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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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IRON DEPOSITS NEAR UNGAVA BAY, QUEBEC

G. A. Gross

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By

G. A. Gross

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
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PREFACE

The iron deposits near Ungava Bay are at the northern end of a long belt of iron-bearing Proterozoic rocks. Although remote, the deposits border on or are near coastal waters. This factor, combined with geological and metallurgical data, suggests that they are a likely source of ore to meet the increasing demand for high-grade concentrates prepared by pelletizing or sintering. This Bulletin gives a general account of the regional geology with description and evaluation of the iron-formation at several localities that are potentially productive.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, November 24, 1960

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IRON DEPOSITS NEAR UNGAVA BAY, QUEBEC

Abstract

Iron deposits near Ungava Bay are within the northern part of the belt of Proterozoic rocks forming the Labrador geosyncline. Along the western and northern borders of the geosyncline the rocks of this belt lie unconformably over gneisses and granite, and in its central and southeastern parts they are highly metamorphosed. Iron-formation is distributed mainly along the western and northeastern borders of the geosynclinal belt and forms part of a succession of sedimentary rocks, which in ascending order consist of mica schist, quartzite, iron-formation, black slate and argillite, dolomite, and phyllite. In the eastern part of the area, these sediments are interbanded with volcanic rocks and are intruded by diabase, gabbro, and ultramafic rocks. Local structures and stratigraphy of the iron-formation are described in some detail in the main areas where iron deposits have been investigated: south of Leaf Lake, in the Ford Lake area west of Hopes Advance Bay, in the area south of Payne Bay, and in the Roberts Lake area north of Payne Bay.

The iron deposits in these areas consist of selected zones of relatively coarse grained metamorphosed specular hematite-magnetite-quartz and magnetite-quartz iron-formation that can be beneficiated to give high-grade iron ore concentrates. The iron-oxide member of the iron-formation constitutes potential iron ore and is referred to as metataconite. It varies in thickness from 50 to more than 200 feet and, where repeated by thrust faulting or tight folding, forms large iron deposits in local structural segments. Textural characteristics and metamorphic features of the iron-formation are described as well as other geological features that are important to economic evaluation and to possible development of these iron deposits. In the area south of Payne Bay, a total of more than one billion (1,000 million) tons of crude ore containing from 24.5 to 35.5 per cent iron has been proven, another billion tons of possible ore has been indicated by geological and geophysical work, and additional large tonnages of ore may be inferred.

Résumé

Les gîtes de fer des environs de la baie d'Ungava appartiennent à la partie septentrionale de la bande de roches protérozoïques qui forme le géosynclinal du Labrador. Le long des limites occidentale et septentrionale du géosynclinal, les roches de cette bande recouvrent en discordance des gneiss et du granite. Quant au centre et au Sud-Est, elles y sont hautement métamorphisées. La formation ferrifère se trouve surtout à la bordure occidentale et du côté nord-est du géosynclinal et fait partie d'une série de roches sédimentaires qui, suivant l'ordre ascendant, se compose de schiste micacé,

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de quartzite, de la formation ferrifère, d'ardoise et argilite noires, de dolomie et de phyllite. Dans la partie orientale de la région, ces sédiments sont interstratifiés avec des roches volcaniques, et il y a intrusion de diabase, de gabbro et de roches ultramafiques. Les structures locales et la stratigraphie de la formation ferrifère sont décrites avec assez de détails dans le cas des principales régions où l'on a examiné des gîtes de fer, soit, au sud du lac Leaf, dans la région du lac Ford, à l'ouest de la baie Hopes Advance, dans la région située au sud de la baie Payne, et dans la région du lac Roberts au nord de la baie Payne.

Les gîtes de fer de ces régions représentent des zones particulières métamorphisées de la formation ferrifère. Dans ces zones, le grain est relativement grossier et la formation ferrifère est composée de quartz-magnétite-oligiste spéculaire, et de quartz-magnétite. Ces associations peuvent être enrichies de façon à produire des concentrés de minerai de fer de haute qualité. Le niveau de l'oxyde de fer de la formation ferrifère représente ce qui pourrait devenir du minerai de fer, et on lui donne le nom de méatataconite. L'épaisseur de ce niveau varie de 50 à plus de 200 pieds, et, là où il y a répétition du niveau due à des failles de poussée ou des plis serrés, il forme de gros gîtes de fer au sein de certaines masses tectoniques. L'auteur décrit les caractéristiques textulaires et métamorphiques de la formation ferrifère et les autres caractéristiques géologiques qui ont de l'importance pour l'évaluation économique et la mise en valeur possible de ces gîtes de fer. Dans la région située au sud de la baie Payne, le volume de minerai reconnu se chiffre par plus d'un milliard (1,000 millions) de tonnes de minerai brut, d'une teneur qui varie de 24.5 à 35.5 p. 100 en fer. De plus, les travaux géologiques et géophysiques ont indiqué la présence possible d'un autre milliard de tonnes, et l'on peut supposer qu'il existe encore d'autres fortes quantités de minerai.

INTRODUCTION

The iron deposits of this region consist of selected zones of iron-formation distributed throughout the northern part of the belt of Proterozoic rocks in the Labrador trough or geosyncline. The regional extent of this large geological feature has been defined in considerable detail by geological surveys conducted by provincial and federal government organizations and by private prospecting groups. Exploration by mining companies has led to the discovery of large deposits of low-grade potential iron ore. In this report some of the important geological and mineralogical features of the deposits are described, and the regional geology and the exploration work carried out before 1958 are briefly summarized.

The principal deposits in the Ungava area are near Payne Bay, Hopes Advance Bay, and Leaf Lake. These deposits are about 300 miles northwest of the iron ore mining district surrounding Schefferville, Quebec, in the central part of the Labrador iron belt. The high quality 'direct-shipping' iron ore from the Schefferville district is transported 360 miles south by rail to the seaport of Sept-Iles on the Gulf of St. Lawrence. Other large deposits of low-grade iron ore in the southwest part of the iron belt near Wabush Lake, 130 miles south of Schefferville, and in the Jeannine Lake–Mount Reed area, 80 miles southwest of Wabush Lake, are being developed.

Like the deposits in the Wabush Lake and Mount Reed parts of the belt, the Ungava deposits consist of selected zones within metamorphosed iron-formation where the iron is amenable to concentration. Results of metallurgical tests on large samples of material indicate that a satisfactory type of concentrated iron ore can be produced economically in the Ungava area. Basic data have been obtained for planning open-pit mines, for the design of processing plants, railways, docks, and other facilities necessary for the production of iron ore in this remote region.

The discovery and detailed examination of iron deposits near the west coast of Ungava Bay are of particular interest because of the active search for iron ore on the North American continent and the growing trend and preference by steel manufacturers for higher grade iron ore. These factors, as well as anticipation of further development of mineral resources in Canadian Arctic regions, have brought attention to the Ungava iron ranges.

Most of the larger iron deposits in this region were examined by the writer during the last part of the 1957 field season in connection with a general study of iron deposits in Canada. Field work consisted of an examination of geological features within deposits, and of general reconnaissance of the geological setting in which the iron deposits occur. Information from published maps and reports, and from unpublished reports of mining companies (*see* Bibliography) has been used to compile a regional geological map.

Acknowledgments

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GENERAL GEOLOGY

The iron-formation in the Ungava area is associated with sedimentary, volcanic, and intrusive rocks that form the Proterozoic belt in the Labrador trough or geosyncline. This arcuate belt of rocks, overlying granitic gneiss along its western margin, extends northwesterly through northern Quebec and Labrador from Wabush Lake in the south to Hudson Strait in the north—a distance of 600 miles. The northern quarter of the belt lies north of Koksoak River, along the west side of Ungava Bay. Where crossed by Koksoak River, the belt is about 50 miles wide but narrows to about 15 miles at Roberts Lake, 200 miles farther north. The main belt terminates north of Roberts Lake where the succession of younger rocks overlying the gneisses forms a broad syncline that plunges south. About 20 miles north of Roberts Lake, on the east side of Armand Lake, a similar group of rocks forms a separate syncline underlying an area about 12 miles long and 4 miles wide.

The western and northern borders of the belt of younger rocks are defined by the unconformity between metasediments and a complex of older gneisses and granitic rocks. The southeast side of the belt of geosynclinal rocks is not clearly defined because eastward most of the sediments and volcanic rocks are transformed to gneisses and schists and become indistinguishable from gneisses of undetermined age.

The distribution of the different groups of rocks is shown on Figure 1, and a general table of formations is included to illustrate the stratigraphy. Stratigraphic details of the iron-formation and rocks closely associated with it are given in the sections dealing with the iron ranges and mining properties. The geological map (Fig. 1) has been compiled from more detailed maps (1 inch equal to 1 mile) published by the Quebec Department of Mines, covering the area along the 58th parallel of latitude. It provides a section across the geosynclinal belt and illustrates many of the principal geological features of the region.

Stratigraphy

Along the western margin of the belt, the succession of geosynclinal rocks above the unconformity with the gneiss, granite, and schist, in ascending order is as follows: slate or greenschist; quartzite, iron-formation; interbanded slate, greywacke, argillite, arkose, and conglomerate; dolomite (Abner Formation); and argillite and arenaceous rocks that are interbanded, towards the east, with lava flows and other volcanic rocks. This generalized succession is typical of the western part and much of the northern part of the geosynclinal belt. The iron-formation is separated from the gneiss and granite by a thin band of schist or slate and a quartzite formation that is from a few tens of feet to 100 feet thick.

Nearly all the iron-formation outcrops are close to the western margin of the geosyncline, except for a few areas where the geosyncline has been raised by folding and faulting and is exposed at the present erosion level.

The central part of the geosyncline between Gérido Lake and Thévenet Lake in the south, is underlain by a group of sedimentary rocks consisting of shale, argillite, siltstone, sandstone, slate, dolomite, and iron-formation, that are interbanded with volcanic flows and pyroclastic rocks. The bands of volcanic rock are more numerous in the upper part of the exposed stratigraphic succession. This succession of rocks is intruded by numerous swarms of gabbro sills that range in thickness from a few inches to hundreds of feet. The group of rocks mapped in detail in the south is considered to be representative of the rock assemblages found throughout the central part of the Proterozoic belt. The succession exposed in the central part of the area is correlated with the upper part of the succession described in the western marginal part of the geosynclinal belt. The total thickness of the rock succession in the Gérido Lake–Thévenet Lake area is not known because basement rocks are not exposed and subsurface information is lacking.

