, or as lens-like blebs within the pyrite. Sphalerite, apparently replacing a chalcopyrite bleb, occurred in one instance.

Metamorphism

The occurrences sampled within the Rouyn-Val d'Or area have undergone low grade regional metamorphism. The grade of metamorphism of these occurrences is that of the quartz-albite-muscovite-chlorite sub-facies of the greenschist facies.

The samples taken south of the main map area, in Surimau twp., are of a somewhat higher metamorphic grade, and lie within the quartz-albite-epidote-biotite sub-facies of the greenschist facies.

SUMMARY STATEMENT

The graphitic rocks studied within the Rouyn-Val d'Or area are metamorphosed carbonaceous shales and intercalated siltstones, and are assigned to the quartz-albite-muscovite-chlorite sub-facies of the greenschist facies. These rocks did not contain any tuffaceous elements. The cryptocrystalline graphitic layers are considered to be originally carbonaceous shales, and result from compaction and metamorphism of hydrolysates, colloids and clay minerals. The coarser laminae and beds are believed to be originally siltstones, composed of coarser and frequently definitely clastic minerals: quartz, feldspar and reconstituted clay minerals, which are now in the form of sericite and chlorite. Occasional carbonate-rich layers may represent original marl layers. The mineralogical characteristics rank these rocks with those of the Paleozoic (e.g. the Lias Shale of Germany), or they may be compared chemically with the euxinic, sapropelic, or gyttja sedimentation of present-day reducing environments.

The pyrite, trace sulphides, and the carbon are considered to be original constituents of the rocks and may likewise be compared to present-day formations (Chapter VI). The existence of organic carbon in the Archaean has been demonstrated by Barghoorn (1965) and others.

The rocks have been deformed tectonically and by soft-rock deformation. Soft-rock deformation is evidenced by the formation of feldspathic microbreccias, and by the introduction of the magnetite-hematite fragments, which are foreign to a reducing environment. The tectonic deformation is confined mostly to the graphitic and pyritic layers. The graphitic layers characteristically deform plastically, being much contorted. The thinner pyritic layers act in a brittle manner and are fractured, boudinaged and rotated, resulting in part in the formation of "nodules," while the graphitic units flow around and about the pyrite. Quartz is typically mobilized and recrystallized in the dilatant areas created by the movement of the pyrite. The contorted features die out rapidly within the siliceous layers, which are little deformed. At most, they show minor micro-faulting. Further evidence for lack of deformation within the siliceous units is afforded by the relative lack of recrystallization of the quartz grains.

The thicker pyrite units (greater than five feet) appear to act as a single tectonic unit and deform plastically, as opposed to the brittle deformation of the thinner variety. A schistose foliation is developed within these pyritic units.

The pyrite is considered to have been precipitated as very fine spherules, which have coalesced subsequent to diagenesis with the inclusion of considerable matrix. The included material has subsequently been, in part, expelled, as determined by inclusion-free pyritic grains, which are rimmed by the previously included matter. Recrystallization and annealing of the pyrite are demonstrated by:

1) A zonal pattern of inclusion-rich and inclusion-free pyrite;

2) Frequent pyrite grains show interface angles of 120°, which Stanton (1968) interprets as indicating recrystallization, etc.

CHAPTER IV

GEOCHEMISTRY OF THE SAMPLED OCCURRENCES

GENERAL STATEMENT

Thirty-two pyrite-bearing graphite rock specimens were analyzed by the Q.D.N.R. Laboratories. Of these, one specimen (E-1) was taken south of the principal study area, in Surimau twp., and three specimens (E-34, 35 and 36) were taken from graphite units associated with economic base metal deposits in other regions. These samples were analyzed for seven major oxides, and seventeen major and minor elements. Speciments E-6 to E-21 represent a continuously sampled section through a graphitic unit, which has been intruded by silicified andesite sills at various levels.

The major element analytical results are compared and contrasted with analyses for graphitic schists, carbonaceous shales and present-day black muds. The major element chemistries are considered to be similar.

The trace element analytical results are discussed and compared to published average values for black shales. In general, the values obtained for the sampled rocks fall within the values expected for black shales.

Graphs have been drawn up which suggest that:

1) The pyrite content generally follows the carbon content (fig. 10);

2) The nickel and cobalt content follow the carbon content (fig. 8);

3) The lead and zinc contents may follow carbon content over small ranges of carbon content (fig. 6 and 7);

4) The lead-zinc ratios, plotted against zinc content in parts per million, show that the values for the Cuprus, Caribou and Kidd Creek ore deposits are anomalous (fig. 4).

A. Bauman (Geological Survey of Canada - personal communication) intends to publish a report on the geochemistry of some 900 graphitic schist occurrences of the Precambrian of Canada (circa 1970). This work should provide a more adequate background for statistical studies than that provided by the limited present sampling.

Sampling Procedure

Sampling was carried out with six principal aims in mind:

1) To obtain a representative sample for each of four commonly occurring forms of graphitic rocks (i.e. a massive, barren, graphitic schist; a massive graphitic schist with variable amounts of nodular and layered sulphide; a graphite-poor layered rock; and finally, a sulphide rich--pyrite, pyrite and/or pyrrhotite--graphitic rock);

2) To obtain the graphitic rocks from as varied a selection of environments as possible (i.e. immediately associated with andesites, rhyolites, sediments and ultramafic (extrusives?) intrusives;

3) To obtain, if possible, a systematic representation of the graphitic units as compiled throughout the map area;

4) To study the chemical variations through a graphitic unit;

5) To obtain samples from graphitic units associated with ore deposits;

6) To obtain graphitic samples associated with economic ore deposits.

In accordance with the above criteria, a total of 28 samples were taken within the study area, and another four from outside the area. As a result of the previously mentioned problems (i.e. scarcity of outcrop, as well as the difficulty in obtaining samples, aim (3) was not wholly realized), the samples taken frequently being grouped within limited areas. For example, samples E-6 to E-21, E-22, 24, 26, 27 and 28 are concentrated within a ten mile radius of the northeast corner of Guyenne twp. Samples E-4, 29, 30 and 32 are concentrated within a 15 mile radius of the southeast corner of Barraute twp. The remaining samples are scattered throughout the area studied.

The second aim was generally attained, with the exception of the rhyolitic association. The graphite-ultramafic association was obtained south of the study area, in Surimau Twp. (E-1).

Samples E-6 to E-21 represent the continuous sampling of a graphitic unit. The different samples were taken on the basis of graphite content, lithology, or varying sulphide content.

The balance of the samples were taken in such a manner that an adequate amount of sample was available for analysis, approximately five pounds. Where the graphitic units were interbedded with other lithologies, a composite sample was taken, so as to arrive at an approximate average for the graphitic units.

The Cuprus Mine sample (E-35) was taken from the mine dump, and the sample from Kidd Creek (E-34) was taken from a graphitic unit contained within the ore horizon. The Caribou sample (E-36) was donated by Mr. W. Roscoe, and is taken from the graphitic schist unit, removed some 50 feet stratigraphically from the massive sulphide mineralization.

All samples were contributed by various individuals and companies, who should be approached should further data be required (Appendix 3).

Analytical Techniques

Analyses were performed at the Geochemical Laboratories of the Quebec Department of Natural Resources.

The analytical techniques are given in Appendix 4, and are listed in the form supplied by the Laboratory; sensitivities and limits of analytical errors are likewise indicated.

GEOCHEMICAL INTERPRETATION AND SIGNIFICANCE

General Interpretation

The chemical analyses of the sampled graphitic occurrences are tabulated on the map sheet of the Rouyn-Val d'Or area (in back pocket). The original analyses are contained in Appendix 5. The chemistry of the sampled rocks is discussed under two headings:

1) Major elements and their oxides;

2) Trace elements.

Major Elements and Their Oxides

The most characteristic feature of the graphitic rocks is their relatively high carbon and sulphide (pyrite) content. The carbon ranges from slightly under one per cent to a high of 17 per cent, the average carbon content being approximately eight per cent. The sulphide content ranges from four to 55 per cent and is almost entirely in the form of pyrite. The pyrite content shows a rough correlation with the carbon content. Fig. 10 shows a graph in which the carbon and pyrite values obtained for each of the analyzed samples have been plotted. The resultant points indicate a linear increase of the pyrite content with increase in the carbon content. This intimate inter-relationship between the iron and carbon is further indicated in fig. 12, which shows the variations of the iron, silica, carbon and alumina through a continuously sampled section.

Table 2, page 66 shows a tabulation of analyses of graphitic and carbonaceous schists and shales, compiled from Pettijohn (1957, p 362), Manheim (1961), and which includes the averaged analyses of the rocks taken within the Rouyn-Val d'Or study area. This tabulation lists analyses of various carbonaceous units taken from the Archaean to the Proterozoic to the Devonian, and through to the present, as represented by the analyses of the sapropelic sediments of the Black Sea (Manheim, 1961). This tabulation demonstrates quite clearly that the carbonaceous (graphitic) rocks have maintained an approximately constant composition through time keeping in mind the variable compositions of the silica, iron and carbon.

The iron and silica contents are inversely proportional to each other (fig. 12). The carbon content varies proportionally with the iron content, and inversely with the silica content.

Peltola (1960) observed that the alumina content shows a marked increase within the carbon-rich layers of the graphitic schists of Outokumpu, Finland. This observation by Peltola is in contrast with the results of the present study, where the alumina content varies proportionately with the silica content, and hence inversely with the carbon content. Peltola further noted that the calcium content increased with decrease in the silica content. This relationship is not observed in the presently sampled rocks and the calcium content may actually increase with an increase in the silica content. The alkali content of the sampled occurrences (potash and soda) increases with increase in silica content. The calcium content (fig. 14) shows a slight and irregular correlation with the curves for the alkalies.

The magnesia content may be correlated with the calcium (fig. 14).

Trace Elements

Silver, molybdenum, platinum, uranium, tungsten, gold and mercury occur in the sampled graphitic rocks in negligible amounts and are, therefore, insignificant as possible pathfinder elements.

Gold, Tungsten and Platinum

Gold and tungsten were not detected, while platinum was detected at the detection limit of less than 0.02 p.p.m.

Mercury

Mercury was detected at the detection limit of 2.5 p.p.m.

Uranium

Uranium, mostly undetected, occurred in a few samples showing values of 3 to 4 p.p.m. The uranium content in the sampled occurrences falls within the lower range of average values for black shales, given by Hawkes and Webb (1962) as ranging from 2 to 300 p.p.m.

Molybdenum

Molybdenum was either not detected, or occurred in amounts to 6 p.p.m. No correlation exists between the molybdenum and carbon contents. Peltola (1960) reports an average molybdenum content for the Outokumpu Black Schists (Finland) at 160 p.p.m.; Boyle (1968) gives an average molybdenum content for the Keno Hill graphitic rocks of five to 52 p.p.m. (from 29 composited samples). Manheim (1961) reports a molybdenum content of 35 p.p.m. for the Black Sea muds. Hawkes and Webb (1962) indicate a normal range of 10 to 300 p.p.m. molybdenum for black shales. Thus, it is apparent that the molybdenum content for the presently sampled occurrences falls below the range of values typically given for such rocks.

Silver

The silver values range from 0.5 to 2.1 p.p.m. in the graphitic rocks sampled within the study area and those sampled at Cuprus and Caribou deposits. The graphitic rocks sampled at the Kidd Creek deposit show a high silver value of 23.4 p.p.m. The average silver content of black shales is 5 to 50 p.p.m. (Hawkes and Webb, 1962). The silver values are, therefore, anomalously low, with the exception of the value shown by the sample taken at the Kidd Creek deposit.

Vanadium and Chromium

Vanadium and chromium are considered together, in view of the fact that their ratios are taken to indicate the environment in which they are found (Bauman, A., 1968--personal communication).

The vanadium content occurs in the presently sampled rocks in amounts ranging from 0.004 to 0.03 per cent. The chromium content in the same occurrences, occurs in amounts ranging from 0.002 to 0.09 per cent. Black shales commonly carry 0.005 to 0.2 per cent vanadium and 0.001 to 0.05 per cent chromium (Hawkes and Webb, 1962).

The vanadium and chromium curves (fig. 15), as plotted for the analyses of the continuously sampled graphitic unit in Desboues Twp. indicates that the chromium and vanadium contents parallel the carbon content. Peltola (1968) has shown that the vanadium and chromium contents increase with the carbon content in the Black Schists of Finland. Ostroumov (1957) has noted that the vanadium content increases with the carbon content in black shales, and explains the increase as being due to the formation of vanadium organic compounds, which are formed by the interaction of the vanadium rich minerals in the sediments with the carbonaceous matter, which thus remobilize the vanadium, concentrating it in the carbon rich layers.

Le Riche (1959) suggests that a vanadium content up to 150 p.p.m. is related to the silicates, and the balance is thereafter related to the carbon, or to the increase in the carbon.

Peltola (1960) assumes that the vanadium is precipitated as the hydrooxide by reduction to a lower valency, and that it is "fixed" as a sulphide

Figure 4

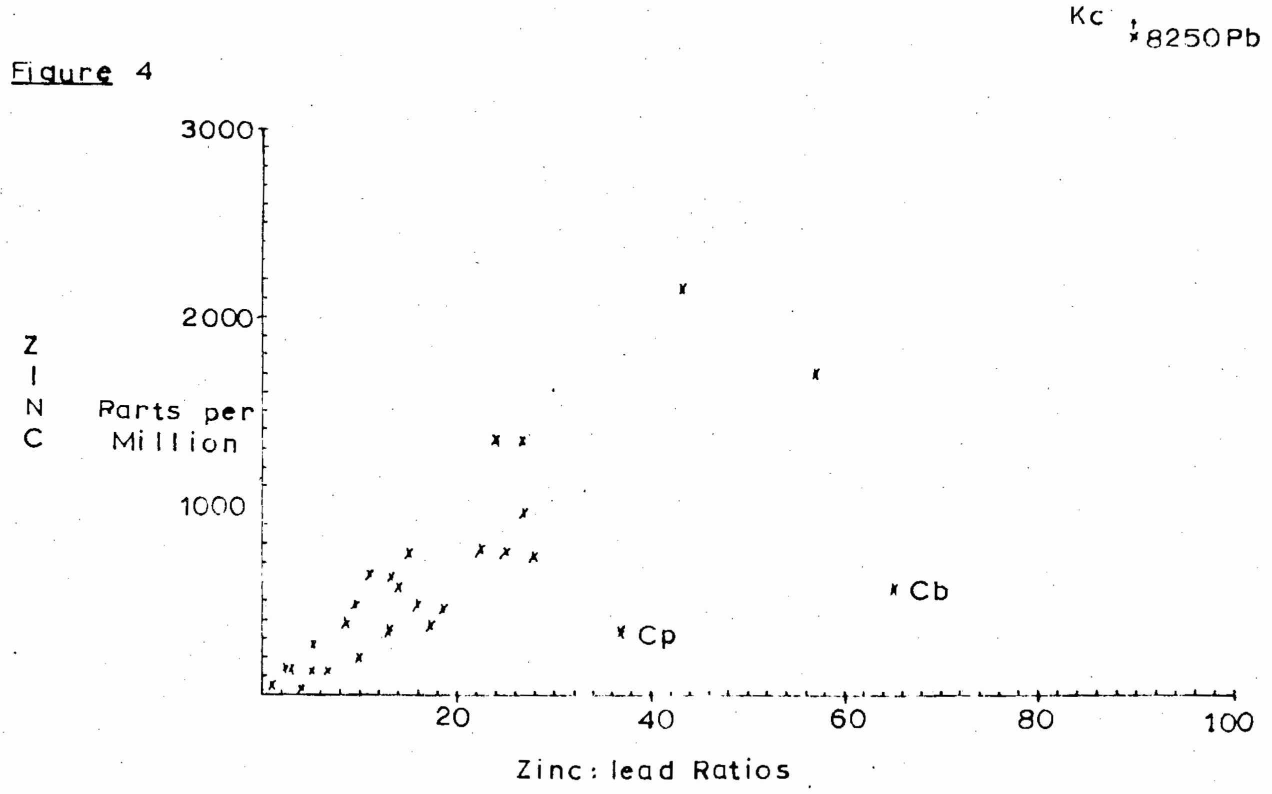


Figure 5

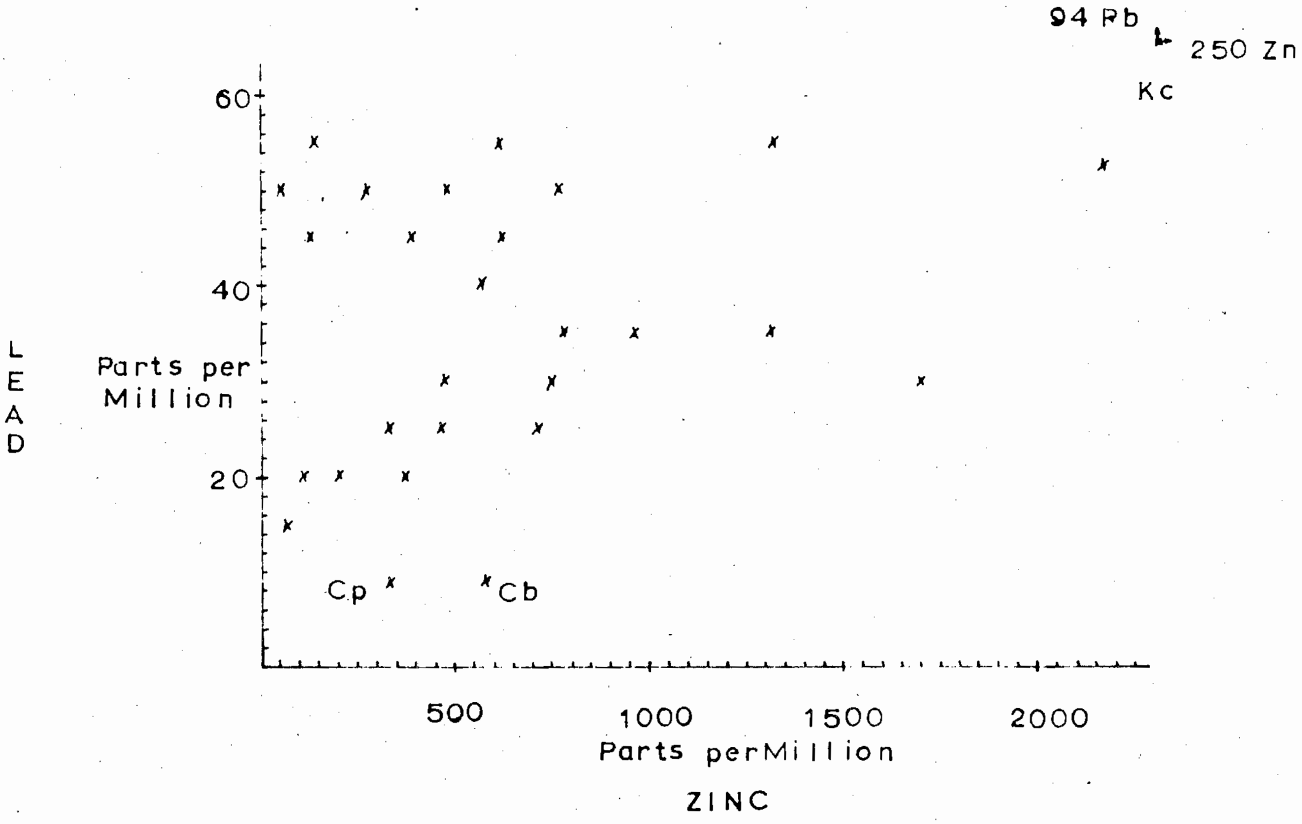


Figure 6

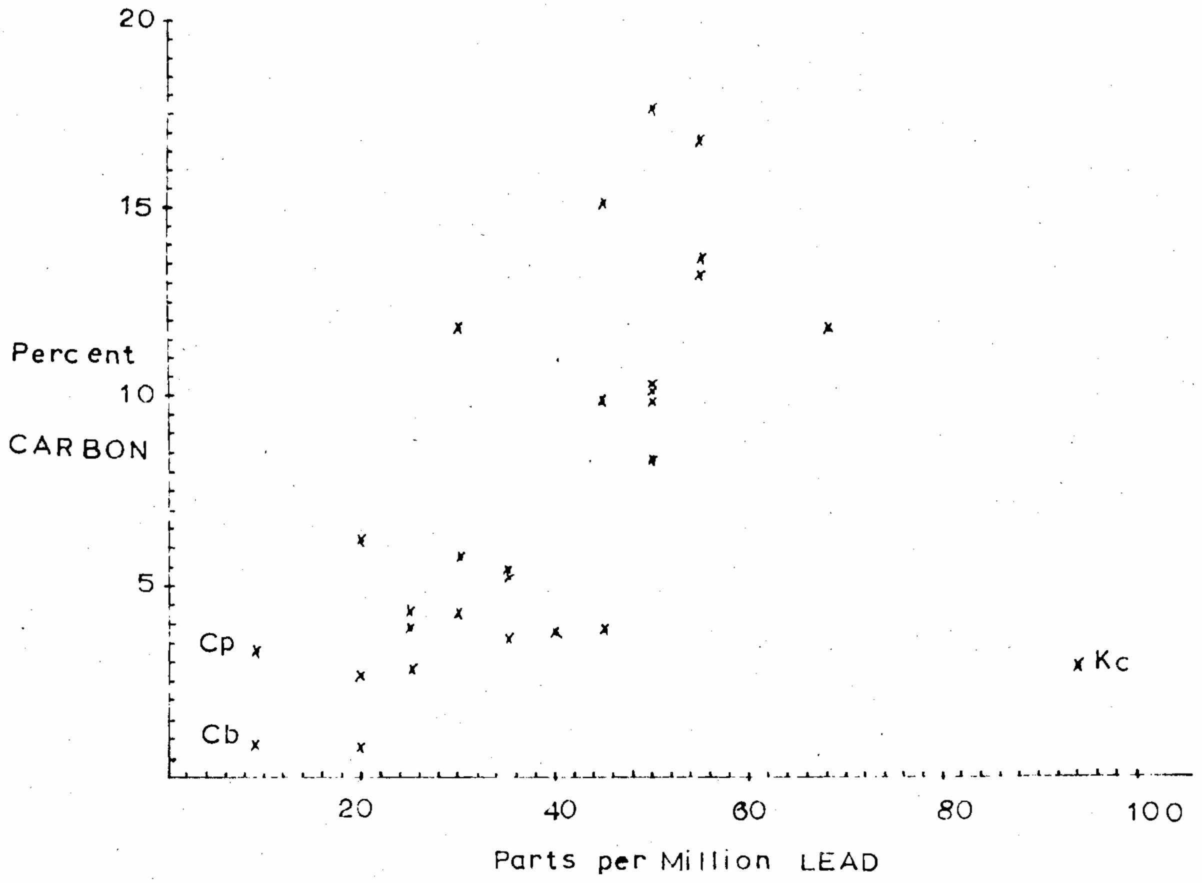


Figure 7

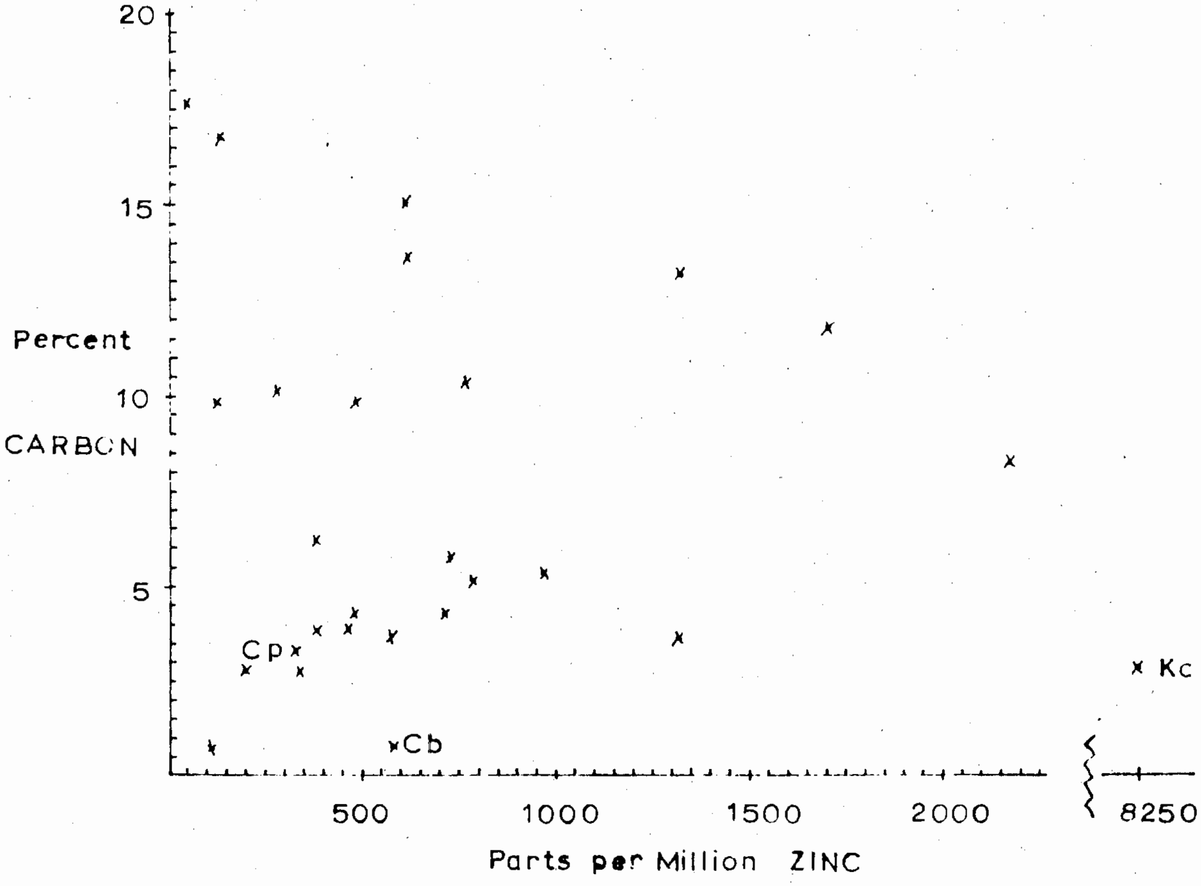


Figure 8

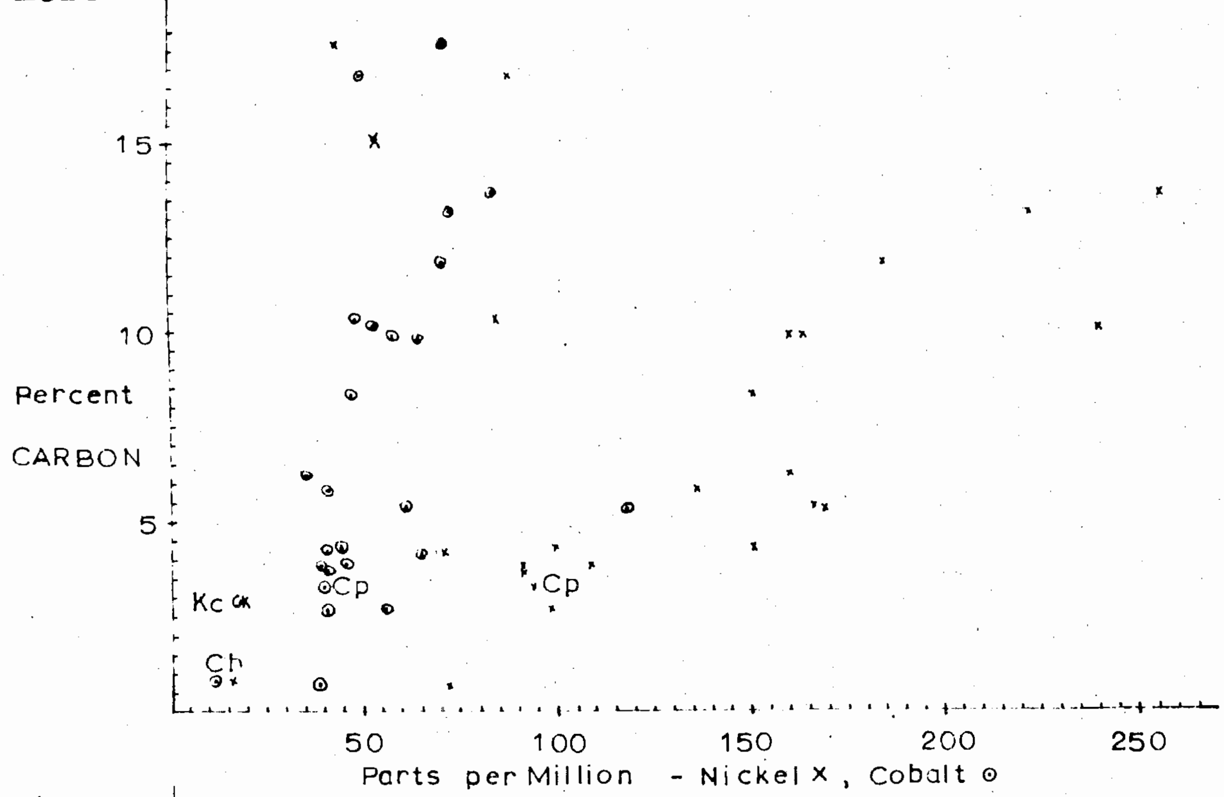


Figure 9

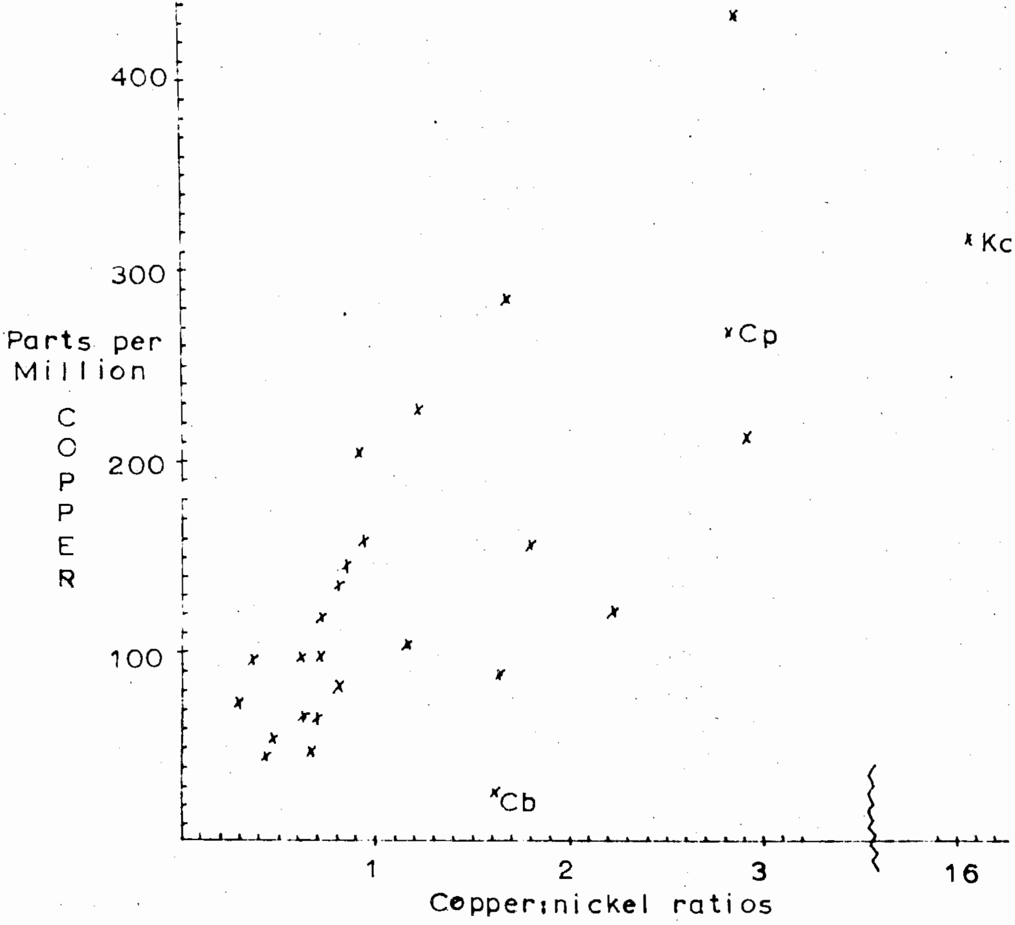


Figure 10

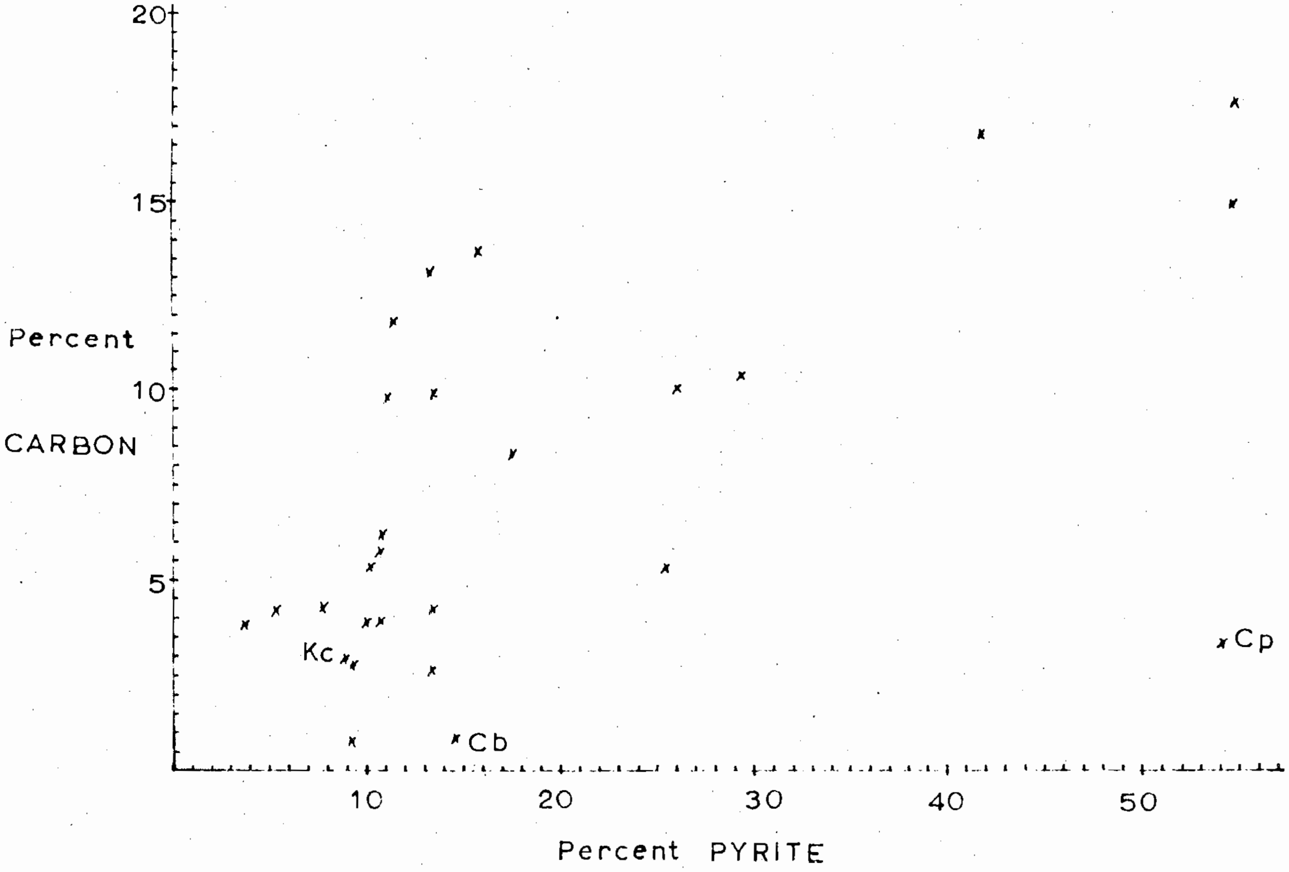
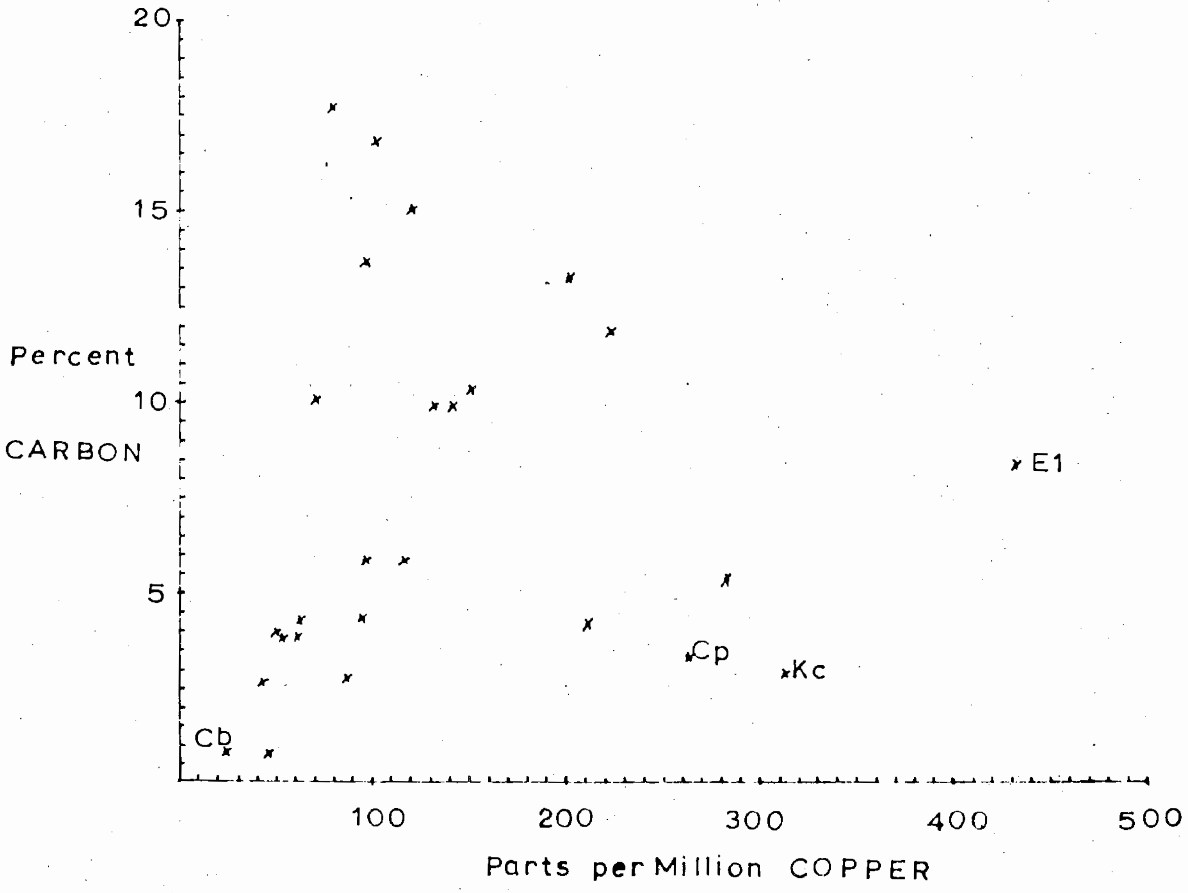


Figure 11



or sulfo-salt of a heavy metal.

The chromium content of the analyzed graphitic specimens shows considerable variation, as previously indicated, but typically occurs in amounts lower than the vanadium. Krauskopf (1956) and Peltola (1960) assume the chromium to be removed from the sea water by local reduction and by precipitation as the hydroxide.

A. Bauman, of the Geological Survey of Canada, (personal communication) states that the vanadium/chromium ratios may be used to indicate the environmental conditions in which these elements are deposited. Thus, a vandium/chromium ratio of: $1 > 10$ indicates a gyttja environment, ≥ 1 indicates a sapropelic environment, and < 1 indicates that the elements are present in the silicates.

The vanadium-chromium ratios for the sampled occurrences within the map area range from < 1 to approximately 5. These ratios would indicate that the graphitic occurrences sampled were formed under sapropelic reducing conditions.

Titanium

The titanium oxide content of the sampled graphitic rocks ranges from 0.09 to 1.24 per cent and shows an unweighted average of 0.37 per cent TiO_2. Peltola (1960) gives an average titanium oxide content of 0.46 per cent for hydrolysate sediments. The titanium content of the sampled occurrences is approximately proportional to that of the alumina.

The titanium content in the sampled occurrences is apparently within the normal range for such rocks.

Tin

With the exception of the tin analysis for the Kidd Creek graphitic schist, the results of the tin analyzes range from below the detection limit (of 10 p.p.m.) to 20 p.p.m. The Kidd Creek deposit sampled occurrence gives a value of 200 p.p.m. Mason (1966) gives an average tin content in shales of 6 p.p.m.; Hawkes and Webb (1962), however, quote a value of 40 p.p.m. for shales.

Nickel

The nickel content of the sampled graphitic rocks ranges from 16 to 256 p.p.m. The unweighted average nickel content for the analyzed rocks is 129 p.p.m. Hawkes and Webb (1962) indicate that a range of 20 to 300 p.p.m. for blackshales is normal.

Degens _et al_ (1957) quote an average nickel content for these rocks as being 510 p.p.m. Krauskopf (1956) believes that the nickel content of black shales is, for the most part, extracted by biogenic processes.

Fig. 8 shows a graph of the carbon content (in per cent) plotted against the nickel and cobalt contents (in parts per million) of the analyzed samples. This graph indicates that the nickel and cobalt contents bear a close relationship to the carbon content. Fig. 13 further shows that the nickel contents for the samples from the Kidd Creek and Caribou deposits are anomalously low, whereas that for the Cuprus Mine sample conforms to the established trend. The nickel to carbon relationship is interesting, and may be worthy of further study. Nickel/cobalt ratios plotted against carbon for these samples resulted in a random plot.

Cobalt

The cobalt content of the sampled occurrences ranges from 12 to 118 p.p.m. and shows an unweighted average value of 66 p.p.m. The average range for cobalt in black shales is 5 to 50 p.p.m. (Hawkes and Webb, 1962). Peltola

(1968) indicates an average cobalt content in black schists of 76 p.p.m. Fig. 8, as stated above, shows a graph of the carbon values plotted against the cobalt values of the sampled rocks. This graph indicates that the cobalt increases in proportion to the carbon, but at a lesser rate than the nickel. As in the case with the nickel graphs, the cobalt versus carbon values from the Caribou and Kidd Creek samples are somewhat anomalous, whereas that for the Cuprus Mine sample lies within the average trend.

The cobalt is considered to be biogenetically precipitated (Krauskopf, 1956).

Graphs showing nickel and cobalt contents plotted against magnesia contents, and nickel/cobalt ratios plotted against iron (for values of the analyzed samples) gave completely random plots.

Lead-Zinc

The zinc content of sampled occurrences, with the exception of that for the Kidd Creek deposit sample, ranges from 50 to 2,160 p.p.m. The analysis of the sample from the Kidd Creek deposit is an anomalously high value of 8,250 p.p.m. The unweighted average of the zinc content for these rocks is 653 p.p.m. The value for the Kidd Creek sample is not included in this average. Hawkes and Webb (1962) give a normal range for zinc in the black shales of 100 to 1,000 p.p.m. Manheim (1961) indicates that the Black Sea sapropelic sediments contain 110 p.p.m. zinc. A graph in which the zinc values are plotted relative to the carbon content (for the analyzed samples see fig. 7) gives a broadly scattered range of values, with approximately one-third of the values, between two to six per cent carbon, possibly revealing a correlation between the carbon and zinc contents. The zinc values for the samples from the Kidd Creek, Caribou and Cuprus deposits all lie outside the main concentration of points. No conclusions can be drawn on the basis of the limited sampling.

Fig. 4 shows a graph in which the zinc/lead ratios are plotted relative to the zinc content of the sampled occurrences. The ratios of the values for the samples taken in the map area increase relative to the zinc content in a linear fashion, whereas the ratios of the values for the samples taken from outside the area are anomalous. This anomalous relationship should be investigated. A graph (fig. 5) in which the lead values are plotted against the zinc values, corroborates the anomalous relationship of the lead and zinc values of the samples taken outside the study area.

Boyle (1965) has analyzed the pyrite in the graphitic shales, etc., at Keno Hill. Boyle determined that the zinc content is enriched some 13 times in the pyrite, as compared to the zinc content of the whole rock.

The lead content of the sampled occurrences ranges from 9 p.p.m. to 94 p.p.m., typically being less than 55 p.p.m. The sample taken from the Kidd Creek deposit is anomalous with a lead value of 94 p.p.m. The unweighted average lead content for the samples taken within the study area is 38 p.p.m. Hawkes and Webb (1962) give the normal lead content in black shales as ranging from 20 to 400 p.p.m. Manheim (1961) gives the lead content for the Black Sea sapropelic muds as 25 p.p.m.

A graph in which the lead values are plotted against the carbon content of the sampled occurrences, shows that the lead may be dependent on the carbon content.

Copper

The copper content of the sampled occurrences ranges from 26 to 431 p.p.m. Hawkes and Webb (1962) indicate that the normal copper content for black shales ranges from 20 to 300 p.p.m. Manheim (1961) gives the copper content for the Black Sea sapropelic muds as 78 p.p.m. A graph (fig. 11) in which the copper values are plotted against the carbon content of the sampled occurrences, indicates that a slight correlation exists between the copper and the carbon contents over two to six per cent carbon. Where the ratios of the copper and nickel values are plotted against the copper values of the sampled occurrences, the ratios plot in a generally linear manner, increasing with the increase in copper content (fig. 9). A few of the ratios lie outside of the indicated linear, including the ratios derived from analyses of the samples from the Kidd Creek, Caribou and Cuprus deposits. This should be further investigated.

Discussion of the Stratigraphic Variation Throughout a Graphitic Section

Samples E-6 to E-21 represent a continuous sampled section through a graphitic unit. This sampled occurrence is located in Desboues Twp.

The chemical variations observed in this section are drawn from the graphs shown in Fig. 12 to 15. These are discussed only in a general manner.

The alumina content varies proportionately with the silica; these two oxides vary inversely with the iron content. The soda, potash and, to a lesser extent, calcium contents vary proportionately with the silica content. The magnesia content varies proportionately with the alkalie content in an irregular manner. The titanium content varies irregularly, and with no obvious relationship to the other elements.