A number of different dolomite formations are identified in the region south of Leaf Lake. Of these, the Abner Formation is the thickest and best defined. It is present with arenaceous rocks that lie stratigraphically above the main iron-formation exposed along the western margin of the belt. This formation is described by Bérard (1959) as massive, buff weathering, and characterized by abundant small quartz veins. It has not been found north of Leaf Lake. Another dolomite band south of Leaf Lake—which outcrops east of the Abner Formation —is thought to be a stratigraphic horizon (Bérard, 1959) different from the Abner Formation and is characteristically thinly bedded, laminated or flaggy, slightly metamorphosed, and contains many argillaceous and sandy interbeds. In the south-central part of the area dolomite lenses are present in arenaceous beds below the iron-formation.

Rocks in the geosynclinal belt east of Thévenet Lake are more highly metamorphosed than those in the western and central parts. The rank of metamorphism increases eastward and transitions can be followed across the regional trend from argillite, phyllite, and other sedimentary rocks, to biotite-muscovite schists, or schists of varied composition containing garnet, staurolite, or sillimanite. East of Thévenet Lake and in the Freneuse Lake area the increase in rank of metamorphism is pronounced; dolomite rocks are transformed to actinolite metadolomite, calc-silicate-rich bands, or amphibolite; other sedimentary rocks are changed to various types of schists; and pillow lavas and gabbro sills are changed to amphibolites. Because of this gradation, the eastern limit of the belt is obscure. In the Olmstead-Gabriel Lakes area it is difficult to determine whether schists and gneisses are derived from geosynclinal rocks or whether they are early Precambrian gneisses of the basement complex that formed the floor of the geosyncline. Faults have been recognized along the eastern trough margin by Fahrig (1955, 1956a) and Sauvé (1957), who note that rocks on both sides of

fault zones are of similar metamorphic rank and that lithological types can generally be correlated. Faults therefore appear to cut a belt of rocks deformed by the same period of orogeny.

The problem of the age relationship between the two large areas of gneiss around Rénia Lake and Hall Lake and the adjacent bands of schist and metasedimentary rocks is similar to that just described along the eastern margin of the belt. The sedimentary schists may lie unconformably on older gneisses, or the gneisses may be more highly metamorphosed and granitized trough rocks. Gélinas (1958) noted that the gneisses near contacts with schists contain bands rich in feldspar and quartz interlayered with bands rich in biotite, implying a sedimentary origin, and that near the contact the foliation in the gneisses is parallel to that in schists and to the banding in dolomite within the schists.

Farther north in the Leaf Lake and Hopes Advance Bay areas, Béland and Auger (1958) indicate from their experience that two possible criteria may be useful in defining the eastern border of the belt of geosynclinal rocks. The first is based on the position of pegmatite dykes which are abundant in the 'Archæan type', or what are thought to be older gneisses, but have not been encountered in iron-formation or in the basal sedimentary rocks of the basin. Secondly, the 'Archæan type' gneisses are more sericitic and feldspathic than the basin rocks which are rather quartzose and biotitic.

Narrow bands of serpentine-rich ultramafic rock occur in the Freneuse Lake and Thévenet Lake areas, and thin lenticular sheets occur in the central part of the geosynclinal belt north of Payne Bay (Béland and Auger, 1958). The quartzite, iron-formation, dolomite and arenaceous rocks distributed in the western and northern parts of the belt show evidence of having been deposited in shallow water, possibly in a continental shelf environment. The rocks in the central and eastern parts are considered to be of equivalent age to the western rocks but to have been deposited in a eugeosynclinal environment.

Metamorphism

The increase in rank of metamorphism from west to east across the southern part of this region is of special significance in defining the limits of the geosynclinal belt and in understanding tectonic features of the area. Along the western margin of the belt where the main iron-formations are affected, these changes are of further economic significance. Northward, the rank of metamorphism increases from the chlorite zone in the south towards the Hopes Advance Bay and Payne Bay areas, where the rocks contain garnet, biotite, diopside, and hypersthene, and then decreases somewhat towards Roberts Lake.

The iron-silicate minerals consisting mainly of grunerite, hypersthene, and other iron-rich amphiboles and pyroxenes are believed to have formed largely from pre-existing iron silicates which recrystallized to form these minerals that are stable under high-rank metamorphic conditions. Some of the iron silicates may have formed from the reaction of siderite with quartz. Siderite is unstable at higher temperatures regardless of confining pressure, and iron from siderite

may have combined with available silica to give silicate minerals. Magnetite sometimes forms when siderite breaks down under higher-rank metamorphic conditions. It is noteworthy that siderite was identified in some of the iron-formation south of Leaf Lake, but ferruginous carbonates from the Ford Lake-Payne Bay area were shown by X-ray determinations to consist of dolomite. None of the carbonate observed in the field in this area has the characteristic chocolate-brown weathered

General Table of Formations south of Leaf Bay

Finger Lake area (Bérard, 1957)	Gérido Lake area (Bergeron, 1954; Sauvé, 1955)	Thévenet Lake area (Gélinas, 1956)	Freneuse Lake area (Sauvé, 1957)
Gabbro sills	Gabbro sills	Pegmatite dykes	Pegmatite dykes
		Amphibolite, blotchy amphibolite with pegmatite	Mica schist with numerous thin amphibolite sills
Lavas, volcanic rocks	Lavas, volcanic rocks	Ultramafic rock	Amphibolite, ultramafic rocks, in part metamorphosed blotchy gabbro
Argillite, lava, phyllite, sandstone	Shale, siltstone, sandstone, dolomitic shale	Pillowed amphibolite	
Dolomite (Abner)	Iron-formation	Biotite-muscovite schist, with amphibolite, with pegmatite	
Sandstone, greywacke, arkose, conglomerate	Shale, siltstone, arenaceous rocks		
Slate and argillite		Grunerite schist	Iron-formation
Iron-formation		Conglomerate or breccia	
Quartzite, slate and greenschists		Calc-silicate rocks, with amphibolite	
Unconformity		Biotite-muscovite-garnet schist, amphibolite, and garnet amphibolite with pegmatite	Mica schist, minor quartzite, garnet schist, in part staurolite schist, part sillimanite schist
Gneiss, granite, schists		Dolomite-marble, amphibolite, fine-grained quartzite, biotite diopside schist	Actinolite-marble, actinolite-diopside marble, calc-silicate rocks, actinolite-diopside gneiss, actinolite breccia.
		Grey and pink gneiss, with amphibolite with pegmatite, augen gneiss	Microcline gneiss, mainly fine-grained gneiss

Lithological groups are listed from older to younger in ascending order and are not correlated between areas.

surface of the siderite farther south. Either siderite was never present in the Ford Lake-Payne Bay area or it has decomposed in this zone of higher-rank metamorphism.

Regional Structure

The rocks of the geosynclinal group appear to form a thin blanket or veneer over the older gneiss complex in the western and northern parts of the geosynclinal belt. The present outcrop pattern indicates that the younger sedimentary rocks were deposited over the gneisses on a gently undulating surface that formed broad depressions separated by low rounded hummocks and ridges. At the present erosion level most of the rocks in the trough are preserved in broad synclines and basin structures separated by domes and ridges of gneiss, and the margin of the geosyncline belt is very irregular. The iron-formation is very near the base of the sequence of layered rocks and is exposed over an unusually long strike length around the margins of the numerous basins and depressions. Many of these basin structures are deformed locally by folding and faulting but the broad regional pattern of rock distribution is well defined. The iron-formation and other sedimentary members thicken appreciably from the margins towards the centres of existing basins, suggesting that most of these depressions were originally embayments on the ocean floor. Deformation throughout the region is largely a result of tectonic thrusting from the east or northeast, and the structural pattern varies in different areas.

In the area south of Leaf Bay the quartzite, iron-formation, and other rocks near the western margin dip gently eastward, from a few degrees up to 30 degrees, but are more highly deformed to the east. In the south-central part of the area the regional fold pattern consists of elongated anticlines and synclines with axes striking north to northwest. Secondary folding and thrust faulting on the limbs of these major folds, with tectonic transport to the west, has caused further deformation in this area. Most of the beds dip east, some are overturned, and the axial lines of the folds plunge at low angles or are gently undulating. The magnitude of the regional folds is indicated by the five major synclines separated by four anticlines in the 30-mile section between Gérido Lake and Freneuse Lake. The gabbro sills follow the fold pattern of the sedimentary and volcanic rocks and are believed to have been intruded towards the close of the main period of folding. This general structural pattern is typical of the area extending north as far as Ford Lake.

At the west end of Ford Lake the boundary of the belt of younger rocks swings about 90 degrees from northwest to east-northeast and continues for about 25 miles in this direction as far as Hopes Advance Bay. From there it again resumes a northwest direction. The unconformity between the younger trough rocks and the older gneisses generally dips southeast between Ford Lake and Hopes Advance Bay, and the fold structures to the south in the central basin area plunge southeast. The unconformity north of Ford Lake, where the

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trough border swings sharply east, is distorted into a number of synclinal lobes that trend northwest and extend over the gneisses, giving this border a ragged outline on the map. These synclinal lobes which occupy embayments on an early shoreline are further deformed by folding and faulting. This deformation has caused doubling up, thickening, or repetition of the iron-formation within the local basins and fold structures that form the Ford Lake group of orebodies.

The western border of the geosyncline south of Payne Bay has a somewhat similar type of structural configuration, but the border is more deeply indented than at Ford Lake. Two narrow synclinal basins within 25 miles of Payne Bay extend about 10 miles northwestward from the main basin area before plunging out. The quartzite and iron-formation overlying the gneisses in this area are deformed locally by northwest-trending folds and thrust faults, and the iron-formation on the west flank of the southern syncline forms the Morgan iron range. In some parts of this area, as in the Bay zone south of Payne Bay, numerous thrust faults are present and the iron-formation is repeated several times in local imbricate structures on east-dipping faults.

The main geosynclinal belt extends for about 40 miles north of Payne Bay and is defined on the west and east sides by the unconformity between younger sedimentary rocks and older gneisses. On the west side of this basin the quartzite, iron-formation, and associated sedimentary rocks dip east at a low angle and the border of the rock belt is very irregular. Rocks on the east side of the basin dip vertically to steeply west, or in some places may be overturned to the west even to the extent of forming recumbent folds. Near the north border of the geosynclinal belt, deformation is not as intense as it is farther south and the succession of sediments forms broad open synclines that plunge south into a local depression north of Roberts Lake.

About 10 miles north of the main geosyncline and east of Armand Lake, iron-formation and other sedimentary rocks form a small basin structure about 12 miles long and 4 miles wide.