The cobalt and nickel contents are irregularly proportional to each other (the nickel occurring in greater amounts) and vary as a function of the carbon content. Although the iron and carbon contents vary in an approximately symmetrical manner, fig. 13 demonstrates that the nickel and cobalt contents, while a function of the silica content, are not associated with the iron.

The copper and zinc contents exhibit roughly parallel variations throughout the section (fig. 15), whereas the lead content shows no relationship to the copper or zinc contents. The above element contents are only slightly portional to the carbon content. This apparent lack of correlation between the copper, lead and zinc contents and the carbon content is further supported by the rather inconclusive graphs in which the copper and zinc contents are plotted against the carbon content (fig. 7 and 11). They may, indeed, relate more closely to the alumina content. A correlation with the Al_2O_3 would support the observations by Krauskopf (1957), which indicate that these elements are brought into the black shale environment in the adsorbed state (in this case with the clay faction). Although the curve for the lead content is only slightly variable, it would correlate most nearly with the Al_2O_3 curve (fig. 12 and 15).

The vanadium-chromium curves generally correlate with each other, with the exception of the anomalous condition observed in sample E-9. The curve of these two elements would correlate most closely with the SiO_2 or Al_2O_3 curves.

In view of their negligible concentrations, in the analyzed rocks, variations curves were not plotted for the following elements: gold, silver, molybdenum, uranium, tin, tungsten and mercury.

The following graphs have been drawn on the basis of the analytical values obtained for samples E-6 to E-21 which represent the continuous sampling of a graphitic unit in Desboues Twp. The points are plotted at the mid-point for the sampled width. The sample number for each section is noted. The curves represent the geochemical variations throughout the sampled horizon.

Figure 12 - Variation in SiO_2, Al_2O_3, Fe and C
Figure 13 - Variation in CaO, K_2O, Na_2O and MgO
Figure 14 - Variation in TiO_2, Co and Ni
Figure 15 - Variation in V, Cr, Cu, Pb, and Zn

Figure 12

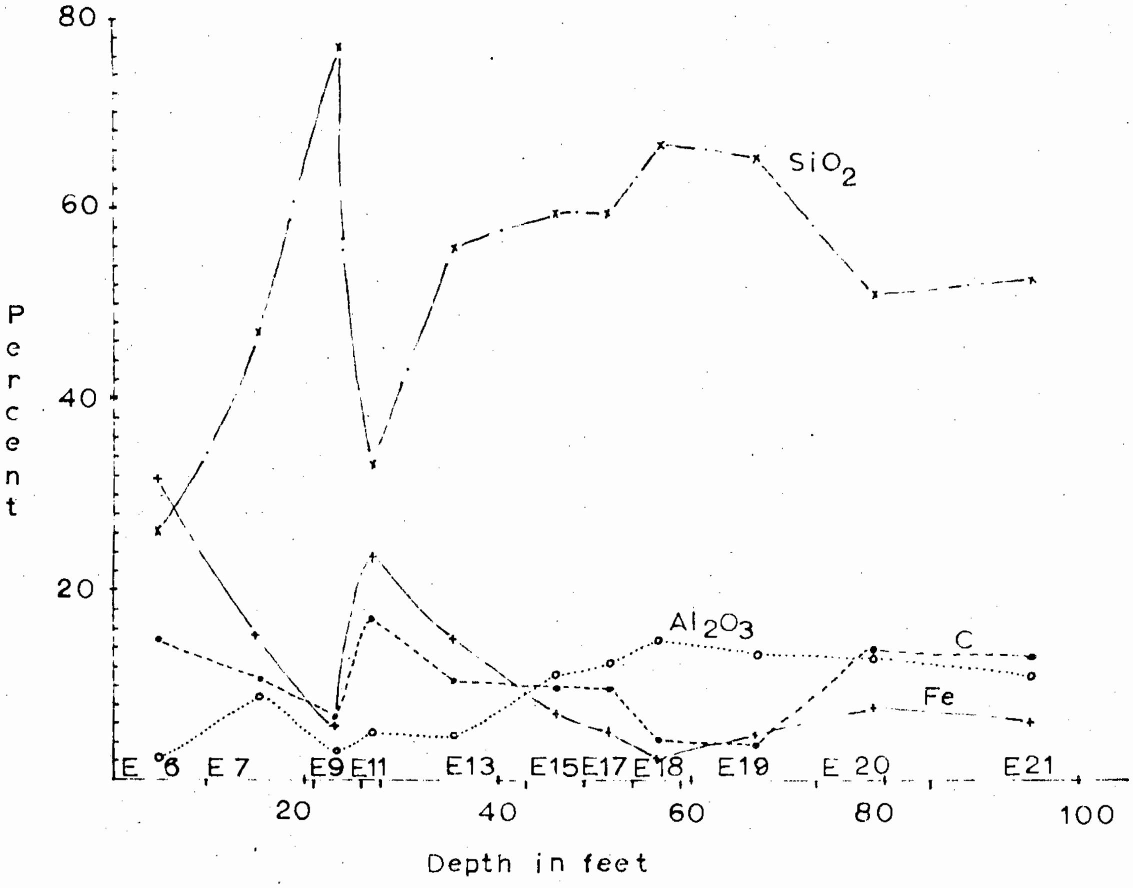

80
60
40
20
Percent
SiO$_2$
Al$_2$O$_3$
C
Fe
E 6
E 7
E9
E11
E13
E15
E17
E18
E19
E 20
E21
20
40
60
80
100
Depth in feet

Figure 13

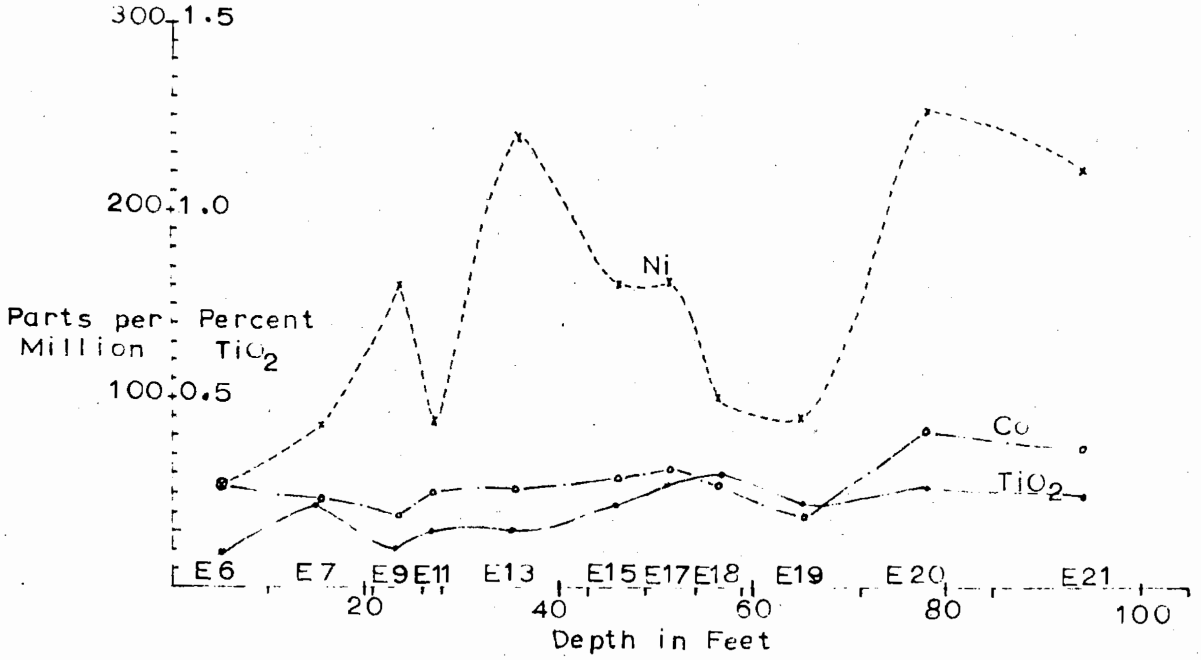


Figure 14

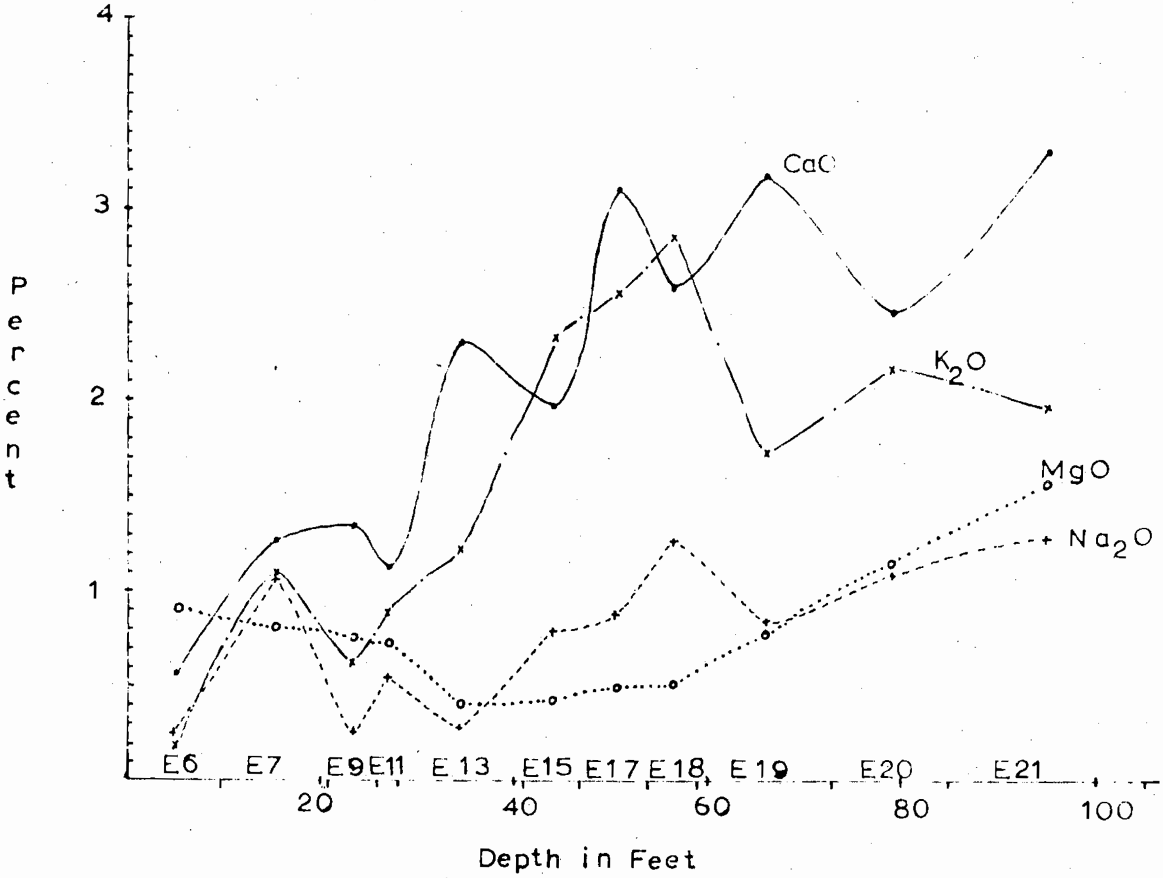
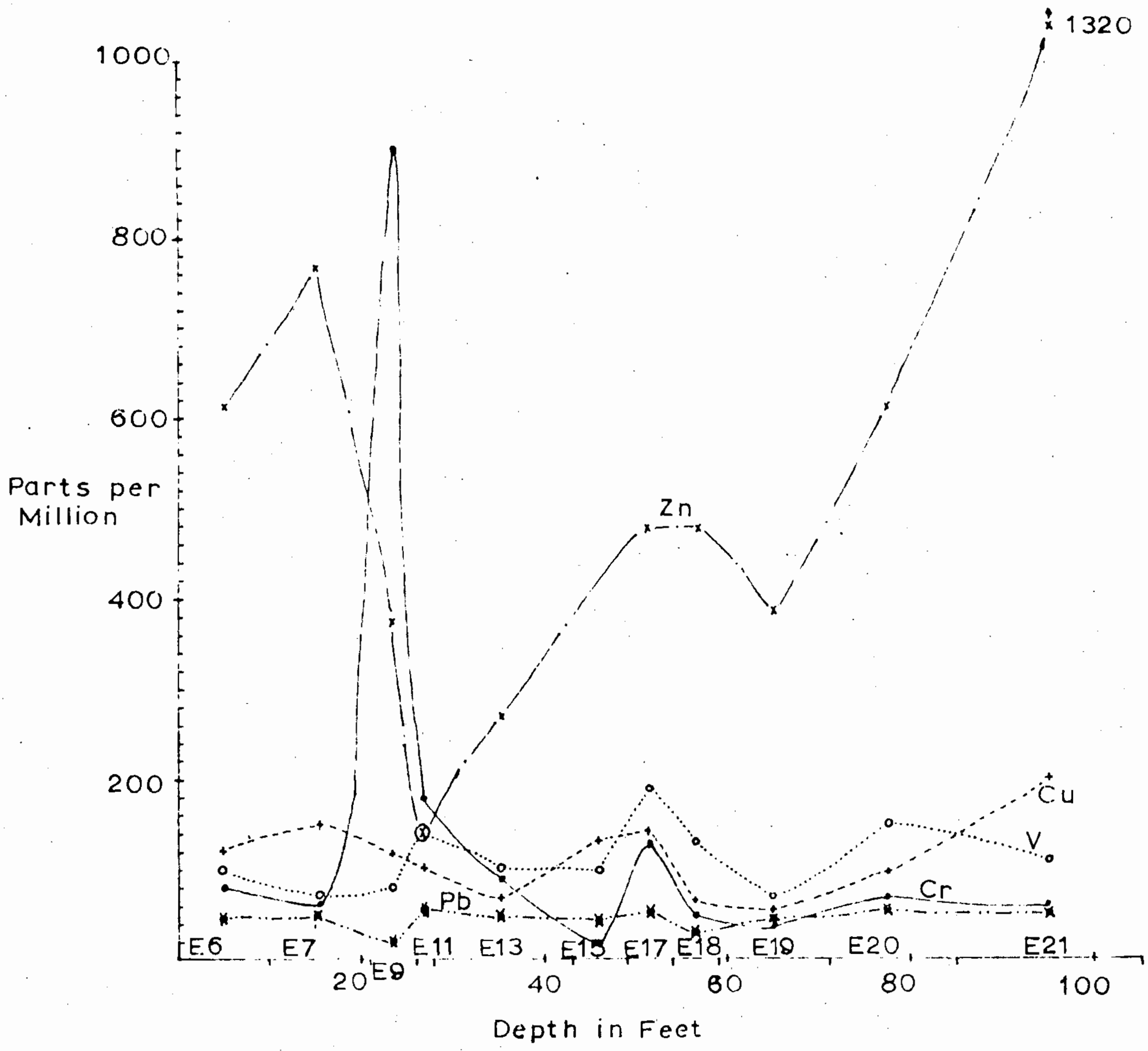


Figure 15


1320
1000
800
600
400
200
Parts per Million
Zn
Cu
V
Cr
Pb
E6
E7
E9
E11
E13
E15
E17
E18
E19
E20
E21
20
40
60
80
100
Depth in Feet

CHAPTER V

GEOPHYSICAL DATA

GENERAL STATEMENT

The Rouyn-Val d'Or area has been extensively prospected using electrical geophysical means. This general method is employed in view of the fact that the type of deposits typically being sought are often of the "strata bound" massive sulphide type, showing andesite-rhyolite associations. These massive sulphide bodies are electrically conductive and, as such, are amenable to electromagnetic excitation. A variety of prospecting devices using electromagnetic principles are currently available (Hansen, *et al*, 1967, Dobrin, 1960, etc.), which will detect conductive features within the earth. Two systems are the most commonly used:

1) An airborne system which is used to cover large tracts of land, and which will indicate conductive sections, and

2) Ground systems which may be used to "follow-up" the airborne indicated anomalies.

The airborne and ground systems, operating on the basis of electromagnetic principals, are respectively known as airborne electromagnetic (AEM) and ground electromagnetic (GEM) devices.

The intensive electrical geophysical prospecting since the early 1950's has resulted in an immense accumulation of geophysical data for the Rouyn-Val d'Or area. The compiled geophysical information (in back pocket) represents only a small fraction of the accumulated total.

Ground electromagnetically activated conductors may be caused by any one of the following: wet shears, graphitic beds, sulphide-bearing units, overburden-bedrock interfaces, clay lenses within the overburden, etc. AEM will indicate anomalous conditions for any of the preceding, as well as for rivers, swamps and man-made features. Thus interpretations of indicated anomalous conditions are many and varied. A number of the above anomalous conductive features may be eliminated by the variation of the frequency of the electromagnetic field pulse. Swamps, and other "wet" features, will not be electrically activated, or, if so, only weakly, at low frequencies (less than 600 cps). Graphite and sulphide-caused conductors are generally not discriminated by virtue of their electromagnetic properties. Drilling, trenching, or other means of exposing the bedrock must be used to discriminate between these important causes of electromagnetic anomalies.

In view of the incomplete information available, no attempt has been made to estimate statistically the percentage of conductors attributed to graphitic versus non-graphitic sources.

Nine distinctive conductive belts are recognized, which are distinguished on the basis of frequent conductive units within each belt; the occurrence of graphite is typically coincident with the defined belts. These belts are considered to delineate large-scale structural features within the area, and are considered to represent a period of time when carbonaceous sedimentation was widespread. As such, on a large scale, they may act as marker horizons. In detail, the individual occurrences are of inadequate continuity to provide more than very local marker horizons.

Airborne Electromagnetic Data

All available AEM surveys (as filed for assessment) have been compiled and plotted on the accompanying map (in back pocket). The anomalies have been plotted as filed; no attempts were made to re-interpret the material.

Airborne electromagnetic information is rarely submitted for assessment purposes, the ground "follow-up" work being typically filed. Thus, only a limited amount of AEM has been plotted. It may, however, be assumed that most regions, which show GEM data, have been flown. AEM data was plotted in the following twps.: Haig, Vauquelin, Senneterre, Courville, Barraute, Duverny, Landrienne, Ligneris, Berry, Guyenne, Clermont, La Sarre, Chazel, Palmarolle, Montbray, Duprat, Duffresnoy, Clericy, Dasserat, Beauchastel, Rouyn and Joannes.

The AEM data is used for interpretive purposes only when it is "backed up" by either GEM and/or graphitic occurrences.

A strong correlation exists between AEM and GEM data in four regions:

1) In Clermont Twp. passing into Chazel Twp.;

2) The Ligneris Twp.-North Guyenne Twp. region passing into Berry Twp., plus a weaker, but definitely correlated, section in S.E. Guyenne Twp.;

3) Barraute-Carpentier Twps., where a strong but separated correlation exists;

4) North Vauquelin.

The AEM anomalies vary from isolated points (picks), which are located on one flight line, to a series of "picks" producing a linear of up to three miles extent (i.e. adjacent flight lines locate anomalies which suggest that they are points on a single linear conductive feature).

Ground Electromagnetic Data

Approximately 400 assessment files have been searched, resulting in the compilation of some 600 ground electromagnetically indicated conductors.

The GEM anomalies are transferred from assessment maps, which vary in scale from 1" = 100' to 1" = ½ mile, to the present compilation, 1" = 3 miles. Every attempt has been made to maintain the original features. Although drag folds, flexures and faulted effects are reproduced, it is obvious that these features will be largely obscured as a result of the scale of the present compilation. These features are regarded as significant with regard to ore localization, as exemplified at the Kidd Creek and Bathurst ore deposits.

No attempts have been made to re-interpret the anomalies, and they are largely plotted as filed.

The ground electromagnetically-indicated conductors range in length from approximately 100 feet (i.e. a strong indication on one line which is not observed on adjacent lines) to approximately four miles (North Carpentier Twp.). A mean length for the conductors of the Rouyn-Val d'Or area is estimated at between half a mile to three-quarters of a mile.

The majority of the conductors have been detailed using a variety of vertical loop type devices; a lesser number are surveyed using horizontal and vertical loop devices. An insignificant number of the anomalies have been detailed by various other electrical methods.

STRUCTURAL INTERPRETATION BASED ON THE GEOPHYSICAL RESULTS

On the basis of the compiled GEM data of occurrences of graphite and, to a very limited extent, of confirmatory AEM data, nine, broadly defined, graphitic belts are delineated. The significance of these, where possible, is discussed in relation to the structure of the area as a whole. These belts are named with reference to the twps. in which they occur.

The defined graphitic belts are conformable with the geology; this conformity is extended downward from the scale of the "belts" to that of individual conductors comprising the "belt."

Extrapolation of the graphitic "belts" is hampered by lack of information.

This lack of information is attributed to the lack of information available rather than to the physical lack of conductive units.

The following outlines the postulated graphitic belts:

1) Desmeloises-Barraute-Haig Belt: The combined graphitic and conductor data lie within an overturned canoe-shaped structure, whose "prows" are located in Desmeloises and Carpentier Twps. This "belt" is the most extensive and well-developed of the graphite belts in the area, and, if accepted as such, extends approximately 130 miles from the northwest to the southeast corners of the map. This inverted canoe-shaped structure is interpreted as being a large-scale anticline (anticlinorium), probably a vertically-inclined, isoclinally folded, doubly plunging anticline. Compression has been most extreme at the "prows" of the structure, resulting in an effective doubling of the width of the limbs.

2) The Rouyn Area Belts: One belt is defined by the frequent "bunches" of relatively short and discontinuous conductors, as found in Montbray, Dufresnoy, Dasserat and Bousquet Twps. No evidence is available to suggest that the conductors are caused by graphitic units.

A close examination of the orientation of several of these "bunches" suggests that they may indicate an irregular "Z"-shaped fold--the top of the "Z" lying at the south end of Lac Duparquet, the bottom of the "Z" being in the vicinity of Lac Armour and extending eastward into the middle of Beauchastel at Arntfield.

A few graphitic occurrences exist outside of this envisaged fold.

A second "belt," within the Rouyn area, is postulated as extending from the east side of Lac Duparquet to the middle of Clericy Twp. This southeasterly trending arcuate belt is delineated by scattered conductors and graphitic occurrences extending from Lac Duparquet to Clericy Twp., where a considerable number of conductors present a confused picture. This belt is terminated by the Porcupine-Destor fault, which trends southeasterly through the northern part of Clericy Twp. The conductors within this belt typically lie within the mafic volcanic rocks, but in close proximity to, and parallel with, the rhyolitic units. The two postulated belts present a rimming effect about the central Rouyn area, which is partially enveloped by these "belts."

3) The Cadillac-Bourlamaque-Pershing Belt: This belt is represented by two widely separated units which have been grouped together by virtue of their proximity of the Cadillac-Larder Lake "Break." This belt parallels the Cadillac-Larder Lake "Break," and is some 80 miles long and two-to-three miles wide. Only a few, widely scattered conductors exist within this belt; these lie within the sediments and in close proximity to the volcanic rocks. The conductors are particularly well-developed in Cadillac Twp. No drill results are available to indicate the nature of the conductors in the western section of the belt. It is possible that, to the west, in Joannes Twp., the Davidson Creek fault has offset the belt to the north, as seen in Clericy Twp.

The easterly portion of this belt is in South Louvicourt, Vauquelin and Pershing Twps. The existence of the belt is supported by the presence of eight graphitic occurrences, with a few correlative conductors in Vauquelin and Pershing Twps.

4) Lac Malartic Belt: Two concentrations of conductors exist in this zone, probably representing one continuous zone trending from northwest Lac Malartic, in La Motte Twp., into west Vassan Twp. In central La Motte, the majority of the conductors, which are unexplained, are conformable with the

granite rocks intruding into the ultramafic sequence in which the conductors lie. Two discordant sets of conductors exist immediately north of the ultramafic rocks. One set, in mafic volcanic rocks, parallels the regional east-west trend; the second set, in sedimentary rocks, is normal to the regional trend. Conceivably, the sediments containing this second set represent a discordant, rotated roof pendant within the granite batholith.

A series of discontinuous conductors, contained predominantly within ultramafic sequences, occurs on the east side of Lac Malartic and extends into Vassan. Limited drilling suggests that the conductors are caused by graphitic sediments intercalated with the ultramafic units.

5) Fiedmont-Pascalis-Vauquelin-Haig Belt: This south-easterly trending zone is postulated on the basis of generally scattered conductors and graphitic occurrences. The zone is well-defined only in north Vauquelin Twp. The conductors are typically concordant with the nearby lithologic contacts, but are, however, discordant at the westerly side of the zone in the south part of Fiedmont Twp. Graphitic occurrences confirm a probable graphitic source for the conductors.

6) Bernetz-Hurrault-Laas Belt: The available data indicates a well-developed zone of graphitic units, trending in an east-southeast direction. The zone is a minimum of one mile wide at the northwest end, and four miles wide at the east end. The conductors are typically conformable with the granite-sedimentary rock contact. The abrupt change in attitude of the conductors in the volcanic rocks of north Tonnaucourt Twp. suggests either an unconformity or a fault--this feature is again suggested in the Ducros-Delestre Belt.

7) Delestre-Ducros Belt: This zone is particularly well defined by conductor data and by minor graphitic occurrences. The zone is approximately

one-and-a-half miles wide and four to five miles long, and is conformable with the lithological contacts. This zone may be extrapolated to include the conductors and graphitic occurrences located in south Bartouille Twp. This extrapolation would suggest either that the sedimentary contacts, as shown, are incorrect, or that the sedimentary units are locally unconformably overlain by the volcanic rocks.

A further extrapolation would join the Delestre-Ducros and Bernetz-Laas Zones, a postulation that would agree with the interpretation for the southerly lying Desmeloises-Barraute-Haig structure.

8) Duparquet-Destor-Privat Belt: The suggestion of an easterly trending graphitic belt in this area is afforded by the scattered but persistent occurrence of graphite, extending from northeast Duparquet to Lac Lois in Aiguebelle Twp. GEM data locally correlates with, and extends, the drill data. The graphitic occurrences lie typically on the perimeter of the rhyolitic unit to the north. Further extension of this belt to the east (as is probable) is prevented by lack of information.

9) Villemontel-Landrienne-Barraute Belt: This belt is postulated on the basis of irregular and inadequate data. It is suggested that this is a faulted (drag folded?) zone, extending from central Villemontel Twp. to southeast Barraute Twp.

The total lack of information in Manneville Twp. and in the western half of Villemontel Twp., when coupled with the lack of accessibility, suggests that little or no work has been done in these twps. Conceivably, the last postulated belt may continue into the Duparquet-Destor belt.

Summary Statement

Nine moderately-strongly indicated graphitic belts have been postulated.

These may actually prove to be less in number, if additional evidence shows that some of the belts are actually continuous. These belts may be interpreted as being inter-related in the form of several east-southeasterly trending isoclinal folds, which have been variously faulted and disrupted by granitic intrusions. The widths of the belts vary from under one mile to as much as 15 miles (Desmeloises). The extreme width in Desmeloises and Carpentier Twps. is considered to be due to extreme isoclinal folding, effectively doubling original widths.

The various belts are interpreted to represent a time interval when carbonaceous sedimentation was widespread, throughout a period of widespread volcanic activity.

CHAPTER VI

GRAPHITIC AND CARBONACEOUS OCCURRENCES IN OTHER REGIONS

A DISCUSSION

GENERAL STATEMENT

Carbon-bearing rocks, predominantly shales and their metamorphic equivalents, are widespread throughout the stratigraphic column. The carbon occurs in various forms, from graphite and lower order carbon forms, to various hydrocarbons, bitumens, alkanes, etc. The carbon, as formed within the shales, is believed to be of a syngenetic, and probable organic, origin.

The oldest dated occurrence of organic carbon is found in the Fig Tree Formation of South Africa (Barghoorn et al, 1965, and Hoering, 1965). The carbon in the Fig Tree Formation is believed to be three billion years old. The youngest accumulation of organic carbonaceous material is presently taking place in areas where relatively slow sedimentation and stagnant, and hence reducing, conditions exist: in deep sea basins, lagoons, deltas, fjords and isolated or "barred" basins such as the Black Sea. Biogenic carbon has been variously identified in carbonaceous units spanning a time interval from the present to three billion years ago.

Carbonaceous sedimentation has been typically widespread, areally as well as in time. The deposition of individual carbonaceous sedimentary units has covered hundreds of thousands of square kilometres (e.g. the Chattanooga Shale).

The carbonaceous units, most typically, have served as repositories for the accumulation of many of the chalcophile and lithophile elements which typically accumulate within these units in amounts several times above their normal concentrations in other sedimentary types.

Iron, in the form of pyrite, is a common and widespread characteristic element of the carbonaceous rocks. The presence of pyrite is not, however, invariable, and its absence may indicate a non-marine origin for the containing shale units (Krauskopf, 1967). The pyrite is believed (Boyle, 1968) to be the host for a number of the trace elements commonly present in carbonaceous rocks.

Economic sulphide deposits of the "strata-bound" type occur as conformable lenses, either within the carbonaceous shale units or in nearby sulphide deposits which reveal a similar association. These sulphide deposits are characterized by their great lateral extent as compared with their vertical extent (i.e. thickness), and by their characteristic conformity within the enclosing rock units.

A number of sulphide deposits, other than the "strata-bound" type, are indicated as having more than a casual relationship to nearby carbonaceous (graphitic) shale units (e.g. Keno Hill). Boyle (1968) suggests that the shales have been the source of metallization for the formation of the deposits.

Studies by Love (1962), Baas Becking et al (1961) have indicated that the sulphide found within the carbonaceous shales, and frequently within the associated ore deposits, are biogenically precipitated. Sangster (1968) has compiled valuable sulphur isotope data, which would substantiate a syngenetic, biogenetic origin for many of the "strata-bound" sulphide deposits.

PYRITIC FORMATION IN BLACK SHALES

Carbonaceous sedimentation is taking place today in many and diverse locations throughout the world. Typically, the most extensive locii of black shale sedimentation are in basins of a restricted nature; these may or may not be forming at great depths. The single most important parameter is an oxygen deficiency, which may result from:

1) Restricted basins into which freshly oxygenated water is not circulated;

2) Sedimentation of an adequately rapid nature, such that organic matter is not oxidized; as well as in an environment in which currents are not effective in resorting the sediments.

The associated sedimentation is typically very fine-grained (i.e. clay size particles). The above sedimentation is variously described as euxinic, sapropelic or gyttja (Marmo, 1960). The sapropelic environment is characterized by stagnant waters and strong hydrogen sulphide production. The gyttja environment is transitional between the oxidized and sapropelic environment, and characterized by a reducing environment which may or may not have hydrogen sulphide production, and which is overlain by oxygenated water, (Manheim, 1961). The hydrogen sulphide is considered to be produced by sea-water sulphate reducing anaerobic bacteria, or organisms, in the sediments. The organic matter, as already discussed in the geochemistry of these rocks, is responsible for the bulk of the heavy metals being brought into this environment, as adsorbates, and colloids (Papunen, 1968 and Krauskopf, 1956). The heavy metals are also partially transported into the site of deposition as ions adsorbed to the clay faction. According to Papunen, the clays in the fresh waters will initially adsorb the chalcophile elements, which are then desorbed upon introduction into a saline reducing environment.

The iron is thought to be brought into the environment in the form of organic colloids, and as ions adsorbed to the clay particles. This iron, which is only weakly bound to the clay particles, then easily reacts with the biogenically produced H_2S to form a hydrous iron sulphide; the exact form of this initial precipitate is still in doubt.

Anaerobic bacteria are considered to play the prominent role in the deposition of the iron. The iron appears as hydrous-troilite according to Dunham (1960). Gammon (1961) states that a high concentration of H_2S would be toxic to the bacteria, and that it must be "fixed." This is done by the formation of the iron sulphide, which is deposited as very fine spherules. Baas Becking and Moore (1961) have performed experiments using bacteria taken from a reducing deltaic environment and deposited the sulphides of a number of metals, including those of Cu, Pb, Fe, Zn, and Hg. Love (1962) demonstrated that the pyritic spheres, as found in the Kupferschiefer of Germany, contain microfossiliferous cores of an organism which he has named _Pyritosphaera barbaria_ (Love, 1957). Love and Zimmerman (1961) have demonstrated the existence of translucent organic bodies in the pyrite spheres as found at Mt. Isa, Queensland. Thus, there is adequate evidence to show that pyrite is biogenically produced. Dunham (1961) suggests that in some cases, the pyrite is found within the organisms as a result of their iron requirements. The most widespread and versatile sulphur bacteria is _Desulforibrio desulfuricans_; it may be found in fresh and marine waters.

Studies by Papunen (1965), conducted in the Bothnian Sea, determined that the sapropelic sediments contain opaque spherules which were, in part, disordered idiomorphic pyrite and, in part, ordered framboids. They generally showed a zoning with a very small pyritic core, about which radiate ordered marcasite prisms. The spheres of pyrite, as found in the Kupferschiefer, are typically fine framboids composed of idiomorphic crystals (0.025 to 0.005 mm).

The pyrite, as found in the carbonaceous shale and sediments, has been shown to be directly related to the carbon content; this relationship is used to determine whether the sedimentation is fresh water or marine. Peltola (1968) shows that the sulphide content of the black schists of East Finland closely parallels the carbon content; this phenomenon is further observed in black shales throughout the stratigraphic column: the Upper Carboniferous Shale of St. Hippolyte, France; the Devonion Shales of Ohio, the Precambrian shales of Nagarjunasgar, India. Strakov (1960) (in Peltola (1968) shows that the irregular distribution of the pyrite parallels that of the carbon in the Black Sea; again Strakov (1959) (in Peltola, 1968) demonstrates that in rocks of marine origin, the FeS_2:C (residual) ratios fluctuate between 0.2 to 2.0, but are typically between 0.5 to 0.8. In rocks of continental origin, the ratio FeS_2:C is given as 0.03 to 0.06; deposits in the intermediate environment will give ratios 0.06 to 0.03. Degens (1965) suggests that marcasite is characteristic of a fresh water formational environment, as opposed to a marine environment, in the formation of pyrite.

In the literature summarized, no mention was noted of the pyritic spheres attaining the sizes found in the study area (i.e. up to two inches diameter). Typically, the sizes for these spheres were given as from less than four to 25 microns. The characteristics of these smaller spheres closely correspond to those of the larger "nodules" described for the Rouyn-Val d'Or area, and it is inferred that the processes involved in the formation of these spheres, as found in the study area, are identical to those cited. The larger spheres are, most likely, the result of rotation and aggregation of large numbers of the smaller spheres by dynamic metamorphic processes.

FORMATION OF THE NON-FERROUS SULPHIDES

Trace amounts of chalcopyrite and sphalerite are commonly recognized as associated with the pyrite. As stated in the preceding section, experiments by Baas Becking and Moore (1961) have demonstrated that anaerobic bacteria are capable of precipitating the sulphides of Cu, Zn, Pb, Ag, as well as Fe. Thus, a biogenic mode of precipitation for the sulphides of the above elements is feasible. This mode of precipitation for these metals as the sulphide is further suggested by Krauskopf (1956).

Cheney and Jensen (1962) have stated that, because of the toxic nature of the concentrations of Cu found in the shales of the Zambian Copper Belt, bacteria cannot be expected to survive. The work of Baas Becking and Moore (1961) negates their statement. Cheney and Jensen then postulated a mechanism for the deposition of the Cu, which fits in with the occurrence of the Cu mineralization as found in the Copper Belt. Their contention is that the copper is brought into the marine environment as hydrolysates, and that only a very small percentage will be dissolved by the sea water (which contains 0.003 p.p.m. ionic Cu). According to their hypothesis, when the Fe is biogenically precipitated as the sulphide, the precipitation of the Cu as the sulphide is immediately required. This is demanded in any Fe-Cu-containing solutions in which the relative solubilities of the sulphides are not reversed. Thus, if pyrite is accumulating, there must be a corresponding deposition of the Cu, replacing the Fe; this deposition of the Cu will shift the equilibrium, which results in less Cu being available for replacement away from the source of the solutions. This hypothesis explains the sequential copper deposition as detailed by Garlick (1961) for the Zambian Copper Belt. This sequence may equally well be explained by the preferential presence of the copper precipitating bacteria, decreasing away from a source.

The ideas outlined above are, no doubt, operable, but it is doubtful that simple erosion of the surrounding land mass is adequate to explain the quantities of copper found. Jensen and Cheney suggest that the 116 p.p.m. Cu average content, as given for the American igneous rocks, is an adequate source. But other sources should be sought. The average copper content for non-economic black shales lies within the above cited quantities. More likely, the copper is deposited biogenically.

The copper mineralization at the White Pine Copper deposit of Michigan has been revealed to show a close association with biogenic carbohydrates. Oils, alkanes and microfossils are frequently found in the centres of the mineral grains.

If minute, biogenically produced, amounts of the above-mentioned sulphides are possible, then there should be no reason why larger amounts of Cu, Pb, and Zn should not be so deposited; it may be suggested that larger amounts are deposited as a result of a greater than normal inflow of these metals. (By normal is meant that inflow associated with the peneplaination of the continents.) Thus, volcanic exhalatives, rich in these metals, flowing into a reducing environment, would provide the metallization required. Anaerobic bacteria, which can subsist in a reducing environment, would produce the hydrogen sulphide necessary to precipitate the sulphides of copper, lead and zinc. The ratios of the different elements occurring would be dependent on their original ratios. Dunham (1961) has demonstrated that these bacteria are extremely versatile and that they are found at depth in the ocean deeps (to 5,000 metres), and also at similar depths in oilfields.

Metallization is currently proceeding in the deeps of the Red Sea, where an estimated three billions of dollars worth of minerallization have formed on the sea floor. Brines here are found to contain Zn, Cu, Fe, and Mn, in concentrations 1,000 to 5,000 times that above sea water (Miller, 1966). It was not noted whether bacteria are involved in the precipitation of these metals.

Sangster (1968) in a detailed isotopic study of the sulphur in "strata-bound" sulphide deposits of both volcanic and sedimentary associations, concludes that:

> "A close agreement exists between the isotopic conpositions of strata-bound sulphide deposits and bacterially produced sulphides with regard to the trend directions, range in average magnitude of the fractionation relative to that of the original sea water sulphate."

GRAPHITIC (CARBONACEOUS) SHALE ORE ASSOCIATIONS

Table No. 1 tabulates six distinctive copper-lead-zinc-silver deposits of the "strata-bound" type which show a close spatial relationship to graphitic, or carbonaceous shale (schist) associations. The Keno Hill lead-silver deposit has been included, although it is not a strata-bound sulphide deposit. This listing is only a partial tabulation of existing "strata-bound" deposits and is presented in order to emphasize the association of the carbonaceous rocks with the presence of ore deposits.

ORIGIN OF ARCHAEAN GRAPHITE

Graphitic occurrences are widespread in the Archaean, and may be found throughout the world, associated with greenstone occurrences within Precambrian Shield areas.

The graphite, as typically found, occurs within sedimentary units, predominantly metamorphosed shales. The graphitic occurrences in the Rouyn-Val d'Or area suggest that the graphite in the sampled occurrences is an original constituent of these rocks. The graphitic rocks may be compared

TABLE I SELECTED ORE DEPOSITS SHOWING GRAPHITI

Mine or Mining District	Locality	Host Rocks			Country Rocks	Principl Mineral-ization
		Hanging Wall	Foot Wall	Host		
Bathurst	New Brunswick	graphitic argillites, sericite, chlorite schists, andesite, tuffs, iron formation, feldspar, augen schists, graphitic cherty units			sheared andesites and tuffs, quartzites, graphite schists, sericite, chlorite schists and tuffs, sheared rhyolites, iron formation	FeS$_2$, Fe PbS, CuF ZnS ± Co Fe$_2$O$_3$
Kidd Creek	Timmins, Ontario	andesite ± rhyolite tuffs and graphitic sediments	rhyolite and rhyolite tuff	massive sulphides and minor graphitic schists	rhyolite ± graphitic sediments, andesite, dacite, peridotite	FeS$_2$, Zn CuFeS$_2$,
Cuprus Mine	Manitoba	graphitic schists and sheared basic volcanoes			sheared andesitic volcanics, diorite, slightly sheared volcanics	FeS$_2$, Fe CuFeS$_2$, FeAsS$_2$ ±
Keno Hill	Yukon	quartzites, greenstones			phyllite, argillites ± limestone, quartz mica schists, graphitic schists, quartzites	FeS$_2$, Fe PbS, ZnS bergite, + second minerali
Kupfer-schiefer	Germany	limestone	conglomerate	shale with bitumenous layers	shales, siltstones, sandstones	Cu$_5$FeS$_4$, CuFeS$_2$,
White Pine	Michigan	shale	shale	carbonaceous shale	shales, siltstones, sandstones	Cu$_2$S, Cu CuFeS$_2$, Cu$_5$FeS$_4$, FeS$_2$, Ag
Zambian	Africa	quartzite, argillite, feldspathic quartzite	conglomerate, arg. quartzite, feldspar quartzite, conglomerate	shale quartzite greywacke	shales, siltstone, argillite, impure dolomite, mica quartzite, greywacke	CuFeS$_2$, Cu$_5$FeS$_4$, FeS$_2$, Cu CuS, Co$_2$ Co$_3$S4, M

C (CARBONACEOUS) ASSOCIATIONS

le	Spacial relationship of the graphitic (carbonaceous matter) units to the ore bodies	Length of graphitic unit/or of ore bodies*	Meta-morphic grade	Age	Local or regional structures
eS Fe	graphite intimately associated to approx. 100' separation - occ. not noted	400* to 3,800'	low green-schist	Ordovician to Silurian	strong folding, moderate faulting frequently present, strong deformation
nS, Ag	intimately as discrete units within the ore zone	~ 2,000'	low green-schist	Archaean	drag folded, steeply dipping structure; strong deformation
eS, 2	immediately enveloping and intimately associated	500'* to 700'	green-schist	Archaean	strong folding, strong deformation
eAsS$_2$, , frei- CuFeS$_2$, lary zation	predominantly underlying the quartzitic units within less than 500'	15 miles by 4 miles	low green-schist	Late Precambrian to Paleozoic	Deposits occur in dilatant zones in competent rocks - mild deformation and considerable faulting
Cu$_2$S, PbS, ZnS	carbonaceous matter generally abundant within the ore units	approx. 100 miles	diagenic	Permian	very gentle folding, minor faulting
nS,	carbonaceous matter: petroliferous products abundant in some beds within the ore units	100 miles	diagenic to low green-schist	Late Precambrian	gentle folding, one major fault
$_2$S, CuS$_4$, oS$_2$	carbonaceous matter abundant in some beds within the ore units	80 miles	low to medium green-schists	Late Precambrian	complexly folded, minor faulting

TABLE 2

Chemical Composition of Carbonaceous Shales
(Per Cent)

Constituent	A	B	C	D	E	F	G	H
SiO_2	51.03	60.65	36.37	58.03	63.09	33.15	39.00	50.42
TiO_2	-	0.62	0.39	0.64	0.99	-	0.72	0.37
Al_2O_3	13.47	11.62	6.90	15.00	18.58	17.30	14.20	10.95
Fe	-	-	-	-	-	-	-	9.62
Fe_2O_3	8.06	0.36	-	3.67	2.17	2.6	7.7	-
FeO	-	-	2.35	5.82	2.73			-
MnO	-	0.04	0.002	0.09	0.22	0.25	5.2	-
MgO	1.15	1.90	0.65	1.64	2.67	1.0	2.7	1.23
CaO	0.78	1.44	0.13	0.26	1.11	10.4	2.2	3.00
Na_2O	0.41	0.60	0.26	3.52	4.54	1.0	0.3	1.72
K_2O	3.16	3.10	1.81	3.60	0.54	3.0	4.3	1.90
H_2O +	0.81	3.77	1.25	3.46	2.69	1.7	-	-
H_2O -		1.19	0.55	0.84				
P_2O_5	0.31	0.18	0.20	0.16	0.12	-	-	-
CO_2	-	1.65	-	0.03	-	9.24	-	-
S	7.29	3.20	-	0.04	tr.	2.31	2.8	-
C	13.11	9.20	7.28	3.27	-	9.06	4.6	7.88
FeS_2	-	-	38.70	-	-	-	-	-
V_2O_5	-	-	0.15	-	-	-	-	-
Total	99.58	99.52	96.992	100.07	99.45	91.01	83.72	87.09

A-F Pettijohn 1957 (P.362) Permian, Devonian and Precambrian black shales

G Manheim, F. T. 1961 - Black Sea sapropelic sediment

H Average values for 24 analyses of graphitic rocks from the Rouyn-Val d'Or area

Oparin (1957) discussed in detail the possible evolution of abiogenic organic compounds through to the evolution of biogenic organic compounds. In essence, Oparin postulates that carbon is present in the earth's core, as elemental carbon, and as the carbides of iron and nickel. The carbides of iron and nickel, when brought into contact with water, produce methane and hydrocarbons (this may be observed today). Electrical discharges and ultraviolet radiation energize inter-reactions between methane and the hydrocarbons, which produce a multitude of organic compounds, such as alcohols, aldehydes, and alkanes, as well as liberating hydrogen and oxygen. The oxygen so produced served to convert an originally postulated reducing atmosphere to an oxidizing atmosphere. This atmospheric change would require two to three billion years. It may be that a number of the inorganically produced hydrocarbons may have been preserved as part of the normal sedimentary sequence.

Oparin further suggests that, prior to the formation of an oxidizing environment, about two to three billion years after the formation of the earth, anaerobic life forms may have already envolved, and he points to modern day anaerobic algae. These anaerobic life forms would have lived on exogenous organic substances (Ivanhoe, 1966). The accumulation of these early life forms may have been an original source of carbon in the shales.

The discussion presented above would suggest that carbon, as found in the Archaean graphitic occurrences, may have been originally either organic or inorganic in origin. Limited studies of the carbon forms in two areas, South Africa and Ontario, have indicated that rocks, dated at three and two billion years old respectively (Havering, 1965 and Barghoorn and Schopf, 1966), contain organic carbon.

A possible approach to further exploration of the presumed presence of organic life in the Archaean would be to determine whether the sulphur in the commonly associated sulphides has been biogenically fractionated (i.e. whether the S^{32} isotope has been enriched over the S^{34} isotope).