IRON DEPOSITS IN THE REGION

Potential deposits of ore in this region comprise those zones within the iron-formation that can provide suitable high-grade concentrates by beneficiation. Such zones contain about 35 per cent iron, and consist of granular mixtures of magnetite, specular hematite, quartz and iron silicate minerals in variable proportions. The zones of iron-formation selected for mining in the northern Ungava iron ranges are much coarser grained than taconite mined in Minnesota and are generally less complex mineralogically. The distinction between coarser grained highly metamorphosed recrystallized iron-formations of the Labrador geosyncline and other fine-grained iron-formations called taconite is emphasized. The coarse grained type is called metataconite in this report; it has been called itabirite, but as that term is somewhat ambiguous its use is undesirable. Although the iron deposits discussed are all of the general metataconite type, they may be classified into subtypes on the basis of mineralogical and compositional differences. Various kinds of metataconite usually occur as separate stratigraphic zones or facies and require separate methods of beneficiation to obtain satisfactory grades and recovery of iron concentrate.

The regional map shows the general known distribution of iron-formation throughout the northern Ungava region. In some parts of this belt the iron-formation has been mapped in detail and explored by diamond-drilling, but in other parts of the area information is limited. A number of factors are important in evaluating prospective iron deposits and in determining what constitutes potential ore.

Metataconite zones are stratigraphic units or members, and local stratigraphy forms the basis for interpretation of information from mapping and test drilling. Many of the primary sedimentary features in the rock members have been destroyed by metamorphism or structural deformation. The nature and distribution of original facies may, therefore, be difficult to recognize in some zones. An understanding of the sedimentary environment in which these rocks were deposited is of considerable value in determining local distribution of different iron-formation facies and in finding metataconite zones.

The various lithological facies or zones that make up the iron-formation are fairly consistent in their relative positions in the stratigraphic succession. In general, the lower zones are thin-banded grunerite, ferruginous dolomite, magnetite, and quartz rocks, which grade upward into the principal metataconite facies composed of banded iron oxide and quartz. The metataconite varies from banded mixtures composed predominantly of magnetite and quartz to mixtures composed of specular hematite and quartz. Other facies of metataconite consist of interbanded magnetite-rich and hematite-rich layers with numerous layers of intimately mixed hematite and magnetite grains. A transition zone above the metataconite

is composed of grunerite, hypersthene, other iron-silicate minerals, ferruginous dolomite, magnetite and quartz which grades to the upper part of the iron-formation called cap rock. Most of the cap rock is composed of banded quartz layers with variable amounts of ferruginous dolomite, grunerite, and iron silicates. Although the metataconite facies are lenticular and range in thickness from 50 to 300 feet, this horizon appears to persist throughout the western and northern parts of the region. Determination of the true stratigraphic thickness of the metataconite facies in local areas is important when prospecting for zones of ore suitable for mining. Where the beds are tightly folded or steeply dipping the stratigraphic thickness will closely approximate the width of mineable zones; where beds are low dipping or nearly horizontal the amount of overburden and waste rock that can be removed will depend on the thickness of the metataconite bed to be mined.

A fairly detailed knowledge of the structural geology of an area is essential in evaluating metataconite deposits. Structural features that are desirable and which tend to increase the amount of metataconite within a small area include thickening of beds in the crestal parts of folds, doubling up and repetition of ore beds by folding, and repetition of ore beds by thrust faulting. In some parts of the northern Ungava region relatively undeformed metataconite zones or facies are not thick enough to be of economic interest under present conditions but potential ore zones occur where this stratigraphic member is repeated by structural features. Structural deformation can also be disadvantageous, however, when barren material is mixed with ore through folding and faulting.

With the exception of the cap rock, the iron-formation contains from 30 to 37 per cent total iron. The iron that is combined chemically with silica, magnesia, and calcium in the iron-silicate minerals and in ferruginous dolomite or ankerite is not available as recoverable units of iron in commercial concentrates. Iron in siderite may or may not be recoverable depending on the beneficiation methods used. Usually in determining grades of crude ore only the iron present in iron-oxide minerals, mainly magnetite and specular hematite, is considered. Iron present as carbonate is almost negligible in most of the metataconite in the region so that assays of acid-soluble iron are accepted as representative of the iron to be recovered as concentrates.

In this region magnetite is the predominant iron-oxide mineral found with iron silicates and carbonate in the transition facies both above and below the main iron oxide and quartz metataconite zones. Because the magnetite can be concentrated by simple magnetic separation methods, some transition zones low in magnetite content may be potential ore. In other parts of the region the potential ore zones consist predominantly of magnetite mixed with either granular quartz or iron-silicate minerals, and the grade of crude ore is determined on the basis of recoverable magnetite. It is expected that in some deposits composed of magnetite with minor hematite only magnetite will be concentrated and the small amounts of hematite will be discarded in the tailings.

Much of the metataconite in the northern Ungava region consists of intimate mixtures of magnetite and hematite in quartz. Only limited amounts of iron oxide can be recovered from this material by gravity separation methods in use at present, and it will be necessary to recover both hematite and magnetite in order to obtain a satisfactory ratio of concentrate to crude ore. Metallurgical research shows that this type of material may be utilized after roasting in a reducing environment and converting all iron oxide to magnetite followed by further grinding and magnetic separation. Other possible separation methods under investigation include flotation, high and low intensity dry magnetic separation, and electrical high-tension separation. The appropriate method to be used for beneficiating a particular metataconite deposit depends mainly on the mineralogy and texture of the material and a good understanding of the mineralogical character of the ore is essential.

Texture and grain size are significant features to be considered in evaluating potential ore, as they determine the fineness of grinding required to liberate ore minerals from gangue. They also reflect the rank of metamorphism and conditions under which the iron-formation recrystallized. Metamorphism of the iron-formation consists mainly of recrystallization of iron-oxide minerals and quartz with the accumulation of the iron and silica in larger and coarser mineral grains. Where the iron-formation has a granular to sugary texture the iron is usually present in discrete grains of fairly uniform size and can be liberated from gangue much more easily than it can from relatively unmetamorphosed cherty iron-formations. It is generally true that the size of mineral grains increases proportionately to the increase in rank or intensity of metamorphism. The rank of metamorphism can be inferred from the kinds of minerals developed in a rock of a certain composition and they in turn reflect the physical-chemical environment in which they formed. However, certain other factors are influential in determining grain size, such as the amount of moisture or volatile constituents in a rock and the period of time over which recrystallization and metamorphism took place. The influence of these factors is difficult to evaluate.

Although it is necessary to perform laboratory tests on samples of metataconite in order to determine their amenability to concentration, an appreciation of metamorphic features in the iron-formation and associated rocks is useful in understanding textural characteristics of potential ore zones.

The chemical composition of an iron ore, of either direct shipping quality or concentrate, must satisfy certain rigid specifications to be acceptable for large steel plants and blast furnaces. Ideally an iron ore should contain more than 50 per cent iron, less than 8 per cent silica and 4 per cent alumina. Calcium and magnesium may vary in amounts up to several per cent as they neutralize or combine with silica in a furnace slag. Certain constituents are undesirable, phosphorus should not exceed 0.18 per cent, and sulphur and titanium should each be less than 0.1 per cent. Only very small amounts of other elements such as copper, nickel, chromium, zinc, or arsenides may be tolerated unless the ore is to be used for special purposes. Manganese is beneficial in ore used for basic

open hearth processes but ore for acid open hearth should not contain more than 0.5 per cent. Manganese in excess of 2 per cent is usually purchased for the same price as units of iron except in the case of manganiferous ore where premium prices are paid. Concentrates produced from metataconite ore of the Ungava region are characteristically low in phosphorus, titanium, sulphur, and other deleterious constituents, and processing of these ores will be directed mainly to upgrading the iron content by removal of quartz and silicate minerals. Concentrates that satisfy chemical specifications can be further processed by pelletizing or sintering to obtain suitable ore structure or texture for the various types of steel-making methods.

The evaluation of a metataconite deposit requires consideration of a large number of factors and every deposit or group of deposits within an area requires separate appraisal. The shape, size, grade, and type of metataconite deposits are geological features that must be known before suitable mining methods can be devised. A large part of development costs may depend on the geographical location of a deposit and its proximity to established transportation routes. The type and cost of a beneficiation plant that can produce a marketable concentrate depends on the mineralogy and texture of the metataconite. Iron ore is a bulk commodity that must satisfy rigid grade and structural specifications in order to be sold in highly competitive markets. Very extensive study and testing of the many features of metataconite deposits are necessary before large expenditures of capital are warranted for the development and production of iron ore concentrate from this type of material.

Leaf Lake-Finger Lake Area

The concession held by Consolidated Fenimore Iron Mines Limited in 1957 consisted of 375 square miles of land that extends from a point 8 miles south of Ford Lake to Dragon Lake south of Finger Lake—a belt 55 miles long. In 1958 application was made to have the exploration licence revised to cover 142 square miles that extend from Dragon Lake to Leaf Lake. Exploration work, started in 1951 and continued to the end of 1957, has demonstrated the continuity of the iron-formation in a north-south direction throughout the area. Most of this work was carried out between the north end of Finger Lake and Leaf Lake with examination of three prominent outcrop areas called North Finger Lake, Middle Outcrop, and South Leaf, situated from south to north in this order along the iron belt for a distance of 6 miles. Detailed examination and diamond-drilling has been confined to the North Finger Lake outcrop where eighteen vertical holes were drilled in 1956 and eleven more in 1957 to intersect the low easterly dipping iron-formation. According to the company's annual report for 1957, these drill-holes indicated 74,030,000 tons of potential ore grading 29.4 per cent iron with the possibility of proving many times this amount of ore in the area.

Topographical relief does not exceed a few hundred feet; and the western border of the younger Precambrian rocks is marked by a prominent range of hills that trend north to northwest. A flat coastal plain covered by gravel and boulder deposits and glacial till extends southward from Leaf Lake for several miles and is disrupted by numerous isolated steep-sided hummocks that rise 50 or 60 feet above the surrounding plain (*see* Pl. X C).

This concession area straddles the west border of the belt of Proterozoic rocks that unconformably overlie older Precambrian granite, gneiss, and metasedimentary rocks. The younger Precambrian rocks consisting of quartzite, iron-formation, black shale, arkose, dolomite, biotite sericite schist, and volcanic rocks, intruded by gabbro sills, strike north to northwest, dip 10 to 30°E, and are only slightly deformed along the west side of the geosyncline. About a mile east of the exposed contact the rocks are much more highly deformed, being tightly folded with some folds overturned to the west and disrupted by numerous thrust faults that strike northwest and dip steeply east. The most prominent faults along the western margin of the geosyncline, which pass through the gneisses and low-dipping sedimentary rocks, strike northwest, have left-hand displacement of up to a mile, and are spaced at intervals of three quarters of a mile to 2 miles.