CHAPTER VII

SUMMARY AND CONCLUSIONS

Electromagnetic geophysical prospecting has over the last 20 years revealed the presence of immense volumes of graphitic material, which are intercalated with the volcanic rocks of the greenstone belts of the Canadian Precambrian Shield. These graphitic rocks were largely unsuspected prior to this geophysical development; they were largely unsuspected because of the widespread glacial debris cover, and because of the ease with which such rocks are eroded. During the early 1950's, electrical geophysical prospecting devices detected large numbers of electrical conductors, which, in these early years, were thought by many to be caused by sulphide bodies. Subsequent drilling determined that the majority of the conductors were caused by graphite. A tendency resulted to "write off" the occurrence of a conductor which appeared to be of relatively great linear extent as being due simply to graphite-bearing units. The discovery of Kidd Creek ore deposit by the Texas Gulf Sulphur Company, about 1964, caused the mining industry to re-evaluate their ideas about the association of graphitic units with massive sulphide ore deposits. The Kidd Creek deposit has a graphitic unit passing through the massive sulphides.

The Rouyn-Val d'Or area was chosen for study for the following reasons:

1) The abundance and availability of information;

2) The excellent accessibility prevailing throughout the area;

3) This is an economically important mining district, and the data compiled might have immediate interest and use to the mining community in this area.

This thesis has been undertaken in the nature of a pilot study in order to determine the following:

1) Whether a compilation of available electromagnetic data, in conjunction with available information on the graphitic occurrences, would aid in the structural interpretation of this area, (and hence in other greenstone belts), as well as to provide the mining industry with a compilation of the available information on the area;

2) To determine the character of some of the graphitic-bearing rocks in the area;

3) To determine whether graphitic rocks, which are intimately associated with ore deposits, showed significantly different geochemical characteristics from those of graphitic rocks which do not have an ore association. And, to determine if these differences could provide a relatively inexpensive tool for eliminating unfavourable graphitic units.

The compilation of available electromagnetically-indicated conductors, and of graphitic occurrences has outlined nine graphite-rich belts, which may be inter-related, and which, in the case of the Desmeloises-Barraute-Haig belt, indicates a definite structure--that of an isoclinally folded, doubly plunging anticline. The information on which some of the belts are postulated is meagre, but it is considered that the compilation proves that this information is a viable tool in the structural interpretation of an area in which the graphitic units occur. Furthermore, the compilation of this data should provide the mining industry with a useful record of work done.

The graphitic units, which are extended and correlated by the geophysical work, define broad-scale marker zones. The prevalent occurrence of graphite units at specific horizons is considered to represent widespread carbonaceous sedimentation over specific intervals of time. Age-dating of lead occurrences within these units may confirm this opinion.

Thin section, polished section, and geochemical studies of a limited number of occurrences suggest that the pyrite-bearing, graphitic rocks are of sedimentary origin, and that the graphite is an original constituent of these rocks. The sampled occurrences are considered to be the Archaean analogues of modern-day sapropelic black muds, and are metamorphosed carbonaceous shales and siltstones. The textures and structures within the rocks studied, suggests that they have undergone both soft rock deformation, and tectonic deformation. The graphitic rocks are relatively incompetent, and have deformed by flexural slip. The tectonic forces have been transmitted through the rocks by movement or slip along the graphitic laminae, and, as such, the constituent minerals (e.g. the quartz), show little evidence of deformational stresses. The evidence would appear in the form of recrystallized quartz grains and in quartz grains showing little undulatory extinction, which have not been recognized.

The graphitic rocks show variable amounts of pyrite, which may generally be related to the graphite content. The pyrite contains trace amounts of sphalerite, chalcopyrite, and pyrrhotite. These sulphides are considered to be of syngenetic origin, and are in amounts compatible with the postulated sedimentary origin.

The overall geochemistry of the analyzed graphitic occurrences is compatible with the chemistry of carbonaceous shales and siltstones found throughout the stratigraphic column, and agrees generally with the chemistry of modern-day sapropelic accumulations. The majority of the trace elements occur in amounts which are within the computed averages for carbonaceous shale units. Three graphitic occurrences, intimately associated with ore deposits from other regions, were sampled for the purposes of determining whether they showed any significant chemical differences relative to the graphitic occurrences from the Rouyn-Val d'Or area, which are not ore-associated. The most significant difference noted lay in the lead to zinc ratio, in which the graphitic occurrences from the Cuprus, Caribou and Kidd Creek deposits showed anomalously high zinc to lead ratios. The copper to nickel ratio of the outside graphitic occurrences are inconclusively anomalous, relative to the copper to nickel ratios within the study area, and warrant further study before any conclusions are drawn.

RECOMMENDATIONS

On the basis of the work performed, and of the results which have been achieved, it is recommended that:

1) The compilation of geophysical data, and graphitic occurrences, should be continued. This would serve to either substantiate or refute the interpreted structures. A compilation of this data on a scale 1" = 1 mile geological maps would greatly aid in the interpretation of small-scale structures (e.g. drag folds and faulted sections, etc.);

2) The compilation of accurately located sulphide masses should be instigated and correlated with the present compilation;

3) Detailed structural studies of the graphitic occurrences should be initiated, in view of the fact that they appear to best reflect deformation, and so may provide a more accurate interpretation of the tectonic history of the area;

4) Sulphur, carbon, and lead isotope studies should be conducted in order to more accurately confirm the sedimentary origin of the sulphides, the probable organic origin of the graphitic material, and to correlate the separate postulated belts, which might conceivably delimit a specific time datum;

5) The anomalous zinc to lead ratios observed in the sampled graphitic occurrences associated with the named ore deposits, warrant a detailed investigation, which should attempt to delimit the extent to which the zinc in the graphitic units may be expected to be anomalous on strike from a deposit.

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APPENDIX I

SOURCE OF GEOLOGICAL AND GEOPHYSICAL DATA

This appendix lists only the data that may be reviewed by the public at the offices of the Resident Geologists in Rouyn and Bourlamaque (Val d'Or), as well as The Department of Natural Resources in Quebec City.

The following sources are listed under the name of the filing company, the twp. under which the data is filed, and by the GM number assigned by the Mining Recorder to the particular file. (GM=Minerals Deposit Brch.) The company names are not completed for the sake of convenience, i.e., Mines Limited, etc.

COMPANY	GM NUMBER	TOWNSHIP
Dobieco Mines	17595	Aiguebelle
Bargold	16677	Barraute
East Sullivan	3633C	
East Sullivan	10550D	
Hollinger Quebec Expl.	12012	
Quebec Divers. Mining	1817	
St. Pierre, P.E., Property	4569A	
St. Pierre, P.E., Property	4569B	Barraute
Allied-Pitch-Ore Mines	15968	Beauchastel
Horne Fault	4858	
Wm. Leys Mining	7768C	
Mespie M.L.	4666	
Mespie M.L.	4553	
Newrich Expl.	16824	Beauchastel
Hudson Bay Mng.	11417A	Bernetz
Serem Ltee	21905	Berry
Berube J.P.	12650	Bourlamaque
Kerr-Addison	13604	Bousquet
Mooshla Mines	13731	
Norlex	13310	Bousquet

COMPANY	GM NUMBER	TOWNSHIP
Delta Mining	12948	Cadillac
Delta Mining	13521	
Fortier-Chartier	14756	
M. Millenbach Claims	15867	
Rio O'Brien Syndicate	11884	Cadillac
Boylen M.J.	16546	Carpentier
Glacier Explorers	15874	
Lenmac	15490	
Mokta	16483	
Rio Tinto	11122	Carpentier
Aube Option	3748C	Chazel
Kerr-Addison	6486A	
Mining Corp.	3854B	
Oditan Mines	5819B	Chazel
Area M.L.	13960	Clermont
Camflo-Mattagami	9180	
Cominco	12567	
Desmont Mining	4184	
Noranda Mines	13727	
Vicour M.L.	3759A	
Ebor Uranium	4117B	Clermont
Alba Expl.	4640	Clericy
Cleranda Copper	4550B	
Cleranda Copper	14796	
Dobieco	17595	
Gaitwin	3971A	
Kontiki Lead-Zinc	4724A	
Lexindin	4375	
Mallen Red Lake	3842A	
Maralgo	4480A	
Martin H.E.	3704A	
Mespi M.L.	4623	
New Delhi	4229A	
New Kirk	3704B	
Paul Liane Expl.	4925	
Rio Canadian Expl.	3734A	
	3828	
	4355	
	4356	
	4548	
	4583B	
	3734B	
Rio Canadian Expl.	3903E	
Tiara	5120	
Tiara	5186	Clericy

COMPANY	GM NUMBER	TOWNSHIP
Berthiaume	4869A	Courville
Berthiaume	7384	
Big Town Copper	6581	
	6700	
	15694	
Big Town Copper	15948	
Eastville Gold	7248	
Eastville Gold	7573	
Marriette	2277A	
	16618	
Marriette	16828	Courville
Coral Mining	4479A	Dalquier
Barry Expl.	4809	Dasserat
Bordulac	5555	
Gui-Por Uranium	12620	
Payrock	3946	Dasserat
Area M.L.	13961	Desmeloises
Buffalo Canadian	4664	
Central Mining	4785	
Cyprus Expl.	3460G	
Cyprus Expl.	3460A	
Dominion Asbestos	4343	
Dominion Asbestos	4724	
Dominion Gulf	968B	
Dominion Gulf	2047B	
Dupuy M.L.	6200	
Fleetwood-Yellowknife	3852	
Noranda Mines	13727	
Premier Border Gold	4620	
Rio Canadian Expl.	3576B	
Stratmat	4582C	
Tiara	4281	
Tiara	4434	
Tiblemont Goldfields	4228	Desmeloises
Beattie-Duquesne	4071A	Destor
Conwest	4062	
Mining Corp.	15786	
Paramaque	13423	
Rio Canadian Expl.	4556A	
Roy, G.C. Claims	3824	
Uddlen M.L.	4468	Destor
American Expl. & Chem. Corp.	3622C	Disson
Gulf Lead Mines	15549	Dollard
Gulf Lead Mines	18717	Dollard

COMPANY	GM NUMBER	TOWNSHIP
Lancer Petroleum	16182	Dubuisson
New Jersey Zinc	2957	
North Sullivan Contact	11939	Dubuisson
Valray Expl.	7923	Ducros
Area M.L.	13963	Duparquet
Bagamac	4154	
Cyprus Expl.	3460B	
Cyprus Expl.	3460C	
Lang, B.W.	10407	
Lang, B.W.	10874	Duparquet
Mespi M.L.	4931A	Duprat
New Campbell	11025	
New Vinray	4457	
Nickel Offsets	10036	
Norque	12748	
St. Jude GML	4392	
St. Jude GML	5304	
Silanco Mining	4463	
Southwest Potash	9998	
Southwest Potash	10560B	
Sunburst Expl.	10829	Duprat
American M&M	13874	Duverny
Bonwitha	11060	
Dumar Gold	6351	
Southvue	5436	Duverny
Alsab Mines	6087	Fiedmont
Malartic GFL	3874A	
Rio Tinto Canadian	11123	
Span North Mining	13582	Fiedmont
Amos Syndicate	14606	Figuery
	14659	
Amos Syndicate	14675	
Kidd Mining	16262	
North American Rare Metals	14509	
Radiore Uranium	13128	
Radiore Uranium	13129	Figuery
Centurion Mines	9235	Guyenne
Centurion Mines	10151A	
Mining Corp.	10818	Guyenne
Hudson Bay	11022	Haig
Rio Tinto Canadian Expl.	11136	Haig

COMPANY	GM NUMBER	TOWNSHIP
Area M.L.	10139	Hebecourt
Area M.L.	10140A	
Cyprus Expl.	3460D	
Royce, A.C. Claims	12945	Hebecourt
Beaucoeur	4637	Joannes
Cleranda Copper	14796	
Desmont M.L.	4638	
Malartic GFL	4693	
Northcal	5628	Joannes
Hudson Bay	11418B	Laas
	11418C	
Hudson Bay	11418D	Laas
Malartic GFL	4331A	Lamorandiere
Rouleau, E.	17352	
Terra Nova Expl.	13880	Lamorandiere
Aqua Mining	11893	Lamotte
Ascot Metals	3959C	
Consol. Negus	5773	
Delta Mining	16086	
Glenmar Lithium	3690B	
Marbridge	16366	Lamotte
Amos Syndicate	14606	Landrienne
Bonwitha	11060	
Kidd Mining	16262	
Malartic GFL	4838	
New Vinray	3865	Landrienne
Baycourse	6548	La Pause
Mespi ML	4623	
Rusty Lake Mining	17247	La Pause
Dominion Asbestos	4642	La Reine
New Thurbois Mines	4587A	
New Thurbois Mines	4587B	
Norcopper & Metals	4560A	La Reine
Barnat	10913	La Sarre
Dominion Gulf	1939	
McGregor, J.G. Claims	3832A	La Sarre
Centurion	10142A	Launay
Rio Canadian Expl.	6257	Ligneris

COMPANY	GM NUMBER	TOWNSHIP
Area Mining	12937	Malartic
Black River	13191	
Clinger Gold	17251	
Kaiser Mines	17562	Malartic
Mespi ML	4585	Montbray
Noranda Expl.	17200	
Osisko Lake	4567	
Southwest Potash	10831	Montbray
Cannon Mines	17618	Montgay
Cry-Vallier	12442	Montgay
Noranda Mines	5681	Palmarolle
Soquem	20154	Palmarolle
Dome Expl.	13193	Pascalis
Terra Nova	12918	
Utopia	13599	
West Malartic	4238B	Pascalis
East Sullivan	1458	Pershing
Villemaque Expl.	10258	Pershing
Destor ML	7135	Poularies
Noranda Mines	5681	
Southern Union	5215B	Poularies
Canalynda Copper	4432	Privat
Macamic	1400	Royal-Roussillon
Soquem	20156	Royal-Roussillon
Berthiaume	4969	Senneterre
Consol. Mogul	11143	
Doug. Mackay	7777	
Jubillee Iron	15403	
Jubillee Iron	17100	
Kennco	8691A	Senneterre
Airemaque Expl.	11104	Senneville
Alsab	6087	
Kateri Mining	11023A	
Kateri Mining	11023B	
Rio Tinto Canadian	11123	
Sullivan	12475B	Senneville
Rio Tinto	11369	Tavernier
Rio Tinto	11136	Tavernier

COMPANY	GM NUMBER	TOWNSHIP
Belleterre Quebec	15655	Tiblemont
Janlee Expl.	13212	
Lang, B.W.	14607	
Terra Nova	12918	Tiblemont
Cambridge Mining	13304	Tonnancourt
Quebelle Mining	9340	Tonnancourt
Centurion	10148A	Trecession
	10144A	
	10146	
Centurion	10143A	
Diadem	3887	
Parkdale	19254	Trecession
Rio Tinto Canadian	11123	Vassal
Aqua Mining	12936	Vassan
Bellechase Mining Corp.	19365	
Clinger Gold	17536	
Sanchenko	12947	Vassan
Acme Gas and Oil	16432	Vauquelin
Black River ML	16835	
Camdeck GML	15853	
Chimo Gold	9102	
Lang, B.W.	14607	
Monor Mining	16375	
Noranda Expl.	12984	
Porcupine Prime	4209	Vauquelin
Amos Syndicate	14606	Villemontel
Centurion	9235	
	10149	
Centurion	10141A	Villemontel

APPENDIX 2

GEOLOGY OF THE SAMPLED OCCURRENCES

Thirty-three samples of graphitic rocks were taken, for the various purposes of chemical analyses, megascopic and microscopic studies. Five of these, taken as part of a section, were considered to be crystal tuffs. Subsequent thin section study determined them to be silicified andesites. They are not further considered. Thus, 22 thin sections and 11 polished sections of the graphitic and pyritic rocks were studied. The rocks are discussed under the following headings: megascopic, microscopic thin section, and polished section.

Megascopic Description

The graphitic rocks are subdivided into five distinct categories. These are:

1) A massive, frequently structureless variety, barren of sulphides;

2) A massive variety, essentially as above, but showing variable amounts of pyritic mineralization;

3) A very well layered, poorly graphitic, essentially pyrite-free variety;

4) A well layered, graphitic variety;

5) A sulphide rich, graphitic variety.

The aforementioned pyritic graphitic rocks are similar in occurrence to those termed "Black Schists" by Marmo (1960); or to the "Fahlbands" as described by Gammon (1966).

The graphitic sections of the various rocks are characteristically extremely fine-grained, and vary in colour from cream to light grey, and from light grey through to dark black. They are commonly soft and friable, but may, with a high SiO_2 content, be almost chert like. The graphitic content, in this case, is then only identifiable by the dark colour imparted by this mineral, or by the occasional formation of graphitic slips, which may, in some instances, cross-cut the foliation. The less graphitic, to graphite-free, interbeds are typically coarse-grained. Individual mineral identification is still difficult in these coarser interbeds. Occasionally, a definite suggestion of graded bedding exists, from fine to coarser layers. The layering is varve-like, with the coarser, lighter coloured units being thicker than the finer, graphitic, dark layers. Graphitic layers may vary in thickness from paper thin through to a few feet. Typically, in a "varved" sequence, the graphitic layers are paper thin (less than 0.005 mm. to one to two mm.), and the coarser layers range from less than one mm. to three to four cm.

The richer graphitic sections frequently contain pyritic mineralization in the form of massive beds one to three inches thick, as "nodules" (sub-spherical to ellipsoidal masses, composed predominantly of pyrite) as very fine dust-like aggregates, and as disseminations of pyrite contained within the foliation. The finer beds and disseminations of pyrite, in hand specimen, appear to lie within the coarser, less graphitic, laminae.

The rocks show all gradations of tectonic deformation, as well as non-tectonic deformation (i.e. soft rock deformation). The deformation described as "soft rock" occurs within thin layers, generally one to three inches thick. This type of deformation is in part substantiated by particular layers showing microbrecciation. The microbrecciated layers show a distinct, graded bedding distinguishing this aspect of soft rock deformation from the brecciation of the pyrite, which is attributed to tectonic deformation. Schistosity is well developed, and this may, in turn, show evidence of further deformation in the form of microcrenulations. The more competent pyrite-quartz layers frequently show pinch and swell structures. These layers may further be so extended as to form individual lenses, which may be thrust over one another, or may be folded on themselves. The pyrite "nodules" frequently have pressure shadows, where quartz has migrated into opening spaces formed as a result of the rotation, or formation, of these masses. Possibly the nodules are, in part, formed by complete infolding of a lens on itself. These nodules lie with their long axis either in the plane of the foliation or at approximately 45° to the foliation (substitutes for tension cracks?). Beds of what were originally massive sulphides have been stretched out, fractured and brecciated, with quartz migrating in and filling the resultant spaces. In some instances, if the quartz were removed, it would be possible to fit the pyrite fragments together perfectly. The graphitic and siliceous folia (Plate 20) about these distorted pyrite beds reproduce the resultant structures faithfully, showing evidence of plastic deformation. In most instances, at approximately one to two inches above and below such a distorted bed, the foliation is undisturbed. Microfaulting is commonplace. The graphitic layers are frequently slicken-sided within the schistosity. The evidence for deformation, as described above, is particularly evident in specimens E-6 to E-20. These rocks, representing a continuous section of drill core from Desboues Twp. have been intruded by andesite sills. Elsewhere, the graphitic rocks show remarkable little evidence of deformation, other than those which have been suggested as being due to soft rock deformation.

The remaining sampled occurrences show typical "varved" laminae. Where deformation is apparent in these, it has been localized within the graphitic layers, and is expressed, only midly, by microfaulting within the more siliceous folia. This would suggest the relative incompetence of the graphitic layers versus that of the siliceous layers. In the richer graphitic portions, barren of sulphide, the intense deformation which these units may have undergone, is noted only by an extremely frequent occurrence of quartz, plus minor carbonate-filled hairline fractures which impart a brecciated appearance to the rock (e.g. sample E-11, taken in Desboues Twp.)

Mineralogically, little can be identified other than graphite, quartz, pyrite and sericite. Pyrrhotite, and chalcopyrite, (Samples E-2, 27, and 30) occur sporadically and in trace amounts. Sample E-32 contained moderate amounts of pyrrhotite in hand-specimen, but this was not substantiated in polished section. Sample E-1, taken in Surimau Twp., showed tremolite laths, porphyroblasts, formed, in part, within a pyrite nodule. The pressence of the tremolite, reflects the higher metamorphic grade of the Pontiac Sedimentary rocks. Carbonate occurs only in trace amounts and is detected by the weak effervesence of hydrochloric acid. Sericite porphyroblasts were identified in Sample E-26, intergrown with graphite.

Pyrite occurs in four distinct manners:

1) As massive, and frequently brecciated and fractured, layers, ¼" to 3" thick, about which abundant quartz has migrated;

2) As isolated nodules--subspherical to ellipsoidal masses--of pyrite ranging in dimension from 1/16 to 2", typically 1/8 to 1/4". These isolated masses may or may not align in an original horizon. Commonly, these are weakly fractured, and appear to be inclusion filled--in part with graphite. Not infrequently, they show very fine rims of bright yellow recrystallized pyrite, which in a few instances show protruding crystal faces. The nodules

are generally irregular in detail, showing a finely scalloped effect, locally disrupted by a protruding crystal outline (two to three sided) and are commonly a dull brass colour. One sample, E-11, shows a well-developed concentric structure, with the inner core separated from the outer rim by a thin film of carbonaceous matter. The nodules characteristically show pressure shadows of quartz ± carbonate ± sericite, which are appended to one or both ends of the ellipsoids. The quartz may occasionally surround the nodule, but is filmlike about the short axis. The quartz is not invariably present. Typically, the foliation undulates about these masses and in only one instance was the foliation observed to terminate against the nodule. Folia of graphite and quartz may be folded about these spheres (Plate 1);

3) The massive sulphide described here is separated from the above (1) massive variety on the basis of extent and on deformational characteristics. Sample E-32, taken in Fiedmont Twp., was taken to define this variety of sulphide occurrence. The unit from which E-32 is taken is 20 feet thick; the sample shows 60 to 70 per cent strongly sheared and brecciated pyrite, and lesser amounts of pyrrhotite. The sulphide has been fractured, and brecciated, and subsequently stretched or "smeared" in the foliation. Quartz has, in part, been strongly mobilized and recrystallized about the pyrite, frequently as well-defined pressure shadows. In part, the quartz has simply recrystallized as subrounded masses. Locally, within the sheared pyrite, individual nodules showing diameters to ¼" occur. These may occasionally be almost saucer-shaped;

4) A fourth common occurrence of pyrite is defined as the fine-grained disseminated variety. Typically, the pyrite grains range in size from microscopic to isolated subhedral cubes, 1 mm. square. This pyrite characteristi-

cally occurs in the foliation, or bedding plane, and may be concentrated to such an extent that it forms a rather dull brass-brown tint, which is rather diffuse within the foliation. This variety of pyrite, in combination with the thinner lamina of type (1), typically occurs in the apparently graphite-poor layers, whereas the rest of the occurrences (types 2 and 3), are more commonly associated with the graphite-rich layers.

The forms of the pyrite described above may occur in any combination with each other. The extensive massive (4) variety is distinguished solely on the basis that the pyrite here acts as a coherent rock unit, as opposed to type (2), which acts as a competent unit within the incompetent graphitic layer.