Description of Rock Types in the Area

The lower part of the stratigraphic succession including the iron-formation is well exposed for 4 miles along the range of hills about a mile west of Chioack River and north of Finger Lake. The succession of rocks, as shown in the table of formations for the North Finger Lake area, was examined in greatest detail near Sunny Creek, a small stream that flows east through the middle part of this area and joins Chioack River.

The Precambrian rocks exposed along the west side of the area consist of granite-gneiss, granite, granodiorite, biotite-hornblende schist, amphibolite, and metasedimentary rocks.

The quartzite, referred to by the company geologists as Allison quartzite, is unconformable above the complex of older Precambrian rocks and is mainly a tough, fine-grained, glassy, dark grey to greenish rock that contains some chlorite and other dark impurities. The basal part of the formation is dark green and fairly massive. The middle part is medium to fine grained, lighter grey, with arkosic beds in some places. The upper part of the formation is massive, fine-grained, impure quartzite with slaty bands and disseminated dark constituents. Sufficient fine-grained magnetite is present in the upper quartzite to cause a strong attraction to a hand magnet.

The quartzite is overlain by 10 to 20 feet of thin-banded, dark green to black, magnetite-chlorite-biotite-quartz schist. Schistosity is well developed and parallel to compositional banding and the biotite and quartz are fine to medium grained. The upper 5 to 10 feet of this schist member contains from 20 to 25 per cent of very fine grained (0.01 mm) magnetite and about 5 per cent of carbonate disseminated in isolated fine-grained clusters. Most of the magnetite is present

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as anhedral grains in streaks or thin bands but some grains distributed around oval or elliptical outlines in quartz magnetite laminae appear to be relict features of a granular or oolitic texture. The upper part of this schist may be included in the iron-formation where it has a high iron content. This rock is believed to be the metamorphic derivative of a thin-banded mixed clastic and ferruginous chert rock that was lithologically similar to the upper part of the Ruth slate of the Knob Lake area.

Table of Formations, North Finger Lake Area

	Local Formation Names	Lithology	Approximate Thickness (feet)
Late Precambrian	Mannic schist	Quartz biotite and sericite schist	—
	Abner dolomite	Buff weathering, white to grey dolomite with secondary quartz along bedding planes	—
	Chioack Formation	Black to grey schistose shale, minor arkose	
	Fenimore iron-formation	Spotted silica, granular silica chert with much interbedded carbonaceous material and secondary cummingtonite	50–100
		Interbedded carbonate and chert, white to green chert and medium-to-coarse-grained siderite, some brecciated material towards top	
		Metallic magnetite and silica at top, oolitic and specular hematite at centre, granular quartz with disseminated magnetite at bottom	80–100
		Shale, dark green shale	10–20
	Allison quartzite	Quartzite, white, brown or black, rounded grains with some interbedded shale	30–50
		Unconformity	
Early Precambrian	Archæan complex	Mainly gneissic granite	

Table from Fenimore Iron Mines Limited. Thickness of formations determined by the writer.

Iron-formation. Rocks mapped as iron-formation consist of two main types; the lower iron-formation made up of a magnetite-hematite-quartz facies, and the upper iron-formation made up of interbedded siderite, dolomite, and cherty quartz. Much of the upper carbonate quartz rock does not contain enough iron to be properly classified as iron-formation but because of its intimate relationship with recognized iron-formation it is convenient to consider these rocks as a unit.

The lower facies of the iron-formation is well-banded, dark bluish grey to black, and consists predominantly of magnetite and quartz with some intermixed hematite. The banding or bedding varies in thickness from a fraction of an inch to about a foot and very thin laminations are discernible in many beds. A dark grey speckled jasper band about a foot thick near the base of the oxide iron-formation consists of a mixture of specular hematite and magnetite in a fine granular quartz matrix. About 20 per cent of the quartz is present in one millimetre in diameter or finer, pink to red jasper granules, that are cherty and much finer grained than the surrounding mosaic of quartz. Above this horizon the bulk of the oxide facies consists of interbanded magnetite-rich layers with hematite and layers where hematite predominates. Jasper specks are more conspicuous towards the base of the rock-unit, and the occasional band with a pitted surface contains disseminated clusters of carbonate grains. The quartz is generally coarser grained in the matrix of the rock than it is in iron oxide or jasper granules. The iron-oxide minerals form clearly defined granular or elliptical grain clusters that are derived from an oolitic or granular texture. Discrete grains of anhedral magnetite and hematite, as well as intimate intergrowths of the two minerals, occur in this iron-formation. Narrow bars or bands of specular hematite penetrate the large magnetite grains and fine hematite grains may be clustered around the borders of magnetite grains. Platy specular hematite is developed along later shear planes or planes of schistosity where it cuts across magnetite grains. The top 20 feet of oxide iron-formation is thin banded to slaty, consists predominantly of magnetite in granular quartz and contains a small amount of grunerite and actinolite. The average thickness of the lower part of the iron-formation in the Sunny Creek area is about 85 feet. The iron-formation contains about 30 per cent iron and between one and two per cent manganese.

The upper part of the iron-formation, consisting of banded granular quartz and mixtures of siderite and dolomite, is estimated to be from 50 to 100 feet thick. The lithology is highly variable and intraformational breccia zones are present in the lower 40 feet of this stratigraphic unit. Most of the granular quartz bands are buff to grey on fresh surfaces but weather from light buff to deep rusty brown, depending on the amount and kind of finely disseminated carbonate present. The interbanded carbonate layers are cream to buff-grey and weather to various shades of rusty brown or dark chocolate-brown. They often have a motley brown surface, suggesting an intimate mixture of several kinds of carbonate.

Zones of intraformational breccia or conglomerate in the lower part of this member range in thickness from a few inches, where half-inch bands of quartz are broken up, to zones several feet thick where the fragments are much larger.

Angular breccia fragments, some of which are more than 6 inches thick, commonly rectangular or elongated, are distributed in random orientation in a brown weathering carbonate and granular quartz matrix. Breccia fragments consist of laminated sugary-textured quartz, angular to subrounded carbonate chips that weather to various shades of brown, and some grey oxide facies of iron-formation. The oxide iron-formation fragments are more abundant near the base of this member. A small amount of pyrite is present in the carbonate matrix of this breccia.

Lean carbonate quartz iron-formation bearing fine-grained cummingtonite is interbanded with more massive brown-weathering dolomite above the breccia zones. Spotted carbonate and quartz and interbanded dolomite and quartz with disseminated grunerite make up the upper part of this member. A massive bed, 5 to 6 feet thick, of dark chocolate-brown to black weathering siderite, and a small amount of quartz, is present in the middle part of the upper iron-formation. Powder X-ray patterns of this material confirm that the carbonate in this bed is mainly siderite. Samples of lighter brown weathering carbonate from other beds were identified by X-ray as dolomite and the variation in colour of the weathered surfaces would indicate variation in iron content. Granular textures are discernible in many of the carbonate bands despite extensive recrystallization of this material.

The transition from quartz-dolomite of the upper iron-formation to black schist occurs within a few feet but thin dolomite beds are present in the lower 30 or 40 feet of the schist. The black slaty schist, containing carbon, sericite, and chlorite, called the Chioack Formation has some cummingtonite beds and some arkose beds. The Abner dolomite, which is a buff weathering, white to grey rock, occurs above the Chioack schist, and is succeeded by quartz-biotite schist, known as the Mannic schist. Intermediate to basic lavas are interbedded with some of the Mannic schist in the upper part of this rock succession. Rocks above the iron-formation are intruded by gabbro dykes and sills.

Leaf Lake Iron Range

The iron-formation of the Leaf Lake iron range extends along the west margin of the belt of geosynclinal rocks from Dragon Lake in the south, across Leaf Lake to Pig Lake in the north. Seven ore zones have been investigated on this 100-mile-long range, and the three zones of greatest economic interest have been explored in considerable detail. Of the three zones named the western North Finger Lake, the Middle, and the South Leaf, the western North Finger Lake zone is the largest and lies along the west side of Chioack River about 5 miles southwest of Leaf Bay. The iron-formation is well exposed along the east side of a north-trending range of hills. The deposit forms a monoclinal structure of metataconite that is about 3 miles long and dips 10 to 20 degrees east. The metataconite zone is 80 to 100 feet thick and is composed mainly of thin-banded magnetite and hematite in granular quartz. Diamond drill holes in this zone have indicated more than 74,030,000 tons of potential ore, grading 29.4 per cent iron which can be

mined with a very favourable stripping ratio of waste rock and overburden to ore. The average manganese content in this metataconite is between 1 and 1.5 per cent but is higher in the siderite-rich zones above the metataconite. The phosphorus, titanium, and sulphur content is insignificant.

The Middle zone, 2.3 miles south of Leaf Lake, is more than 2,000 feet long, and is part of a monoclinal structure that dips 20°E. The metataconite is comparable in thickness and grades to that of the western North Finger Lake zone.

The South Leaf zone is immediately south of Leaf River and about a mile west of longitude 70°W on the map. The metataconite zone is thinner in this deposit than in the two deposits immediately south but the grade of material is comparable.

The other four zones as described by Waddington (1960) include the Dragon Lake-Irony Lake, west Finger Lake, eastern North Finger Lake, and the Leaf Lake-Pig Lake zones. The Dragon Lake-Irony Lake zone is 9 miles long and has potential ore reserves of 16,240,250 tons at Dragon Lake and 87,768,780 tons at Irony Lake. It consists of spotted silica carbonate, black-weathering silica carbonate, thin-bedded jasper iron-formation, brown carbonate, and thick-bedded jasper formation. The west Finger Lake zone is 12,000 feet long and 300 to 1,100 feet wide, and consists of interbedded carbonate and chert, some brown carbonate and thin layers of thin-bedded jasper iron-formation usually rich in magnetite. The eastern zone in the North Finger Lake area is 7,000 feet long and consists of magnetite-hematite iron-formation beds up to 65 feet thick which contain 26,358,550 tons of potential ore. The Leaf Lake-Pig Lake zone, which extends north from Leaf Lake for a distance of 13 miles, consists of magnetite and hematite iron-formation similar to that found on the south shore of Leaf Lake. The grade of the ore is somewhat higher than it is elsewhere but the individual bands are narrower.