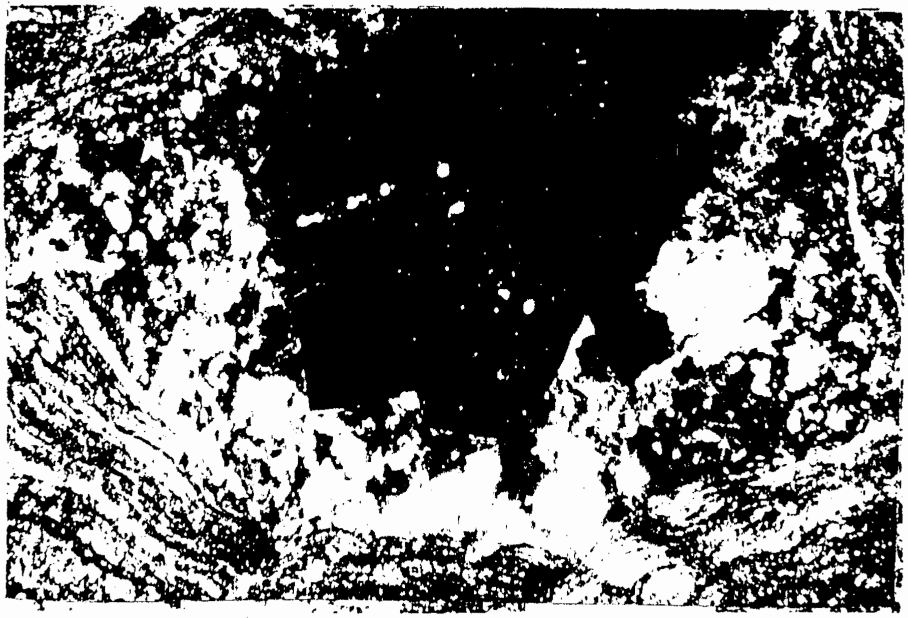
The megascopically visible pyrite content in these rocks is variable, ranging from two to three per cent to 65 or 70 per cent.

Occasionally, cross-cutting quartz-filled fractures may show minor amounts of mobilized pyrite; the amount and occurrence of this pyrite is insignificant.

Thin Section Studies

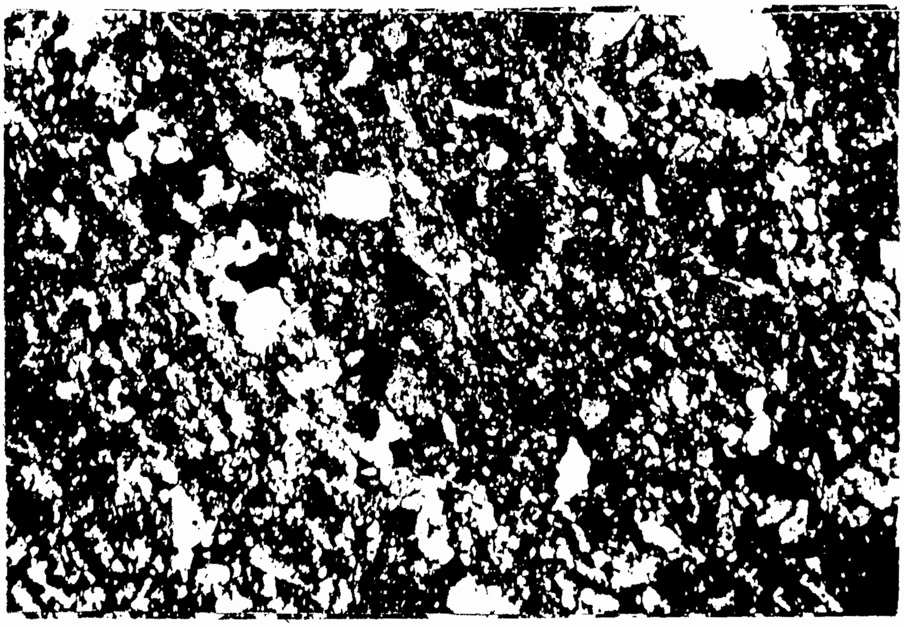
Quartz, sericite, graphite and pyrite are the most commonly occurring minerals, with trace amounts to five per cent of sphene, chlorite, calcite, epidote, magnetite-hematite, microcline and potash feldspar. Plagioclase was occasionally identified as rare clastic grains. Albite is believed to be weakly, but prevelantly, present, both on the basis of limited X-ray analysis and on the basis of the geochemistry of the rocks. Albite was not optically identified in the rocks of the main study area. Albite was identified, optically, along with minor amounts of biotite and tremolite, in samples taken in Surimau Twp. (E-1 and E-2).

Plate 1



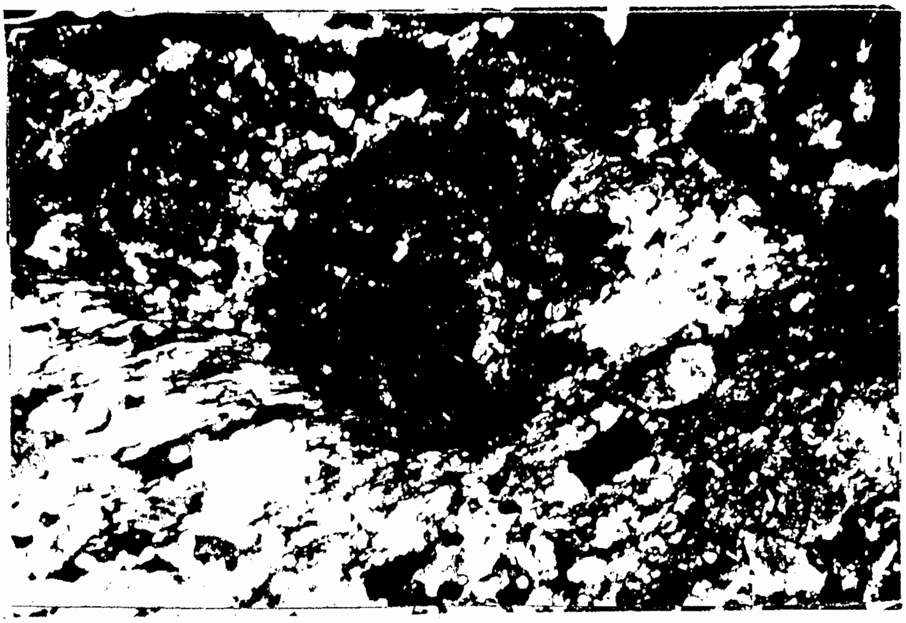
Photomicrograph. x33 - Graphitic (dark) and quartz-sericitic (light) crenulated laminae, undulating about a partially recrystallized "spongy" pyrite nodule. (dark mass) (crossed nicols)

Plate 2



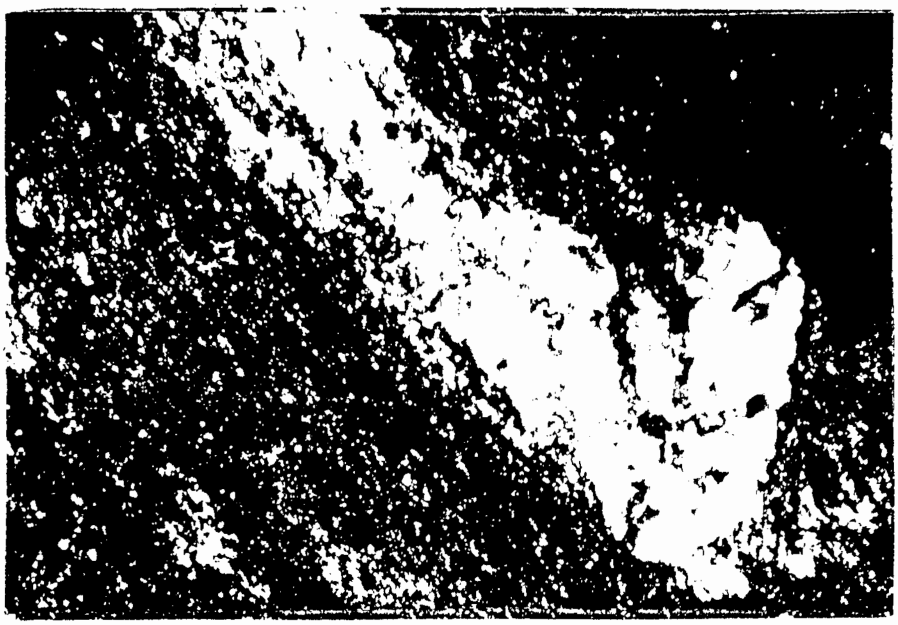
Photomicrograph. x132 - Clastic quartz (white) grains in a fine quartz and sericite porphyroblastic matrix. Note recrystallized quartz lens at the right-paralleling the foliation. (crossed nicols)

Plate 3



Photomicrograph. x53. Lens of pyrite (centre) which has been rotated into a "nodule". Note wedge shaped quartz-filled pressure shadow to the right; and bent, strained lamellae of quartz to the left of the nodule. (crossed nicols)

Plate 4



Photomicrograph. x33. Recrystallized quartz lens in the process of being rotated. The quartz lens is lying in a graphite rich bed; the foliation of which is shown by the aligned cryptocrystalline quartz grains. (crossed nicols)

Quartz

The quartz content is variable, and quartz is typically the most abundant single constituent. Quartz occurs as clastic grains, from 0.3 mm. down to the crptocrystalline, and almost amorphous. The larger grains are typically rounded to sub-rounded, and may, in some instances, show minor recrystallization (i.e. Polygonization (Plate 2). The grains are characteristically elongate within the foliation, which can be seen in the cryptocrystalline grains within the graphitic layers (Plate 4). Most commonly, the quartz is coarser, where little graphite is associated, and decreases in grain size as the graphite content rises (Plate 6). This is interpreted to represent a combination of graded bedding and metamorphic increase in grain size extending away from graphitic layers (i.e. the graphite is interpreted as inhibiting grain growth). This has also been postulated by Peltola (1960) for the graphitic schists of Finland. The quartz grains show little evidence for deformation (i.e. undulatory extinction is not a common feature). Typically, the quartz in the coarser grained layers is associated with lepidoblastic sericite. Graphitic seams and lenses may occasionally be associated with these coarser quartzitic-sericitic layers. The coarser quartzitic layers, under the microscope, may vary in width from a thickness of one to two grains (0.06 mm.) to layers several millimeters across (Plate 2).

A second variety of quartz is frequently noted in the graphitic rocks--a mobilized, recrystallized form, which has migrated into apparent low pressure zones during deformation. This is typically found as fracture fillings, or as "pressure shadows." These "pressure shadows" are often wedge shaped (Plate 3), and filled with quartz, which is commonly lamellar and possibly granoblastic. Undulatory extinction is the rule. Generally, the quartz is fine-grained granoblastic at the perimeter of the wedge and becomes increasingly coarser and lamellar towards the centre, or towards the pyrite which it frequently partially surrounds. The recrystallized grains vary in size from .01 mm. to 0.2 mm. (see Plate 3). The lamellae commonly subtend the quartz-pyrite interface at an angle of 90^o. In some instances, the lamellae are "kinked," no doubt a reflection of continued rotation while they are being formed.

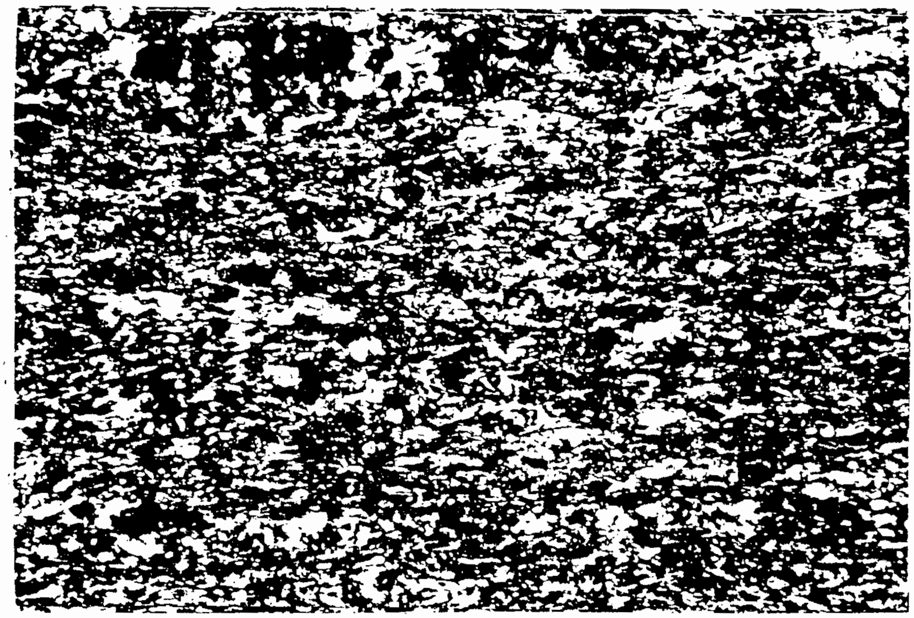
Occasional quartz lenses outline the foliation in the cryptocrystalline laminae; the quartz grains are recrystallized (Plate 4).

Occasionally, a quartz lens is folded on itself, the end result possibly being a quartzitic nodule (Plate 4). Williams, Turner and Gilbert (1954) have interpreted the lenses of coarser grained quartz, within the shale units, to be the result of weak currents. Within the cryptocrystalline graphitic ground mass in some of the layers, an occasional clastic quartz grain occurs.

Sericite

The sericite content is variable, typically being present in amounts ranging from two to three per cent through to 20 per cent (visual estimate). The variation in the sericite is reflected in the wide range shown by the Al_2O_3--2.17 per cent to 16.13 per cent. Sericite is present primarily as lepidoblastic flakes and sheathes, interstitial to the quartz grains. This form of sericite probably is the result of both diagenic and synkinematic processes. These flakes are quite variable in size--.5 mm. to almost submicroscopic aggregates. Occasionally, a moderate amount of sericite occurs as typically post-kinematic porphyroblasts. Sericitic alteration of feldspar is attested to by the formation of minute sericite flakes on feldspar grains. The sericite is best developed in the coarser, quartzitic layers (Plate 5), and to a lesser extent, in the graphitic layers, appearing as

Plate 5



Photomicrograph. x132. Sericitic graphite rich folia; (Sericite-bright laths) Occasional sericitic porphyroblasts transect the foliation. (graphite and pyrite are black) (crossed nicols)

Plate 6

Photomicrograph. x33. Felted quartz-sericite-graphite laminae overlying graphite rich bed (bottom). The graphite (black) occurs as streaks anastomosing about the quartz (grey-white) grains; and as occasional interstitial clots and lenses. (crossed nicols) splotchy, felted aggregates. Minor, relatively coarse sericite is also observed to occur associated with the mobilized quartz, and grows adjacent to the quartz lamellae.

Thus, two types of sericite are observed, a synkinematic variety, which is probably in part diagenetic, and a post-kinematic variety.

Graphite

Optical and X-ray tests on the carbon present in the described rocks have shown that this mineral is not the mineral graphite. However, because of the widespread usage of the term (i.e. graphite), it is retained. It is probable that this carbon is a lower order crystallographic form than that of graphite. Marmo (1953) has termed such an occurrence of carbon as "schungite."

The graphite content is variable and, in the rocks described as graphitic, occurs in amounts from slightly less than one per cent to 17.6 per cent (as determined by geochemical analysis).

Microscopically, the graphite occurs in three distinct forms:

1) As folia, seams and lenses, which anastomose, and may show compaction effects about quartz grains in the coarser quartz sericite laminae (Plate 6);

2) Irregularly outlined clots (Plate 6);

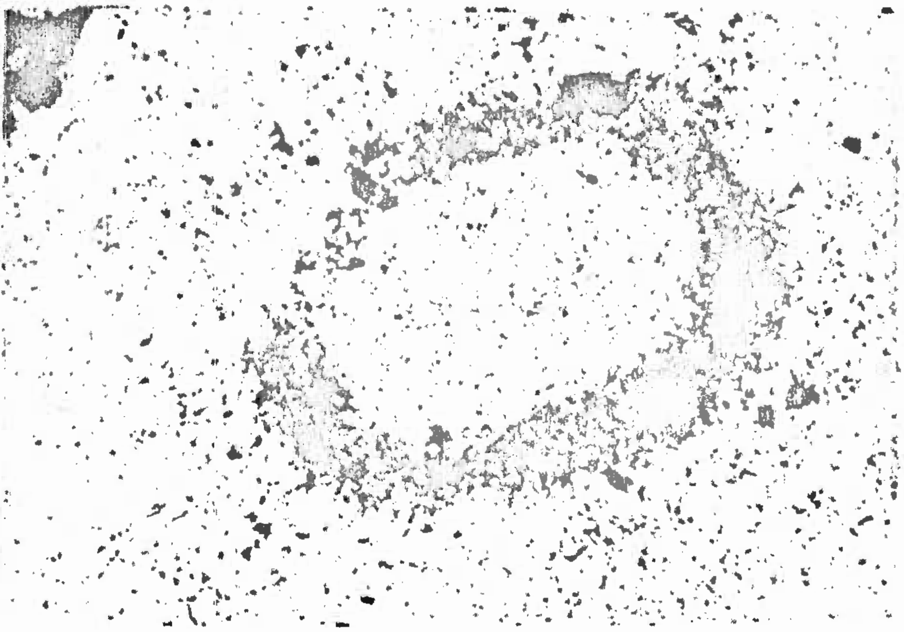
3) As almost submicroscopic dots, occurring particularly within cryptocrystalline layers (Plate 7).

In transmitted light, the graphite is opaque, or the edges may be slightly translucent appearing as a very dark brown rim. In reflected light, the graphite is dark grey to black, and is isotropic.

Plate 7

Photomicrograph. X53- Inclusion filled pyrite grain (white), showing a recrystallized rim. Inclusions may outline original spherules. Dark black specks and clots are graphite. Note "expelled" (?) graphite at the crystal faces.

Plate 8



Photomicrograph. x53- The core of a pyrite nodule as outlined by the elliptical ring of inclusions.

Pyrite

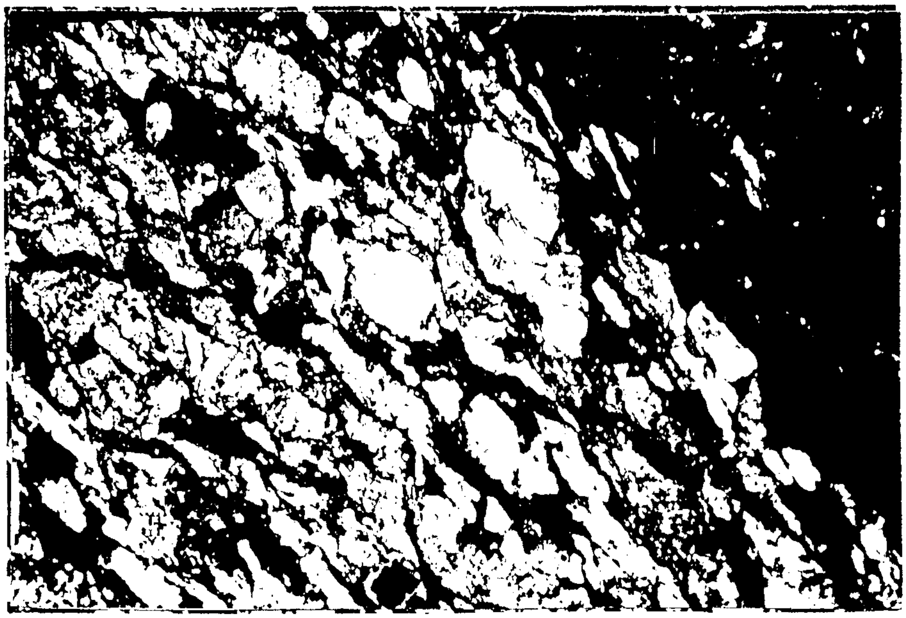
The pyrite content is variable and, in a general sense, varies with the graphite content, suggesting an inter-relationship. Peltola (1960) has demonstrated a direct relationship in the graphitic units of Finland. The microscopically visible pyrite ranges in content from two to three per cent to 65 per cent. The relationship of the pyrite to the graphite is further discussed in Chapter IV. The pyrite and other sulphides are discussed in detail under the polished section description.

In general, the pyrite is inclusion rich, the inclusions consisting predominantly of quartz, lesser sericite, carbonates and graphite. In thin sections, it is frequently difficult to distinguish fine pyrite from the graphite, while in polished sections, it is equally difficult to distinguish the salic minerals from the graphite. The recrystallized pyrite is expressed by relatively inclusion-free masses, rims, and partially developed cubes about the nodules.Occasionally, it is possible to identify graphite as small aggregates rimming the pyrite, which are tentatively suggested as having been expelled by the recrystallized pyrite (Plate 7). In a few rare instances, quartz and graphite encircle an inner core of pyrite, and which, in turn, are rimmed by a greater thickness of pyrite (Plate 8). These core-defining inclusions are typically irregular in width, and, in the instance noted, the width is 0.2 mm. Plate 3 shows a nodule (?) of poikiloblastic (?) pyrite with inclusions of quartz and sericite. This is believed to be caused by the rotation of a small lens of pyrite. Commonly, the pyrite is strongly fractured and shows lamellar quartz recrystallising between the fragments.

Chlorite

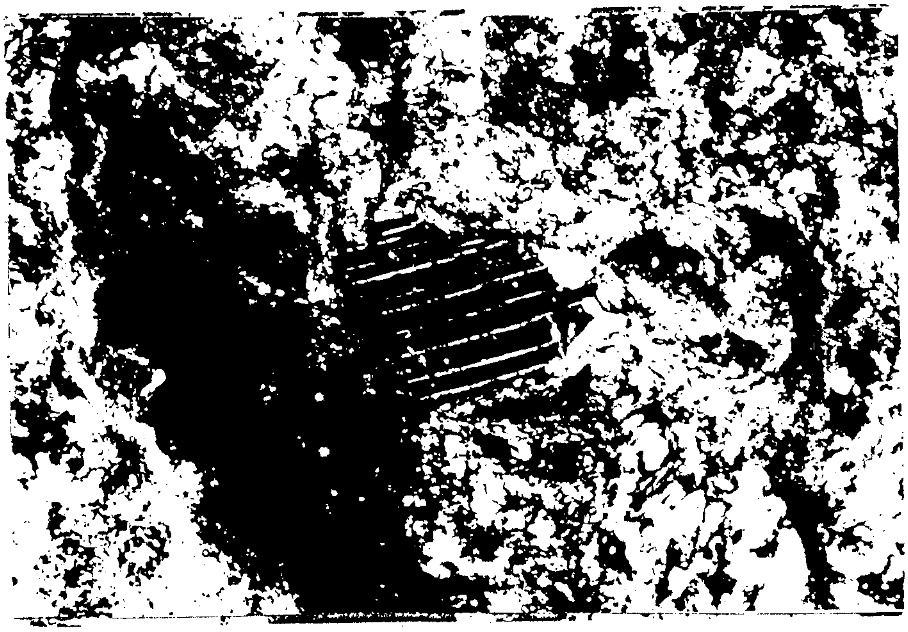
Chlorite is poorly developed throughout the samples; the relative paucity

Plate 9



Photomicrograph. x33 - Sericite altered feldspathic microbreccia; the fragments lie in a graphitic matrix. Note the coarse rounded quartz grains (bright). There is a suggestion of graded bedding upwards (right) in the microbreccia. (crossed nicols)

Plate 10



Photomicrograph. x133 - Clastic grain of plagioclase (showing albite twinning) lying within a felted quartz-sericite matrix. (crossed nicols) is reflected by the low MgO values obtained by geochemical analyses. Visual estimates are not given, the chlorite being typically difficult to identify. Where identified, the chlorite is intergrown with the sericite; it occurs primarily as lepidoblastic flakes and only to a minor extent does it occur as porphyroblasts growing across the foliation. In a few instances, the chlorite, showing very low order interference colours, showed undulose extinction. X-ray analysis confirmed the relative scarcity of chlorite.