According to Waddington (1960) potential ore reserves totalling 266,604,920 tons in the Leaf Lake iron range are estimated to be 45,967,320 tons of carbonate ore containing 20.90 per cent iron, 2.06 per cent manganese, and 35.23 per cent insolubles, and 220,637,600 tons of magnetite-hematite iron-formation containing 31.12 per cent iron, 1.62 per cent manganese, and 43.73 per cent insolubles.

Hopes Advance Bay-Ford Lake Area

In 1951, claims were staked in the Ford Lake area, about 15 miles west of Hopes Advance Bay on the west shore of Ungava Bay by Ross Toms who interested Cyrus S. Eaton of Cleveland in acquiring mining property in this area. On the recommendation of Hugh Roberts, a consultant geologist for the Eaton interests, diamond-drilling and geological investigations were carried out in 1952 under the direction of H. S. Hicks, and considerably more property was staked. With the exception of obtaining bulk samples for metallurgical tests, very little work was done in 1953 and 1954. In 1953, an exploration licence for 160 square miles in

the area was granted to Atlantic Iron Ores Limited, a subsidiary company of Premium Iron Ores Limited. In 1955, a more intensive program of geological mapping and systematic sampling was started under the direction of P. E. Auger, and a diamond-drilling program was begun in 1956. At the end of the 1958 field season a total of 42,440 feet of diamond-drilling, distributed on eight different ore zones or deposits indicated more than 581,700,000 long tons of potential ore with an average grade of 35.7 per cent soluble iron and 225 million long tons of possible ore. Engineering studies and plans have been completed for a beneficiating plant at Hopes Advance Bay, harbour facilities, 20 miles of railway from Hopes Advance Bay to Ford Lake, a townsite, and other facilities required for producing ore. Ungava Iron Ores Company Limited, which is owned jointly by Premium Iron Ores and associated American and Canadian companies and by five West German steel companies headed by F. Krupp of Essen, was formed in 1957 to continue development of properties of Atlantic Iron Ores Limited and International Iron Ores Limited.

Method of Investigation

Results from exploration mapping, systematic surface sampling, diamond-drilling, and detailed geological mapping have been carefully correlated at all stages of development. Geological maps completed in 1952 at a scale of one inch to 2,000 feet and in 1955 and 1956 at a scale of one inch to 1,000 feet, served to show the general distribution of the potential ore zones, the location of continuous channel samples taken at intervals of 1,000 feet, and to permit preliminary estimates of ore reserves and grade to be made. A number of bulk samples used for metallurgical research ranged in size from a few hundred pounds to over 300 tons. The plan for the drill program, based on results from surface sampling and geological mapping, has been to drill holes perpendicular to the banding in the iron-formation at intervals of 200 to 500 feet depending on complications in local structure, on section lines that are spaced 1,000 feet apart. Vertical drill-holes are used for beds with low dips, and holes inclined at 45 to 60 degrees are used for steeply dipping beds. In the Iron Valley zone results from vertical holes drilled at 1,000-foot intervals on a square grid pattern confirmed previous results from surface sampling. Almost 100 per cent of the size E drill-core was recovered during this drilling program. The core was split and samples 5 feet long were taken and classified as one of four submembers of the iron-formation. Experience has shown that satisfactory results are obtained by grouping a maximum of five samples and assaying this composite sample for soluble iron instead of assaying individual samples. Detailed geological mapping, on a scale of one inch equal to 200 feet with 10-foot elevation contours, is done concurrently or following the drilling on a deposit, to help establish tonnage and grade and to provide basic information for the preparation of mine plans. The plane-table survey on which this detailed map is based is controlled by a more accurate transit survey of the property. A topographical and geological profile, on a scale of one inch equal to 50 feet, is prepared for each section that is drilled.

General Geology

The Ford Lake range lies along part of the northwest border of the Ungava geosyncline, and the general geological setting is similar to that of the Leaf Lake area. The younger rocks dip southeast and in ascending order include biotite schist, quartzite, iron-formation, black mica schist, with quartzite, various types of metasedimentary rock, and volcanic rocks intruded by gabbro sills and derived amphibolite. The regional structure in the Ford Lake area consists of a broad synclinal fold that plunges gently southeast. At the west end of Ford Lake the strike of the geosynclinal rocks changes from northwest to east and continues east as far as Hopes Advance Bay where it again swings north. Iron-formation is exposed almost continuously around the perimeter of this syncline from Hopes Advance Bay to the west end of Ford Lake, a distance of 20 miles (*see* Fig. 1). Iron-formation and associated sedimentary rocks dip gently south for the first 8 miles west of Hopes Advance Bay, in the Bay zone, and west from there as far as the east end of Ford Lake it strikes southwest but is more highly deformed. Northwest of Ford Lake the iron-formation strikes northwest and is complexly folded around the axis of the regional syncline. A number of broad open synclines with a few adjacent anticlines overturned to the southwest form the Ford Lake group of orebodies. The axial lines of the smaller local folds plunge gently southeast. An outlier of younger Precambrian rocks surrounding Hicks Lake about 5 miles north of the east end of Ford Lake forms a basin structure known as the Iron Valley zone that is about 1½ miles wide.

Description of Rock Types in the Area

This area has been divided into ten main zones or parts for detailed exploration and investigation of the potential ore (*see* Fig. 2). The descriptions of rock types given below is based mainly on observations made in the Castle Mountain zone. The main formational units do not differ greatly from zone to zone although specific lithological units may be more extensively developed in one area than in another. There may be considerable variation in the stratigraphic order and extent of development of the subdivisions of the iron-formation in the various zones. This local variation is due mainly to changes in deposition of the original sedimentary facies and structural deformation has further complicated a detailed study of the stratigraphy in some of the zones. The Castle Mountain zone has been chosen to illustrate the general stratigraphy because it is easily accessible, the section is well exposed, the zone is in the central part of the area, individual rock members are well developed, and structural deformation is at a minimum.

Granite and granite gneiss complex. The granite exposed in the flat valley bottom on the west side of the Castle Mountain zone is pinkish grey, coarse grained (5 mm), and its components are 20 to 30 per cent grey to bluish grey quartz, 20 per cent biotite in ragged coarse clusters, and the remainder pinkish grey potassium feldspar. Most of the rock is massive with a hypidiomorphic texture, but crudely developed foliation was noted in a few places.

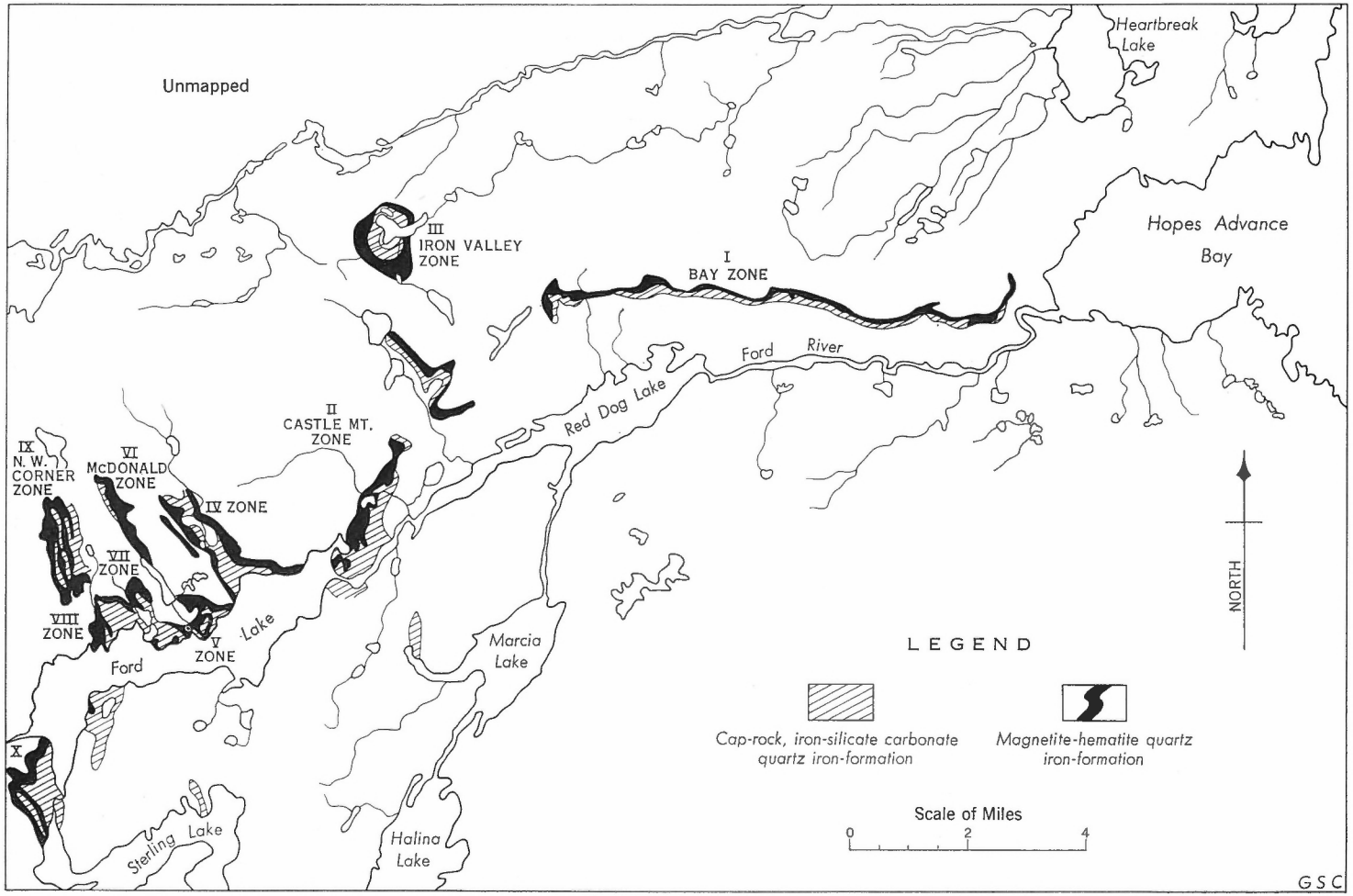


Figure 2. ***Potential ore zones on the Ford Lake iron range. (Based on information supplied by Ungava Iron Ores Company.)***

Ford Lake Formation. Quartzite and garnet biotite chlorite schist make up the Ford Lake Formation, which overlies the granite unconformably and is the basal formation in the section of younger Precambrian rocks. The quartzite member is generally a few tens of feet thick, fine grained, massive to poorly banded, and is interbanded with schist in many places. Garnet and green amphibole are disseminated in some lenses of the quartzite.