Sphene-Epidote

These minerals were identified in amounts less than two per cent; these are noted as isolated grains, typically showing a rounded "insect's egg cluster" shape. The relative abundances are not estimated. The sphene may be distinguished from the epidote by its higher interference colours, while the epidote typically shows a pale light yellowish-green to colourless and pale green pleochroism. The epidote and sphene are considered to be essentially detrital.

Orthoclase and Microcline

Orthoclase and microcline are identified in a number of the specimens. These minerals occur only in minor amounts. Most commonly, the potash feldspars were noted in the microbrecciated layers (Plate 9). These are moderately sericite altered. Elsewhere, the feldspar occurs as rounded to sub-rounded clastic grains lying in a fine-grained matrix. X-ray defraction analyses determined the presence of microcline and/or weak orthoclase in specimens E-11 and E-24.

Plagioclase

Albite was not positively identified optically in the rocks of the Rouyn-

Val d'Or area, although its presence is indicated by Na_2O analyses, as well as by X-ray analysis, which definitely identifies albite in specimen E-21 (and suggested its existence in specimen E-24). Occasional, very fine grains were noted showing fine twinning; these grains were too small to resolve optically.

Albite occurs in the rocks south of the main area, in Surimau Twp., where it is identified in significant amounts.

Specimens E-21 and E-23 (Plate 10) show isolated, rounded to sub-rounded, grains of plagioclase. These have been moderately propyllitized.

Carbonates

Carbonate, probably calcite, occurs in variable amounts frequently showing a distinct preference for the cryptocrystalline layers, where it occurs as disseminated, very fine-grained aggregates and is identified only by its high interference colours. Its occurrence shows a close parallelism with the CaO analyses. The calcite occurs in three forms:

1) As coarse idioblastic crystals;

2) Intergrown with the recrystallized quartz and varying in amount from dominant to only weakly present;

3) Associated with the graphitic sections as described above.

The coarse carbonate may occasionally show isolated, unoriented graphitic inclusions.

X-ray defraction did not detect calcite in specimen E-11, and it appeared only weakly in specimen E-24. The X-ray analyses are confirmed by thin section study, and may indicate that the calcite is the primary form of the carbonate, and that samples with a value CaO less than 1.1 per cent may not be expected to show calcite. This suggestion is further reinforced by sample

E-32, which shows only 0.83 per cent CaO, but does not show calcite in thin section.

Biotite and Tremolite

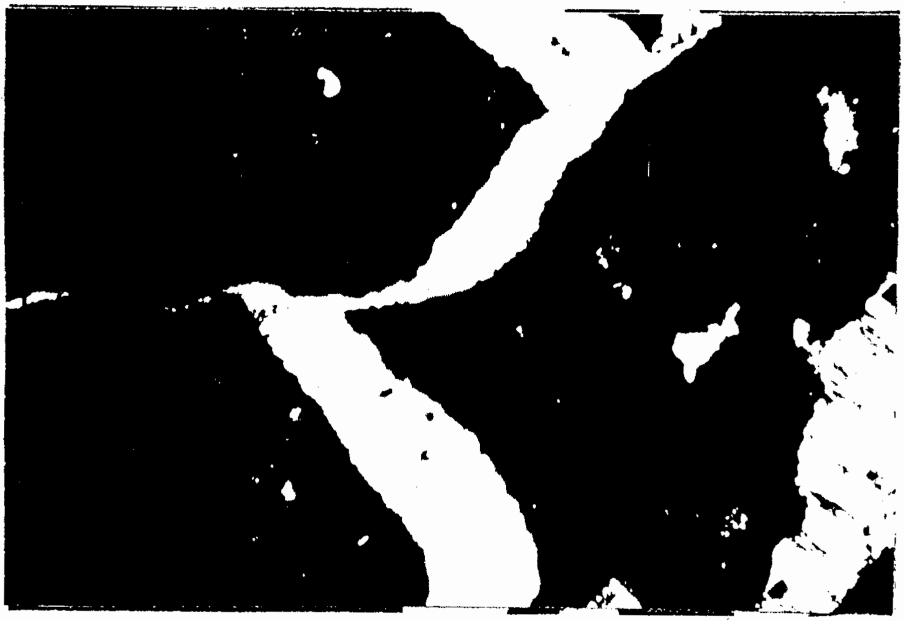
These minerals are identified in Samples E-1 and E-2, taken in Surinau Twp., in the Pontiac Sedimentary rocks. Sample E-1 contains minor biotite, while sample E-2 contains biotite to 10 per cent. In both cases, the biotite is lepidoblastic and commonly diablastic. Two to three per cent tremolite is identified primarily as diablastic lathes typically transecting the foliation. These porphyroblasts attained sizes to 5 mm. One pyritic nodule carried 10 per cent tremolite lathes. These minerals were not identified in the less highly-metamorphosed rocks sampled within the study area to the north.

Reflected Light Studies

Pyrite comprises the principal sulphide. Minor to trace amounts of sphalerite and chalcopyrite are associated with the pyrite. Two instances of hematite-magnetite intergrowths in a quartzitic matrix are noted. Graphite, through opaque, does not exhibit the properties attributed to it under reflected light, although, in some instances, it does stand out as specks and dots, somewhat darker than the surrounding matrix.

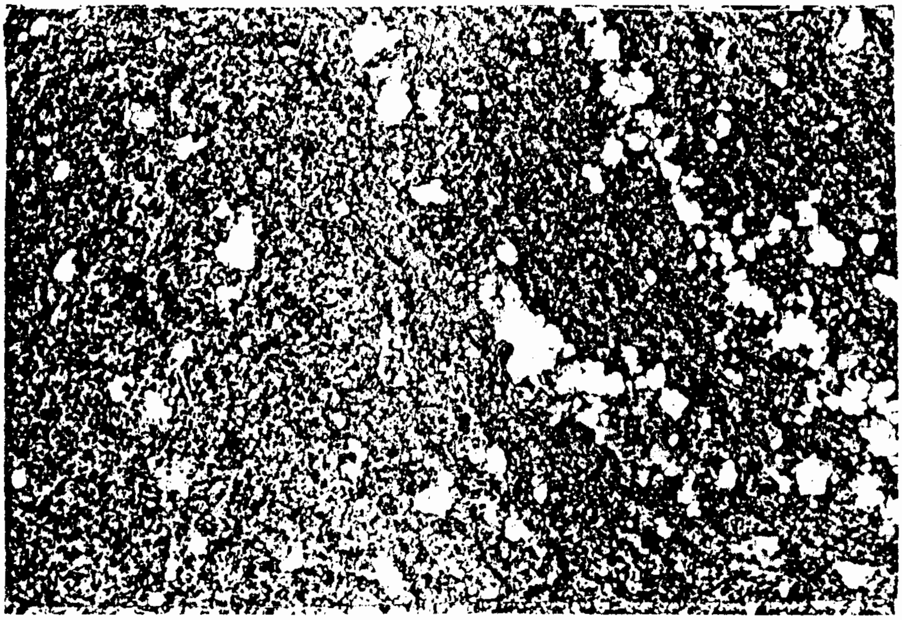
The pyrite, as noted in the megascopic description of the sampled occurrences, occurs in four distinct manners, of which two are inter-related (i.e. the relatively thin bedded form and the thick massive form). Nodules typically occur associated with both forms. In the case of the thin bedded variety, the pyritic units react to deformation as a competent unit within a more extensive incompetent unit, whereas, in the second case, the massive pyrite acts as an incompetent unit. Thus, these two types are distinguished on the

Plate 11



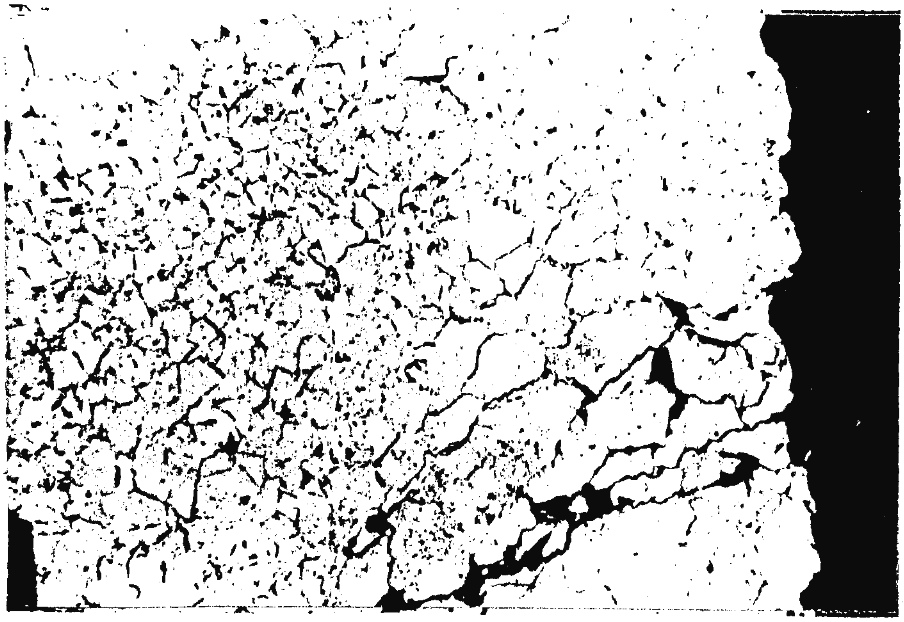
Photomicrograph. x33 - Massive fractured pyrite (black) with lamellar quartz as fracture "heal." (crossed nicols)

Plate 12



Photomicrograph. x53 - Disseminated pyrite (white) outlining the foliation. Note coalescence of fine spherules to form a larger grain. Fine black specks are graphite.

Plate 13



Photomicrograph. x208 - Pyrite with inclusions (black) outlining recrystallized polygonal pyrite grains. Note sphalerite developed in the fractures (dark grey) in the southeast corner.

Plate 14

Photomicrograph. x53 - Foliation indicated by graphite (black) streaks and seams, terminating against a pyrite (white) nodule. Disseminated pyrite "dust" grains are developed within the foliation.

basis of their tectonic expression and except for extent, the mode and occurrence of the pyrite are essentially the same.

In polished section, under reflected light, three forms of pyrite are recognized:

1) Massive pyrite which has undergone extension, brecciation and fracturing (Plate 11);

2) Nodular pyrite composed of "framboidal" clusters (?);

3) Disseminated pyrite, which includes submicroscopic "dust" particles of pyrite, through to fine clusters of pyrite grains (Plate 12), which lie within foliation.

The massive pyrite, in which shearing is effective, is typically brecciated. The fragments are stretched out, or smeared into, and define the foliation. The pyritic fragments are characteristically inclusion-choked; where recrystallization has been effective, the number of inclusions may approach zero. Individual fragments vary in size from 0.005 mm. to one to two cm. An occasional nodule occurs within the sheared pyrite. The pyritic grains frequently suggest that they are formed by the coalescence of a number of subspherical aggregates, which have subsequently partially expelled the gangue minerals; or, this matter has been brought in with the individual spherules, and now outlines the pyrite spheres. Characteristically, these inclusion rims are submicroscopic (Plate 13). In a number of cases, the inclusions delineate definite grain boundaries, which frequently approach Stanton's (1968) 120° interface angle, which he believes indicates recrystallization and annealing (Plates 13 and 20). The pyrite fragments are commonly irregularly fractured, and the fractures filled with gangue, which may corrode the pyrite. Sample E-29 shows gangue-filled fractures in which the fracturing is, in part, controlled by the annealed grain boundaries. In this instance, the boundaries are further defined within the pyrite by the gangue rims.

Further evidence for recrystallization is offered by the common occurrences of well-developed crystal faces protruding from the main pyritic mass. These are, at best, three-sided. In no instance was an euhedral crystal noted. This tendency towards recrystallization is evident regardless of the pyrite classification. Plate 3 shows a lens of massive sulphide in which the pyrite is apparently undergoing rotation. Most of the pyrite, however, is elongate within the foliation, being bounded by predominantly lamellar quartz.

The nodular pyrite occurs in two forms under reflected light:

1) A relatively massive form with nearly submicroscopic inclusions, which outline postulated finer spherules;

2) An inclusion-choked variety, which may show a core and rim effect; the core may sometimes be distinguished from the rim by a considerably greater inclusion content.

The boundaries of the nodules show a combined, scalloped effect, and the effect of the partial development of crystal faces protruding out the main mass (cockade structure). The inclusion content of the nodules ranges from five to 50 per cent. Graphite is probably included within the nodules, but this has not been definitely ascertained. As noted earlier, the suggestion exists that the nodules are formed by the dislocation and rotation of pyrite beds.

A final form of pyrite is found--a disseminated variety, which is pervasive throughout the graphitic rocks. The individual grains vary in size

Plate 15

Photomicrograph. x208 - Pyrrhotite (grey) blebs in a recrystallized pyrite grain. The pyrrhotite outlines are in part controlled by the pyrite grain boundaries.

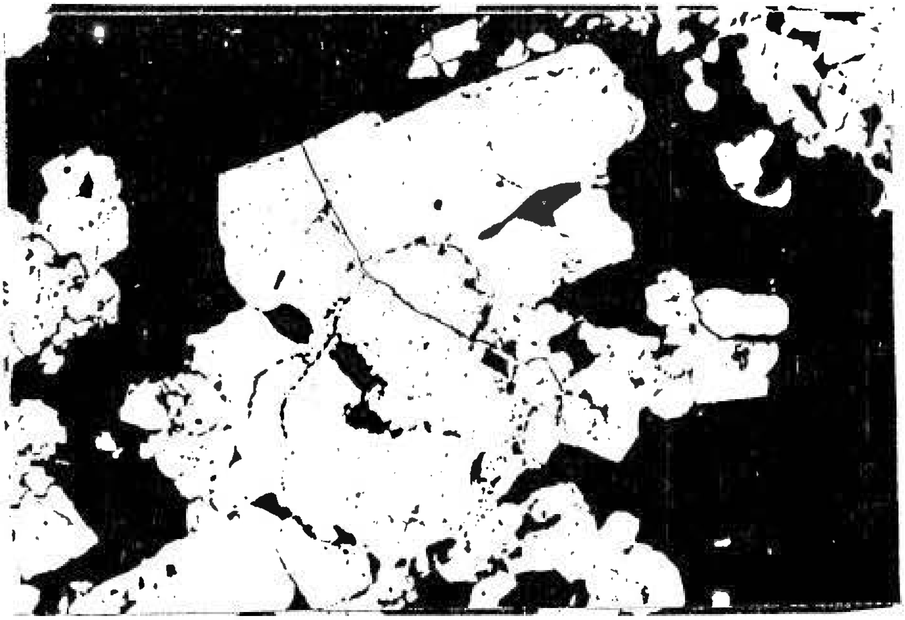
Plate 16

Photomicrograph. x530 - "Exsolution" chalcopyrite occurring as a bleb against a grain of recrystallized pyrite; and interstitial to adjacent pyrite grains. The chalcopyrite grain form has been controlled by the pyrite forms.

Plate 17

Photomicrograph. x530 - A bleb of mixed chalcopyrite (light grey) and sphalerite (dark grey) lying against a pyrite grain (white). The sphalerite is apparently embaying and replacing the chalcopyrite, along cleavage faces and fractures. Note very fine specks of pyrite in the chalcopyrite.

Plate 18



Photomicrographs. x208 - partially recrystallized pyrite with "exsolved" sphalerite (dark grey). In one instance the sphalerite outlines a possible triple point junction (A) of recrystallized pyrite polygons.

from submicroscopic particles--"dust," to larger aggregates of one to two mm. The disseminated variety is most characteristically found in the graphite rich lamina (Plate 14). The larger grains (greater than 0.01mm.) show evidence for the coalescence of two or more spheres (?), as lobate-sublobate inclusion indicated outlines (Plate 7). These grains may also show partially developed crystal faces. Only very rarely, is a nearly euhedral crystal of pyrite noted. Almost without exception, the finest lobate grains show an inclusion. It is suggested that the pyrite deposition occurs as a nucleation process about these cryptocrystalline inclusions. No evidence was noted for an organic core in these grains.

In contradistinction to the suggestion that the pyrite is most commonly associated with the graphite-free (poor) layers (Peltola, 1960), the disseminated variety, as described above, is found, preferentially, in the graphite rich layers.

Opaque Minerals

Pyrrhotite, chalcopyrite and spahlerite are the only other sulphides identified.

Pyrrhotite was identified in two specimens, E-1 and E-6. In one instance, it was noted as a separate irregular mass rimming a pyrite nodule. Plates 14 and 15 show the pyrrhotite apparently replacing the pyrite along grain boundaries and embaying the pyrite. The pyrrhotite, where in contact with the pyrite, typically originates at an inclusion. Stanton (1968) suggests that this is not a replacement texture, but an expression of the recrystallization of the precipitated minerals, in which case, the pyrrhotite has been expelled to the grain boundary of the pyrite. He further suggests that the mineral grain boundaries reflect a combination of the free energy states and relative strengths of crystallization of the minerals involved. In the case observed, the pyrite would show the greater strength of crystallization.

Chalcopyrite was identified in trace amounts. Typically, it is associated with the more massive pyrite or nodules. It shows the same relationship to the pyrite as does the pyrrhotite (Plate 16). In a few instances, it occurs intimately associated with sphalerite. Plate 17 shows an intimate mixture of the chalcopyrite and the sphalerite, lying against a pyrite mass, the grain boundaries obviously being controlled by the pyrite grain. The bleb of sulphide shows the chalcopyrite in intimate association with the sphalerite, and both in association with the pyrite. The sphalerite rims the chalcopyrite and embays it in a concave fashion, as well as apparently replacing the chalcopyrite along cleavage planes. Trace amounts of pyrite lie within the two minerals as nearly submicroscopic flecks. In one instance, the chalcopyrite grows between a pyrite grain boundary (Plate 16).

Sphalerite

Sphalerite occurs associated with the pyrite, but in amounts ranging from traces to possibly one per cent of the sulphide. Besides occurring in a manner similar to that for the chalcopyrite and the pyrrhotite, the sphalerite frequently occurs as apparent exsolution blebs moving out of the pyrite into the fractures, or into intergrain boundaries of the pyrite. Typically, some gangue or inclusion matter is associated with the sphalerite (Plate 18).

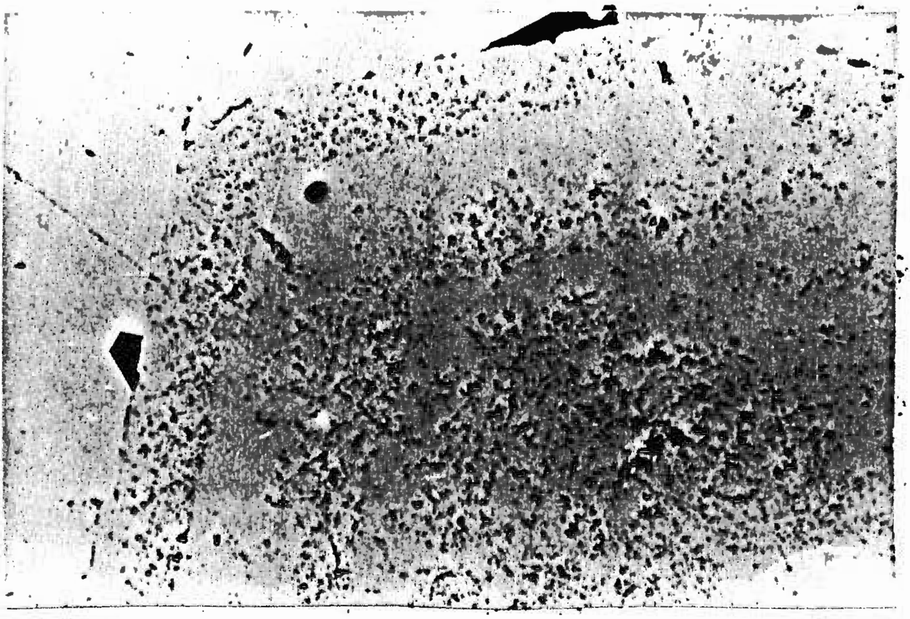
Magnetite-hematite

Magnetite and hematite were identified in one occurrence, sample E-15. The two minerals occur as brecciated intergrowths. They occur within a quartzitic lamina which has been dragfolded about a nearby pyrite mass.

Plate 19

Photomicrograph. x53 - Magnetite-hematite microbreccia in a quartzitic matrix. The hematite occurs as very fine intergrowths in the magnetite (lighter streaks). The photograph is taken on the crest of a microfold. Note bounding graphitic laminae.

Plate 20



Photomicrographs. x530 - Zoned recrystallized polygonal pyrite. Inclusions outline successive stages of recrystallization; and growth of the pyrite grain.

Plate 19 has been taken on the crest of the fold. The hematite occurs as fine exsolution lathes within the isotropic magnetite. One or two of the fragments, which lie on the edges of the quartzitic lens, in close proximity to the graphitic material, have been partially rimmed by pyrite.

APPENDIX 3

SAMPLE DATA AVAILABILITY

E-1, E-2, E-6, & E-36 courtesy Anaconda American Brass Ltd.

E-3 & E-4 contributed by M. La Tulip, courtesy Cremac Exploration Ltd.

E-5 taken in Clericy Twp. courtesy Anaconda American Brass Ltd.

E-6 to E-28 courtesy Soquem

E-29 courtesy the St. Lawrence Columbium and Metal Co.

E-30 courtesy G. Dumont, Consultant

E-31 courtesy Dome Exploration

E-32 courtesy J. Honsberger, Consultant

E-33 courtesy Noranda Mines Ltd.

E-34 courtesy Ecstall Mining Co. Ltd.

E-35 courtesy Hudson's Bay Mining and Smelting Co. Ltd.

APPENDIX 4

METHODS USED BY THE LABORATORIES OF THE DEPARTMENT OF NATURAL RESOURCES OF QUEBEC FOR GEOCHEMICAL ANALYSES

SiO_2:

Classical method. Fusion of sodium carbonate. Two dehydrations by means of hydrochloric acid.
Analytical error: $\pm$ 0.30% at 60% SiO_2

Al_2O_3:

Graviometric method. Precipitation of the oxide.
Analytical error: ± 0.20% at 15% Al_2O_3

CaO or MgO:

Volumetric measurement by titration with EDTA.
Analytical error: ± 0.10% at 5% CaO or MgO
± 0.20% at 10% CaO or MgO

Fe:

Volumetric measurement against potassium bichromate.
Analytical error: ± 0.10% at 5% Fe
± 0.20% at 10% Fe

TiO_2:

Volumetric measurement with iron sulphate in the presence of ammonium thiocyanate.
Analytical error: ± 0.10% at 5% TiO_2

Cr:

Spectrographic analysis.
Detection limit: about 0.0001% to 0.0002%
Analytical error: 15 to 20%

V:

Spectrographic analysis.
Detection limit: about 0.0005%
Analytical error: 15 to 20%

Pt:

Spectrographic analysis preceeded by pyroanalytical enrichment.
Detection limit: about 0.02 p.p.m.
Analytical error: 15 to 20%

The detection limits of the last three elements can not be given in absolute values, because these values vary considerably, dependent on the nature (matrix) of the rocks studied, as well as on the form in which the element occurs.