Table of Formations, Castle Mountain Zone

	Local Formation Names (from Atlantic Iron Ores Limited)	Lithology	Approximate Thickness (feet)
Late Precambrian	Leaf Bay Group	Volcanic and sedimentary rocks. Diorite and gabbro sills, and amphibolite rocks	—
	Red Dog Formation	Micaceous schists and slates with minor carbonate and quartzose beds	—
	Iron-formation and cap rock	Iron silicate-carbonate-quartz iron-formation	50–100
		Grunerite-magnetite-quartz iron-formation	35–50
		Hematite-magnetite-quartz iron-formation	150–200
		Carbonate-iron silicate-magnetite-quartz iron-formation	40–50
	Ford Lake Formation	Quartzite, and garnet-biotite-chlorite schist	up to 100
		Unconformity	
Early Precambrian	Archæan complex	Granite and granite gneiss	

The garnet-biotite-chlorite schist is very thinly banded, highly schistose, dark grey with a greenish cast, and varies considerably in composition and in the relative proportions of different minerals. Thin, fine-grained quartzite lenses are present in many places. Zones 10 to 15 feet thick in the upper part of this schist member contain up to 20 per cent of finely disseminated magnetite that has

considerable garnet and biotite associated with it. Although this rock is completely recrystallized, a delicate interbanding is discernible. Bands, $\frac{1}{4}$ inch thick, consisting of fine-grained, brown biotite, chlorite, and $\frac{1}{2}$ to one millimetre pink sieve textured garnet crystals alternated with $\frac{1}{8}$-inch-thick bands consisting of a fine-grained mosaic of quartz and anhedral magnetite grains. Some very fine grained hematite is present with the magnetite. The garnet-biotite-chlorite schist is lenticular and varies in thickness from a few feet to more than 100 feet.

Iron-formation. The iron-formation is composed of three principal members which are carbonate-iron silicate-magnetite-quartz iron-formation at the base, a hematite-magnetite-quartz or metataconite iron-formation in the middle part, and a banded or spotted iron silicate-carbonate-quartz iron-formation or cap rock forming the upper member.

The transition from garnet-biotite-chlorite schist to the *lower member* of the iron-formation takes place within a few feet in the Castle Mountain section but in some of the other areas the base of the iron-formation is difficult to define. Usually the lower part of the iron-formation can be recognized by the dark amber-coloured grunerite-rich bands, rusty brown carbonate lenses, or magnetite grunerite quartz bands in dark grey schist. Variations within short distances in the lithological facies in the lower iron-formation are indicated by differences in the relative proportions of iron minerals present and by changes in the thickness of the banding. A carbonate-rich facies of this member consists of alternate bands, 1 inch to 4 inches thick, of grey-buff quartzitic rock bearing disseminated carbonate and grunerite, and bands consisting of rusty brown weathering carbonate, coarse-grained grunerite, and finely disseminated magnetite. Thin laminations in the coarser carbonate bands are due to streaks of grunerite or magnetite grains. Some of the carbonate bands or lenses interbanded with quartzitic rock tend to be stubby and irregular with boudinage structure. Where carbonate is less abundant, the iron-formation is usually thinly banded or laminated and is made up of grey quartz layers that alternate with grunerite and magnetite and occasionally grunerite and garnet layers. Some facies contain biotite and green amphibole with grunerite, magnetite, and quartz, and in places platy specular hematite. About 70 per cent of the grunerite is aligned parallel to the bedding and accounts for the good schistosity in this rock, the remainder of the grunerite is randomly oriented in fibrous clusters. Irregularly shaped magnetite grains present in oval clusters appear to be relicts of an original granular or oolitic texture. A specimen of carbonate has been identified in X-ray powder photographs as dolomite and no siderite has been identified in thin sections from carbonate-rich bands. It is believed that the finely disseminated magnetite in dolomite has been derived from siderite during the regional metamorphism. The magnetite-grunerite-carbonate-quartz member of the iron-formation is usually less than 50 feet thick.

The *middle member* forms potential metataconite iron ore in this area. It is composed principally of oxide facies of iron-formation and has a stratigraphic thickness of 160 to 200 feet. In some of the mineable zones this member is much thicker due to thickening and duplication by structural deformation. It has been

demonstrated in less deformed zones that the stratigraphic thickness of the whole member increases rapidly downdip. The figures quoted are probably about average thickness for the middle member.

Four main lithological facies are recognized in this member and are based on the relative amounts of magnetite and hematite present with banded granular quartz. They are mapped as magnetite, magnetite-hematite, hematite-magnetite, and hematite metallic iron-formation. Individual lithological units are lenticular and their order of succession and thickness varies greatly from one drill-hole to the next. Extensive sampling shows that the average iron content is about 35 per cent and that it does not vary greatly from one lithological facies to another.

The banding in this dark grey to bluish grey iron-formation ranges in thickness from one inch to one foot with thin (¼ inch or less) laminations present in most of the better-defined bands. The texture and mineral composition is fairly uniform within an individual band but relative proportions of magnetite and hematite, and the texture of these minerals vary from band to band. The granular to sugary texture of this rock reflects the uniform mosaic or granular intergrowth of the quartz grains that is developed through recrystallization and metamorphism. The iron-oxide grains are irregular in outline and magnetite grains tend to be blocky, but specular hematite grains are usually elongated to platy and, where abundant, the iron-formation may be schistose. Intergrowths of magnetite and hematite grains have mutual grain boundaries or make up clusters of individual grains. Hematite is prevalent along shear planes, and plates of hematite cut across relict textures suggesting that some of it may have recrystallized after the magnetite. Magnetite is the predominant iron-oxide mineral in the upper part of this member where it has grunerite and lesser amounts of anthophyllite or actinolite associated with it. A small amount of carbonate present as disseminations or thin wispy lenses in some beds weathers dark brown leaving small pits or channels on exposed surfaces.

The *upper member* of the iron-formation, called cap rock, is a banded to spotted quartzitic rock, rich in iron-silicate minerals and carbonate. The transition from the grunerite-magnetite-quartz facies of the upper part of the middle or metataconite member to the cap rock member is abrupt and is marked by a conspicuous increase in the amount of grunerite and associated green amphibole. The grunerite and iron-silicate-rich horizon is greenish brown and consists of felty textured grunerite and quartz layers interbanded with magnetite and carbonate-rich layers. The relative proportions of these minerals vary greatly in this thin-banded horizon, which is usually highly deformed and appears to be about 20 feet thick. This horizon grades upward to a lighter buff, thin-banded quartzitic rock interbanded with buff-brown carbonate lenses. Much of the carbonate is present in irregular stubby deformed lenses, but in other zones in the cap rock carbonate occurs as ellipsoidal nodules that range from ¼ inch to 3 inches long in their greatest dimension. These nodules scattered through the quartzitic matrix rock may constitute more than 50 per cent of a single band, and because they weather dark brown leaving deep oval pits on the rock surface the cap rock has a distinctive spotted appearance. Hard pellet-like nodules of carbonate can often

be picked from an exposed surface where sufficient weathering has taken place to release the nodules from the quartzitic matrix. As shown by X-ray analyses, the carbonate in these nodules consists of dolomite. The upper part of the cap rock member contains much less carbonate than does the lower part. The quartz layers interbanded with grunerite or carbonate are believed to be recrystallized chert because of their thin-banded character and the fact that features typical of clastic sedimentary rocks such as outlines of original clastic grains with quartz enlargement have not been detected. The carbonate and iron-silicate bands present with the quartz layers are almost certainly derived by metamorphism of facies of iron-formation, and beds of slate or arkose or other types of clastic rock that would suggest a clastic origin for the quartzose rock are absent. The thickness of the cap rock member ranges from 50 to 100 feet.

Red Dog Formation. The metasedimentary rocks which are conformable above the iron-formation are called the Red Dog Formation by company geologists. This formation is composed of thin-bedded, grey to black micaceous schist and slate with minor carbonate or quartzose lenses or bands.

Leaf Bay Group. Volcanic rocks, present with sedimentary rocks in the upper part of this section, are considered to be part of the Leaf Bay Group in the table of formations used by company geologists. Diorite and gabbro sills intrude the micaceous schists and volcanic rocks. Some of these sills have been transformed to foliated amphibolite rocks by shearing and metamorphism.

Ford Lake Iron Range

The Ford Lake iron range extends for 20 miles from the west end of Ford Lake eastward to Hopes Advance Bay. The location of the potential ore zones is shown on Figure 2. The metataconite in this range consists of mixtures of specular hematite and magnetite in granular quartz and grades 35 per cent iron or more. Deposits along the northwest side of Ford Lake form tightly folded and faulted synclines that plunge southeast, but deposits east of Ford Lake are mainly east- or south-dipping monoclines. Metallurgical tests indicate that a concentrate grading 68 to 71 per cent iron with 96 to 98 per cent recoverable iron can be obtained economically by magnetic roasting of the ore at ¾-inch size followed by grinding and wet magnetic separation.

The various potential ore zones, each designated by roman numerals on Figure 2, are described briefly in order from east to west as follows: *I, Bay zone* extends west from Hopes Advance Bay for 8 miles and the metataconite is exposed along a series of long narrow ridges that rise from 50 to 100 feet above the surrounding country. The metataconite is average grade consisting of banded mixtures of magnetite and hematite in granular quartz with some interbanding of carbonate and iron-silicate-rich material. This iron-formation, in the lower part of the section, lies close to the unconformity with granite gneiss and it thickens and thins along strike forming a series of lenticular metataconite zones that dip from 15 to 45°S. The amount of carbonate-quartz cap rock overlying

the metataconite varies from place to place along strike but a substantial tonnage of potential ore has been outlined which will require the removal of a comparatively small amount of waste rock when mined.

II, Castle Mountain zone extends north to northwest for over 12,000 feet from the east end of Ford Lake and forms a low ridge that rises 50 to 75 feet above the level of Ford Lake. The stratigraphic section for this zone has already been described in some detail in this report. The metataconite is of uniform grade throughout the deposit and is composed of bedded mixtures of magnetite and hematite in quartz. This deposit forms a monoclinal structure that strikes 25°N and dips 10 to 35°SE. Minor undulation of the iron-formation beds is caused by cross-folding and some repetition of the iron beds takes place along low easterly dipping faults which strike south. Primary sedimentary facies of iron-formation thicken appreciably from west to east in this deposit and the metataconite zone is more than 300 feet thick in the eastern part of the potential ore zone.