U:

Chromatographic method developed at the laboratory. J. Plamondon, Economic Geology, Vol. 63, 1969, pp. 79-89.
Detection limit: 1 p.p.m.
Analytical error: 0-2 p.p.m. ± 50%
3-10 p.p.m. ± 25%
10 p.p.m. ± 12%

Mo:

Method of N.J. Marshall, with dithiol.
Economic Geology, Vol. 59, 1964, pp. 142-148
Detection limit: 0.5 p.p.m.
Analytical error: 0.5-2 p.p.m. ± 30%
0.5-10 p.p.m. ± 20%
10 p.p.m. ± 10%

W:

Method developed by P. Bowden.
(Analyst 89, 1964, pp. 771-774)
Detection limit: 2 p.p.m.
Analytical error: ± 23% at 10 p.p.m.

Hg:

The method used is that adopted by the USGS.
(Geol. Survey Bulletin 1152)
Detection limit: 2.5 p.p.m.
Analytical error: This is not mentioned.

Au, Ag, Ni, Cu, Zn, Pb.:

Atomic absorption - the rocks are first digested in aqua regia, then by a mixture of nitric and hydrofluoric acid in a platinum crucible. The resultant solutions, or the extracts, are then anlyzed by atomic absorption.

Detection limits:	Au	0.2	p.p.m.
	Ag	0.4	"
	Ni	1.0	"
	Cu	0.6	"
	Zn	0.2	"
	Pb	2.0	"

Analytical error: about 7%

K:

Flame photometry.
Detection limits: 0.00006 p.p.m.
Analytical error: 1-2%

Na:

Flame photometry.
Detection limit: 0.001 p.p.m.
Analytical error: 1-2%

Sn:

Spectrographic analysis.
Detection limit: 10 p.p.m.
Analytical error: about 10%

Note: the foregoing was translated from the French language brochure prepared by the Laboratory.

APPENDIX 5

The following are the analytical certificates provided by the Quebec Department of Natural Resources Laboratories; they display the results of the chemical analyses of 32 graphitic occurrences. These rocks were analyzed for 24 elements and oxides.

APPENDIX 6

Representative specimens of the graphitic rocks, as sampled, studied, and analyzed, are on file at McGill University, in the Economic Sample Collection maintained by the Department of Geological Sciences. Those samples numbered E-1 to E-36 in the present thesis have been renumbered in the University file, and are now numbers E7671 to E7707 respectively.

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ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT No. 68g-8871 G.
CERTIFICATE

Québec, le 9 décembre 1968.

1 **Echantillon soumis par** / ***Sample submitted by*** Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8871, R-17-68-E1

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.3	p.p.m.
Ni	151	p.p.m.
Cu	432	p.p.m.
Zn	2160	p.p.m.
Pb	50	p.p.m.
Hg	n.d.	
Pt	<0.02 Pt	p.p.m.
Sn	10	p.p.m.
V	0.015%	
Cr	0.005%	
SiO_2	54.02%	
Al_2O_3	10.51%	
CaO	2.78%	
MgO	1.10%	
Fe	9.56%	

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CERTIFICAT
CERTIFICATE *No.* 68g-3872 G.

Québec, le 9 décembre 1968.

1 Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-3872, R-17-68-26

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.9	p.p.m.
Ni	54	p.p.m.
Cu	120	p.p.m.
Zn	615	p.p.m.
Pb	45	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	20	p.p.m.
V	0.010%	
Cr	0.008%	
SiO_2	26.19%	
Al_2O_3	2.17%	
CaO	0.56%	
MgO	0.90%	
Fe	31.62%	

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CERTIFICAT
CERTIFICATE *No.* 68g-8373 G.

Québec, le 9 décembre 1968.

1 Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gites Minéraux.

68g-8873, R-17-68-47

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.6	p.p.m.
Ni	85	p.p.m.
Cu	153	p.p.m.
Zn	765	p.p.m.
Pb	50	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	10	p.p.m.
V	0.007%	
Cr	0.006%	
SiO_2	47.10%	
Al_2O_3	3.72%	
CaO	1.26%	
MgO	0.80%	
Fe	15.17%	

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CERTIFICAT
CERTIFICATE *No.* 63g-8874 G.

Québec, le 9 décembre 1963.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8874, R-17-63-E3

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	36	p.p.m.
Cu	20	p.p.m.
Zn	115	p.p.m.
Pb	15	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.012%	
Cr	0.006%	
SiO_2	61.51%	
Al_2O_3	14.04%	
CaO	4.11%	
MgO	2.20%	
Fe	3.13%	

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CERTIFICAT
CERTIFICATE *No.* 63g-8375 G.

Québec, le 9 décembre 1968.

1 Echantillon soumis par / *Sample submitted by* Dr. O.D. Maurice,
Service des Gîtes Minéraux.

63g-3375, R-17-68-E9

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	160	p.p.m.
Cu	117	p.p.m.
Zn	375	p.p.m.
Pb	20	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.008%	
Cr	0.043%	
SiO_2	76.85%	
Al_2O_3	2.96%	
CaO	1.33%	
MgO	0.75%	
Fe	5.92%	

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CERTIFICAT
CERTIFICATE *No.* 68g-8876 G.

Québec, le 9 décembre 1968.

1 Echantillon soumis par
Sample submitted by Dr. O.D. Maurice.
Service des Gîtes Minéraux.

68g-8876, R-17-68-E-10

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	0.5	p.p.m.
Ni	23	p.p.m.
Cu	9	p.p.m.
Zn	59	p.p.m.
Pb	15	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.006%	
Cr	0.003%	
SiO_2	66.91%	
Al_2O_3	13.71%	
CaO	3.05%	
MgO	1.30%	
Fe	2.38%	

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CERTIFICAT No. 68g-8877 G. Québec, le 9 décembre 1968.
CERTIFICATE

1 **Echantillon soumis par** Dr. O.D. Maurice,
Sample submitted by Service des Gîtes Minéraux.

g-8877, R-17-68-E-11

U	n.d.	
Mo	4	p.p.m.
W	n.d.	
Ag	1.6	p.p.m.
Ni	87	p.p.m.
Cu	102	p.p.m.
Zn	146	p.p.m.
Pb	55	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	20	p.p.m.
V	0.014%	
Cr	0.018%	
SiO_2	33.16%	
Al_2O_3	4.96%	
CaO	1.11%	
MgO	0.72%	
Fe	23.38%	

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CERTIFICATE *No.* 68g-8378 G. Québec, le 9 décembre 1968.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8378, R-17-68-E-12

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	23	p.p.m.
Cu	11	p.p.m.
Zn	43	p.p.m.
Pb	1.5	p.p.m.
Hg	1	p.p.m.
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.004%	
Cr	0.004%	
SiO_2	66.57%	
Al_2O_3	14.18%	
CaO	2.93%	
MgO	1.30%	
Fe	2.09%	

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CERTIFICAT
CERTIFICATE *No.* 68g-3879 G.

Québec, le 9 décembre 1968.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

63g-8879, R-17-68-E-13

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.6	p.p.m.
Ni	240	p.p.m.
Cu	72	p.p.m.
Zn	270	p.p.m.
Pb	50	p.p.m.
Hg	0.4	p.p.m.
Pt	<0.02	p.p.m.
Sn	10	p.p.m.
V	0.010%	
Cr	0.09%	
SiO_2	55.86%	
Al_2O_3	4.82%	
CaO	2.30%	
MgO	0.40%	
Fe	14.81%	

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CERTIFICAT
CERTIFICATE *No.* 68g-8880 G. Québec, le 9 décembre 1968.

1 Echantillon soumis par *Sample submitted by* Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8880, R-17-68-E-14

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.1	p.p.m.
Ni	38	p.p.m.
Cu	15	p.p.m.
Zn	57	p.p.m.
Pb	20	p.p.m.
Hg	1.2	p.p.m.
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.009%	
Cr	0.005%	
SiO_2	61.58%	
Al_2O_3	12.79%	
CaO	6.32%	
MgO	2.11%	
Fe	2.68%	

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CERTIFICAT
CERTIFICATE *No.* 68g-3881 G.

Québec, le 10 décembre 1968.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-3831, R-17-68-A-15

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.1	p.p.m.
Ni	160	p.p.m.
Cu	133	p.p.m.
Zn	129	p.p.m.
Pb	45	p.p.m.
Hg	0.4	p.p.m.
Pt	<0.02	p.p.m.
Sn	10	p.p.m.
V	0.010%	
Cr	0.002%	
SiO_2	59.50%	
Al_2O_3	11.41%	
CaO	1.96%	
MgO	0.42%	
Fe	7.31%	

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CERTIFICAT
CERTIFICATE *No.* 68g-8882 G.

Québec, le 10 décembre 1968.

1 Echantillon soumis par / *Sample submitted by* Dr. O.D. Maurice,
Service des Gites Minéraux.

68g-8882, R-17-68-L-16

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	23	p.p.m.
Cu	11	p.p.m.
Zn	27	p.p.m.
Pb	15	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.004%	
Cr	0.004%	
SiO_2	66.50%	
Al_2O_3	13.57%	
CaO	3.28%	
MgO	0.97%	
Fe	1.74%	

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CERTIFICAT
CERTIFICATE *No.* 68g-8883 G.

Québec, le 10 décembre 1963.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8883, R-17-63-E-17

U	n.d.	
Nb	n.d.	
W	n.d.	
Ag	1.1	p.p.m.
Ni	163	p.p.m.
Cu	141	p.p.m.
Zn	480	p.p.m.
Pb	50	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.019%	
Cr	0.013%	
SiO_2	59.43%	
Al_2O_3	12.13%	
CaO	3.10%	
MgO	0.49%	
Fe	5.16%	

Zoltan Lätzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

PROVINCE DE QUÉBEC
MINISTÈRE DES RICHESSES NATURELLES LABORATOIRES
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ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT *CERTIFICATE* No. 63g-8384 G. Québec, le 10 décembre 1963.

1 **Echantillon soumis par** *Sample submitted by* Dr. O.D. Maurice,
Service des Gîtes Minéraux.

63g-8384, R-17-68-M-18	U	n.d.	
	Mo	n.d.	
	W	n.d.	
	As	0.8	p.p.m.
	Ni	100	p.p.m.
	Cu	65	p.p.m.
	Zn	430	p.p.m.
	Pb	30	p.p.m.
	Hg	n.d.	
	Pt	<0.02	p.p.m.
	Sn	5	p.p.m.
	V	0.013%	
	Cr	0.005%	
	SiO_2	66.64%	
	Al_2O_3	14.58%	
	CaO	2.58%	
	MgO	0.50%	
	Fe	2.44%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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ANNEX E.—PARLIAMENT BUILDINGS

CERTIFICAT
CERTIFICATE *No.* 68g-8835 G.

Québec, le 10 décembre 1968.

1 **Echantillon soumis par** / ***Sample submitted by*** Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8835, R-17-63-d-19

U	n.d.	
W	n.d.	
Mo	n.d.	
Ag	1.1	p.p.m.
Ni	92	p.p.m.
Cu	56	p.p.m.
Zn	390	p.p.m.
Pb	45	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	10	p.p.m.
V	0.007%	
Cr	0.004%	
SiO_2	64.75%	
Al_2O_3	12.93%	
CaO	3.15%	
MgO	0.77%	
Fe	4.67%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur: Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68g-8886 G. Québec, le 6 décembre 1968.

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8886, R-17-68-E20

U	n.d.	
Mo	6	p.p.m.
W	n.d.	
Ag	0.8	p.p.m.
Ni	256	p.p.m.
Cu	98	p.p.m.
Zn	615	p.p.m.
Pb	55	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	10	p.p.m.
V	0.015%	
Cr	0.007%	
SiO_2	50.89%	
Al_2O_3	12.44%	
CaO	2.46%	
MgO	1.13%	
Fe	7.76%	

Zoltan Katzendorfer

H. Boileau
Henri Boileau
(Chimiste-en-chef)

Le Directeur: Charles-A. Olivier
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68g-8887 G.

Québec, le 6 décembre 1968.

1 Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8887, R-17-68-E21

U	1	p.p.m.
Mo	4	p.p.m.
W	n.d.	
Ag	1.3	p.p.m.
Ni	222	p.p.m.
Cu	202	p.p.m.
Zn	1320	p.p.m.
Pb	55	p.p.m.
Hg	0.4	p.p.m.
Pt	<0.02	p.p.m.
Sn	10	p.p.m.
V	0.011%	
Cr	0.006%	
SiO_2	52.59%	
Al_2O_3	11.03%	
CaO	3.30%	
MgO	1.56%	
Fe	6.10%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE No. 68g-8838 G.

Québec, le 9 décembre 1968.

1 Echantillon soumis par / *Sample submitted by* Dr. O.D. Maurice.
Service des Gîtes Minéraux.

68g-8838, R-17-68-E22

U	3	p.p.m.
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	90	p.p.m.
Cu	63	p.p.m.
Zn	570	p.p.m.
Pb	40	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.010%	
Cr	0.005%	
SiO_2	66.55%	
Al_2O_3	12.64%	
CaO	3.92%	
MgO	0.65%	
Fe	1.73%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur: Charles-A. Olivier

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CERTIFICAT
CERTIFICATE No. 63g-8889 G. Québec, le 9 décembre 1963.

1

Echantillon soumis par
Sample submitted by Dr. O.E. Maurice,
Service des Gîtes Minéraux.

63g-8889, R-17-68-E23

U	1	p.p.m.
Mo	n.d.	
W	n.d.	
As	0.8	p.p.m.
Ni	137	p.p.m.
Cu	93	p.p.m.
Zn	750	p.p.m.
Pb	30	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.011%	
Cr	0.016%	
SiO_2	58.70%	
Al_2O_3	12.71%	
CaO	4.39%	
MgO	1.85%	
Fe	4.80%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68g-8890 G.

Québec, le 9 décembre 1968.

1 **Echantillon soumis par** / ***Sample submitted by*** Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8890, R-17-68-E24

U	1	p.p.m.
Mo	n.d.	
W	n.d.	
Ag	1.1	p.p.m.
Ni	185	p.p.m.
Cu	225	p.p.m.
Zn	1700	p.p.m.
Pb	30	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.013%	
Cr	0.026%	
SiO_2	54.10%	
Al_2O_3	12.18%	
CaO	2.54%	
MgO	2.02%	
Fe	6.67%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur: Charles-A. Olivier

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CERTIFICAT *CERTIFICATE* No. 68g-8891 G.

Québec, le 9 décembre 1968.

1 Echantillon soumis par / *Sample submitted by* Dr. O.D. Maurice, Service des Gîtes Minéraux.

68g-3891, R-17-68-E25

U	1	p.p.m.
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	151	p.p.m.
Cu	96	p.p.m.
Zn	705	p.p.m.
Pb	25	p.p.m.
Hg	0.4	p.p.m.
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.022%	
Cr	0.053%	
SiO_2	59.26%	
Al_2O_3	15.02%	
CaO	3.38%	
MgO	2.00%	
Fe	3.57%	

Zoltan Katzendorfer

H. Boileau
Henri Boileau
(Chimiste-en-chef)

Le Directeur: Charles-A. Olivier

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CERTIFICAT No. 68g-8392 G.
CERTIFICATE

Québec, le 9 décembre 1963.

1

Echantillon soumis par Dr. O.D. Maurice,
Sample submitted by Service des Gites Minéraux.

68g-8392, R-17-63-E26

U	1	p.p.m.
Mo	n.d.	
W	n.d.	
Ag	1.1	p.p.m.
Ni	166	p.p.m.
Cu	157	p.p.m.
Zn	960	p.p.m.
Pb	35	p.p.m.
Hg	0.2	p.p.m.
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.020%	
Cr	0.023%	
SiO_2	56.85%	
Al_2O_3	14.90%	
CaO	2.34%	
MgO	2.90%	
Fe	5.42%	

....
Zoltan Katzendorfer

....
Henri Boileau
(Chimiste-en-chef)

Le Directeur:..
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE No. 68g-8893 G.

Québec, le 9 décembre 1968.

1

Echantillon soumis par / *Sample submitted by* Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-8893, AL-17-68-327

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	2.1	p.p.m.
Ni	168	p.p.m.
Cu	284	p.p.m.
Zn	780	p.p.m.
Pb	35	p.p.m.
Hg	0.2	p.p.m.
Pt	<0.02	p.p.m.
Sn	10	p.p.m.
V	0.021%	
Cr	0.005%	
SiO_2	44.72%	
Al_2O_3	13.08%	
CaO	6.01%	
MgO	0.95%	
Fe	14.21%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE No. 63g-8894 G.

Québec, le 9 décembre 1968.

1

Echantillon soumis par / ***Sample submitted by*** Dr. O.D. Maurice,
Service des Gîtes Minéraux.

63g-8894, R-17-68-E23

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	54	p.p.m.
Cu	89	p.p.m.
Zn	330	p.p.m.
Pb	25	p.p.m.
Hg	0.4	p.p.m.
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.012%	
Cr	0.004%	
SiO_2	62.49%	
Al_2O_3	14.25%	
CaO	3.13%	
MgO	1.65%	
Fe	4.95%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68G-3895 G.

Québec, le 9 décembre 1968.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

Parkcourt

68G-3895, R-17-68-E29

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	0.8	p.p.m.
Ni	72	p.p.m.
Cu	48	p.p.m.
Zn	105	p.p.m.
Pb	20	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.020%	
Cr	0.010%	
SiO_2	58.40%	
Al_2O_3	16.03%	
CaO	4.91%	
MgO	1.94%	
Fe	4.22%	

....
Zoltan Katzendorfer

....
Henri Boileau
(Chimiste-en-chef)

Le Directeur:..
Charles-A. Olivier

C.J.

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CERTIFICAT
CERTIFICATE No. 63g-3396 G.

Québec, le 9 décembre 1963.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

63g-3396, n-17-63-530

U	1	p.p.m.
Mo	n.d.	
W	n.d.	
Ag	1.6	p.p.m.
Ni	72	p.p.m.
Cu	211	p.p.m.
Zn	1320	p.p.m.
Pb	35	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.016%	
Cr	0.004%	
SiO_2	6[illegible].12%	
Al_2O_3	11.60%	
CaO	2.51%	
MgO	1.15%	
Fe	6.71%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68G-8397 G.

Québec, le 9 décembre 1963.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68G-8897, R-17-63-831

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.1	p.p.m.
Ni	97	p.p.m.
Cu	44	p.p.m.
Zn	200	p.p.m.
Pb	20	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.030%	
Cr	0.006%	
SiO_2	51.51%	
Al_2O_3	16.13%	
CaO	6.24%	
MgO	1.80%	
Fe	6.15%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68g-8898 G.

Québec, le 9 décembre 1963.

1 Echantillon soumis par / *Sample submitted by* Dr. O.D. Maurice,
Service des Gîtes Minéraux.

[illegible]

68g-8898, M-17-63-E32

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.3	p.p.m.
Ni	44	p.p.m.
Cu	80	p.p.m.
Zn	50	p.p.m.
Pb	50	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	15	p.p.m.
V	0.004%	
Cr	0.014%	
SiO_2	22.56%	
Al_2O_3	2.78%	
CaO	0.33%	
MgO	0.80%	
Fe	33.76%	

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Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68g-8899 G.

Québec, le 9 décembre 1968.

1

Echantillon soumis par
Sample submitted by Dr. O.D. Maurice,
Service des Gîtes Minéraux.

68g-3399, R-17-68-E33

U	n.d.	
Mo	n.d.	
W	n.d.	
Ag	1.1	p.p.m.
Ni	108	p.p.m.
Cu	52	p.p.m.
Zn	465	p.p.m.
Pb	25	p.p.m.
Hg	n.d.	
Pt	<0.02	p.p.m.
Sn	5	p.p.m.
V	0.017%	
Cr	0.015%	
SiO_2	55.95%	
Al_2O_3	12.37%	
CaO	5.91%	
MgO	2.35%	
Fe	4.95%	

Zoltan Katzendorfer

Henri Boileau
(Chimiste-en-chef)

Le Directeur:
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68-9679 G.

Québec, le 25 février 1969.

1

Echantillon soumis par
Sample submitted by Dr. J.D. Maurice,
Service des Gîtes Minéraux.

6 h-9679, 1-34

TGS.

U	3	p.p.m.
Th	n.d.	
W	n.d.	
Au	n.d.	
Ag	20.4	p.p.m.
Ni	19	p.p.m.
Cu	315	p.p.m.
Zn	8050	p.p.m.
Pb	94	p.p.m.
Pt	<0.02	oz./t.
Hg	n.d.	
Co	10	p.p.m.
SiO_2	70.20%	
Al_2O_3	11.59%	
CaO	0.75%	
MgO	1.52%	
Fe	4.93%	
TiO_2	0.22%	
Na_2O	0.79%	
K_2O	2.20%	
V	0.005%	
Cr	0.004%	
C	2.96%	
Mn	0.02%	

....
[illegible]

....
[illegible]
(Chimiste-en-chef)

Le Directeur:..
Charles-A. Olivier

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CERTIFICAT
CERTIFICATE *No.* 68h-9680 G. Québec, le 23 février 1969.

1 Echantillon soumis par
Sample submitted by Dr. G. O. Maurice,
Service des Gîtes Minéraux.

Cyprus.

68h-9680, E-35

U	4	p.p.m.
Mo	n.d.	
W	n.d.	
Au	n.d.	
Ag	2.1	p.p.m.
Ni	94	p.p.m.
Cu	265	p.p.m.
Zn	335	p.p.m.
Pb	9	p.p.m.
Pt	<0.02	p.p.m.
[illegible]	n.d.	
Co	40	p.p.m.
SiO_2	2[illegible].74%	
Al_2O_3	3.73%	
CaO	2.34%	
H_2O	4.35%	
Fe	30.63%	
TiO_2	0.17%	
Na_2O	0.65%	
K_2O	0.35%	
V	0.013%	
Cr	0.005%	
S	3.29%	
Sn	0.00%	

[illegible]

Henri Chibeau
(Chimiste-en-chef)

Le Directeur: Charles-A. Olivier
Charles-A. Olivier

151-fin 21-1-8

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

QUÉBEC

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

CERTIFICAT
CERTIFICATE No. 681-9631 G.

Québec, le 28 février 196[illegible].

Echantillon soumis par
Sample submitted by Dr. C.D. Maurice,
Service des Gîtes minéraux.

Caribou.

[illegible]-9631, B-36

U	3	p.p.m.
[illegible]	6	p.p.m.
W	n.d.	
[illegible]	n.d.	
[illegible]	0.7	p.p.m.
Ni	16	p.p.m.
Cu	23	p.p.m.
Zn	530	p.p.m.
Pb	9	p.p.m.
Pt	<0.02	p.p.m.
Hg	n.d.	
Co	12	p.p.m.
SiO_2	[illegible]1.[illegible]9%	
Al_2O_3	15. 5%	
CaO	0.[illegible]%	
MgO	1.[illegible]7%	
Fe	5.77%	
TiO_2	0.64%	
Na_2O	0.1[illegible]%	
K_2O	[illegible].26%	
V	0.013%	
Cr	0.006%	
C	0.32%	
Sn	0.00[illegible]%	

[illegible]

Henri Boileau
(Chimiste-en-chef)

Le Directeur: ....
Charles-A. Olivier