III, Iron Valley zone, about 5 miles north of the east end of Ford Lake, forms a circular basin structure, more than a mile wide, around Hicks Lake—the border or rim of the basin rising more than 300 feet above the level of the lake. Around the north and east borders dips are near vertical or beds may even be overturned to the west of the basin. On the west side of the basin metataconite is well exposed and nearly flat lying. In the central and northeastern parts of the area iron-formation is downfolded along a northwest-trending syncline and is covered by cap rock and schist.

IV, Number 4 zone forms a northwest-trending synclinal structure at least 8,000 feet long and 2,000 feet wide, which at the south end plunges southeast under Ford Lake. Its central area is covered by cap rock.

V, Number 5 zone extends north for nearly a mile from the central-north shore of Ford Lake. The metataconite beds are several hundred feet thick and form a very complex structure (*see* Fig. 3). At the south end, the metataconite and cap rock form an imbricate structure on faults that dip east and strike northwest. Towards the north the iron beds form a flat basin or saucer-shaped syncline which is thrust west over the crest of an anticline that is overturned to the west. At the north end, the syncline plunges out and the crest of the anticline appears to plunge northwest. Figure 3 illustrates how very complex local structures may be in this region and the necessity of obtaining a thorough knowledge of the stratigraphy and subsurface geology when proving ore and planning open-pit mine operations.

VI, McDonald zone extends for 2½ miles northwest from Number 5 zone, along the west side of a northwest-trending granite ridge and dips 30°W. Drag-folds and fracture cleavage show that the upper beds on this slope have been thrust west relative to lower beds. It seems likely that the granite ridge formed a

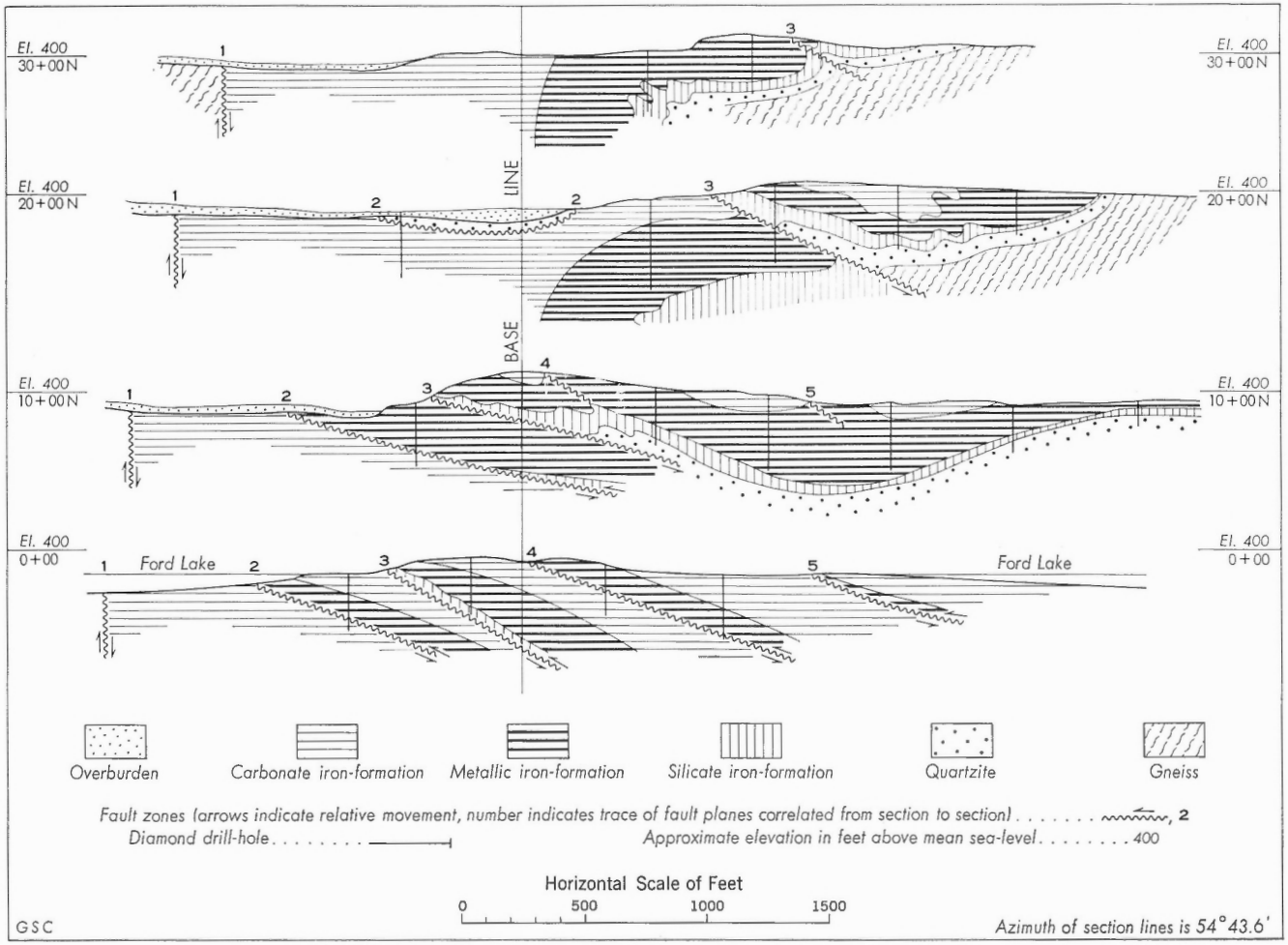


Figure 3. ***Cross-sections illustrating the geology of Number 5 zone in the Ford Lake iron range. Sections are spaced 1,000 feet apart from north to south. (Based on information supplied by Ungava Iron Ores Company.)***

buttress and that only upper beds were transported by the stress directed from the east. Towards the west of this deposit the iron-formation is covered by cap rock and is bounded by a northwest-striking fault.

VII and VIII zones, immediately west of Number 5 zone, underlie an area along the north shore of Ford Lake about 1½ miles wide and a mile long. They consist of two broad synclines that plunge southeast and are separated by a northwest-striking fault.

IX, Northwest Corner zone lies about a mile north of the west end of Ford Lake, and is about 2 miles long and over one-half mile wide. It consists of a number of east-dipping metataconite beds that have not been explored in detail.

X, Number 10 zone, at the extreme southwest end of Ford Lake, is more than 1½ miles long and a mile wide, and consists of a southeast-plunging syncline.

Area South of Payne Bay

The management of Oceanic Iron Ore of Canada Limited was taken over by the Rio Tinto Management Services Limited on May 1, 1956. A wholly owned subsidiary of Oceanic Iron Ore of Canada Limited, Oceanic Iron Ore (Quebec) Limited, was incorporated in the province of Quebec on June 5, 1956, and was granted a special development licence covering 119 square miles west of Ungava Bay extending south from Payne River in New Quebec. Thirty miles south of this property in the Greer Lake area the company has further holdings of about 9 square miles.

Most of this property was originally staked by Ross Toms in 1954, and his claims were acquired by a syndicate headed by Joseph H. Hirshhorn of New York and Toronto. W. L. C. Greer with a party of nine men examined the property in 1954 and recommended further exploration and development work. During the following 3 years, exploration work was directed by A. T. Griffis and included geological mapping, systematic sampling, more than 16,000 feet of diamond-drilling, engineering studies and bulk sampling for concentration tests. Metallurgical testing was conducted at the Mines Branch in Ottawa, at the Ontario Research Foundation in Toronto, at Hibbing, Minnesota, and at Frankfurt, Germany.

General Geology

The general geology for the region south of Payne Bay is shown on a geological map prepared by Bergeron (1957); information from this map is summarized in the regional map that accompanies this report.

Pink and grey granite gneisses and grey quartz-plagioclase-biotite-muscovite gneisses are overlain unconformably by younger Precambrian rocks composed, in ascending order, of quartzite, mica schist, and garnet-mica schist, iron-formation, biotite-muscovite schist, quartz-biotite-muscovite-plagioclase schist, and metamorphosed sedimentary and volcanic rocks intruded by gabbro or derived meta-gabbro.

The area can be considered in two parts that are divided by a north-striking thrust fault that extends from the east end of Slush Lake north to where it passes under glacial deposits about 2 miles west of Brochant Bay. Most of the area east of this fault is underlain by grey quartz-plagioclase-biotite-muscovite gneisses but younger sedimentary rocks including quartzite, iron-formation, mica schist and meta-volcanic rocks underlie an arcuate belt between the thrust fault and a broad curve that extends south from Brochant Bay to De Bonnard Bay. A northwest-trending belt of younger sedimentary rocks about 5 miles south of De Bonnard Bay, approximately 2 miles wide and 5 miles long, forms a narrow southeast-plunging syncline.

Most of the area west of the fault is underlain by younger Precambrian rocks folded into a series of three prominent anticlines and three synclines that plunge gently to the southeast. The east limbs of these anticlines consist of low easterly dipping to flat sheets. In the crestal parts of the folds the beds are tightly folded, thrust faulted, and overturned to the southwest. Imbricate structures are developed in these crestal areas on thrust faults that dip less than 20°E. Locally faulted segments of beds and fault planes may dip much more steeply eastward. Doubly plunging folds and minor drag-folds suggest that there may have been a second stage of folding when cross-folds were developed on the major northwest-trending structures. Many of the structures may be highly complex in detail as Figures 4 and 5 indicate.

A substantial tonnage of ore has been demonstrated in the Payne Bay zone, which extends southeast from Payne Bay for several miles, and in the Morgan Range, which extends southeast from Morgan Lake for about 12 miles.

Payne Bay Zone

The iron-formation of the Payne Bay zone is exposed in a large outcrop on the south shore of Payne Bay where the older Precambrian gneisses and the younger Precambrian schist, quartzite, and iron-formation were examined.

Banded and foliated biotite-feldspar gneisses, granite, foliated amphibolite, and gabbro are overlain by younger Precambrian rocks. The lowest member of the younger group of rocks is a grey to greenish grey, thin-banded, fine-grained, slaty, biotite-chlorite schist that bears a few garnetiferous bands and thin quartz-rich bands. The transition from this lower foliated schist to quartzite takes place within a few feet.

The quartzite at the base of the iron-formation is gunmetal-grey on fresh and exposed surfaces, is massive to crudely banded, medium to fine grained, and appears to be completely recrystallized. On fresh surfaces the rock has a glassy appearance, rounded vitreous quartz grains are visible, a few grains of biotite are disseminated throughout the rock, and in some places thin bands of arkose are present.

Twenty feet of biotite-chlorite-garnet schist, quartzite, and various types of iron-formation form the transition zone between quartzite and iron-formation. A two-to-three-foot band of quartz-specular hematite schist or iron-formation is found in places immediately above the quartzite. Thin glossy plates of specular

hematite coating planes of schistosity are very conspicuous but the specular hematite grains within laminae in the schist are more blocky and less noticeable. Lenses of magnetite are present locally. The remaining upper part of this zone varies greatly in composition and consists predominantly of interbanded lenticular zones of dark grey to black biotite-chlorite-garnet schist. Other rock types in this member that are less well developed are composed of quartz-biotite-schist with bands of pink garnet (¼ inch thick) and porphyroblastic sheaves or clusters of randomly oriented grunerite or cummingtonite, grunerite-hypersthene-quartz schist, thin, dark grey quartz bands with variable amounts of disseminated magnetite or specular hematite, and grey-buff quartz lenses that bear carbonate, grunerite, and hypersthene.

Table of Formations, Payne Bay South Area

	Local Formation	Lithology	Approximate Thickness (feet)
Late Precambrian	Mica schist	Black and dark grey, fine-grained mica schist	
	Iron-formation and cap rock	Grunerite-carbonate-quartz cap rock	–100
		Interbanded specular hematite, magnetite, and grunerite quartz iron-formation	50
		Magnetite-specular hematite-quartz iron-formation, thin banded	80
		Grunerite-magnetite-quartz iron-formation, thin banded, highly schistose	80
		Biotite-chlorite-garnet schist interbanded with quartzite, thin banded, with some magnetite and iron silicates	20
		Specular hematite-quartz iron-formation, glassy quartz and well-developed, platy specular hematite	2–3
	Quartzite	Quartzite, arkosic in places	30–40
	Lower schist	Biotite-chlorite-garnet schist	20–30
		Unconformity	
Early Precambrian	Archæan complex	Biotite-feldspar gneiss, amphibolite, and gabbro	

The banded silicate-magnetite facies in the lower part of the iron-formation rarely exceeds 80 feet in thickness and is usually thinner. It breaks into small angular fragments which produce a rubbly surface on outcrops. It is thin banded (3 to 5 mm), schistose, and composed of alternate bands containing variable amounts of grunerite, magnetite, and quartz. Parts of it contain very little magnetite. A small amount of carbonate distributed in specks, spots, and thin lenses, weathers dark brown and the rock is deeply pitted where carbonate has been removed by weathering. Thin sections of specimens selected for their high iron-silicate content show that this facies is composed essentially of grunerite, hypersthene, and magnetite with parallel bands and streaks of magnetite that are 2 to 3 mm thick. About 50 per cent of the amber to khaki coloured grunerite needles are oriented with long axes in the plane of the banding but the remainder of the grunerite needles are randomly oriented, in a felted mass. These needles average about 2 mm in length, and about 80 per cent of the magnetite is present in irregular to ragged clusters that measure 0.3 to 0.4 mm in their broadest dimension. The proportions of grunerite and hypersthene to magnetite in most of the rock is estimated to be about 3 to 1.

The grunerite-magnetite-quartz schist grades upward to grey-blue metataconite type of iron-formation. This well-banded to laminated formation is of greatest economic interest in the area and is made up mainly of alternate bands of magnetite, specular hematite, and quartz in variable proportions. The banding in most of the rock is ¼ to ½ inch thick, but in local parts of the section it may be 10 inches thick. The lower 20 to 30 feet of the member is rich in magnetite with small amounts of grunerite but higher in the section appreciably more specular hematite is intimately mixed with the magnetite. A small amount of dolomite, probably forming less than 5 per cent of the rock, is distributed as narrow lenses or specks along some layers in the banded structure. It is detected on the weathered surface by pits or pockets with rusty brown coatings or stain. Bluish green amphibole and muscovite grains showing decussate orientation are very sparsely disseminated along some bedding planes.

The quartz in the iron-formation is steely grey to glassy, has a sugary to granular texture and is friable and crumbly in some of the beds. In thin sections the quartz is entirely recrystallized and forms a fine-grained mosaic with very irregular suture-like grain boundaries. The iron-oxide minerals occur in irregular ragged grain clusters disseminated along uneven crudely defined bands. About 80 per cent of the magnetite and hematite is intimately mixed in grain clusters that measure 0.3 mm in their longest dimension. Most of the hematite occurs in platy grains aligned parallel to cleavage planes that transect bedding or compositional banding. Plates of hematite cut across granular intergrowths of magnetite and hematite indicating that it formed after much of the rock recrystallized. The oolitic to granular textures that are conspicuous in the less metamorphosed iron-formation in the central Labrador geosyncline are not well preserved in this area

due to extensive recrystallization of the quartz and the amalgamation of the iron oxide into coarser grains during metamorphism. However, the relict form of the earlier oolitic to granular texture is marked by clusters of magnetite and hematite grains that form oval clusters or rings. This textural feature is usually obscure or absent where cleavage or shearing is developed.

This metataconite formation appears to be fairly uniform in composition both along and across the strike of the bedding, and it is estimated to contain between 30 and 35 per cent of iron. No information is available to the writer on the ratio of magnetite to specular hematite or on how this ratio varies throughout the formation.

A transitional zone from 30 to 50 feet thick is found between the specular hematite-magnetite-quartz member and the upper iron-formation member or cap rock. The lower part of this zone is distinguished by an increase in the amount of grunerite and the interbanding of grey to black magnetite-hematite-quartz bands and khaki coloured grunerite-hypersthene-magnetite-quartz bands. This thin-banded, slaty iron-formation is estimated to contain about 20 per cent of recoverable iron in the form of magnetite. In its upper part the gradation to cap rock is indicated by a decrease in the amount of magnetite and a conspicuous increase in the amount of rusty brown carbonate.

The cap rock weathers rusty brown, varies greatly in composition, and consists mainly of quartz, grunerite, hypersthene, and ferruginous carbonate. Limited field observation suggests that it is less than 100 feet thick but structural deformation has made determination of its true thickness difficult. The greater part of the cap rock is composed of cream to light buff, fine-grained, banded-to-massive quartz rock that has a distinct sugary to granular texture. Bands of quartz ranging in thickness from a fraction of an inch to a foot are separated by layers of carbonate, grunerite, and iron-silicate minerals. Discontinuous bands or lenses of buff weathering carbonate are more abundant within the lower part of this quartzitic member and constitute 20 to 30 per cent of the rock. Most of the carbonate lenses are a fraction of an inch thick but may be thicker in places and because they weather readily they leave deep grooves or channels on the rock surface. The carbonate is creamy grey on fresh surfaces and contains coarse-grained grunerite and hypersthene distributed in crude bands or streaks. Most of the grunerite is deep amber to khaki coloured, and the grains are conspicuously oriented perpendicular to the lenses and bands of carbonate and quartz. Other carbonate grunerite and quartz zones are distinctive for the spotty distribution of $\frac{1}{4}$-to-$\frac{1}{2}$-inch-oval-shaped carbonate nodules. Grunerite in the form of rosettes or oval-shaped grain clusters occurs within the carbonate nodules. Carbonate from this spotted rock was determined by X-ray powder patterns to be dolomite.

The upper iron-formation or cap rock is overlain by a dense, fine-grained, black micaceous schist that may be several hundred feet thick. Schistosity and cleavage planes cut the original thin beds and laminated structure of the rock. This member appears to have been derived from black slate and greywacke.

Structure of the Payne Bay Zone

The structure of the Payne Bay zone was studied in two outcrop areas: one on the south shore of Payne Bay, and the other—the Black area—about 2 miles southeast of the shore outcrop. In the shore outcrop, segments of the succession of younger Precambrian rocks are repeated a number of times by faulting and the bedded rocks and faults dip 50 degrees northeast and strike southeast.

In the Black area a number of faults and folds are exposed on the slopes of a prominent hill and the geological structure can be studied in detail. Iron-formation and parts of the rock succession are repeated on thrust faults that strike north and dip 20 degrees or less to the east and some segments of the rock succession appear to be folded in two directions. The first order of folds have doubly plunging axial lines that trend north to northwest. Most of these folds have gently dipping east limbs but the west limbs dip steeply west or are often overturned to the west. The west limbs of anticlines may be eliminated by local thrust faults that strike northwest, dip steeply east, and cut the crests of many of the folds. Cross-folds that plunge to the southeast appear to be imposed on the first order of folds but these cross-flexures may be the result of steeply plunging axial lines of the first order of folds. A diagrammatic cross-section of the structure in this area was sketched in the field and is shown in Figure 4. It is noteworthy that iron-formation with other parts of the succession is repeated four times by faulting in this major imbricate structure.

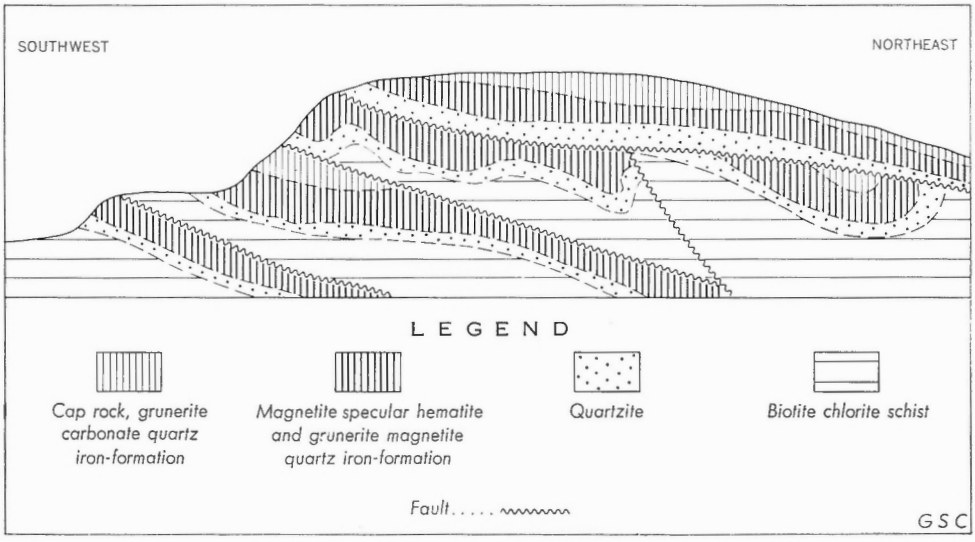


Figure 4. ***Diagrammatic section, approximately 3,000 feet long, of the geological structure in the Black area south of Payne Bay. (Based on a field sketch.)***

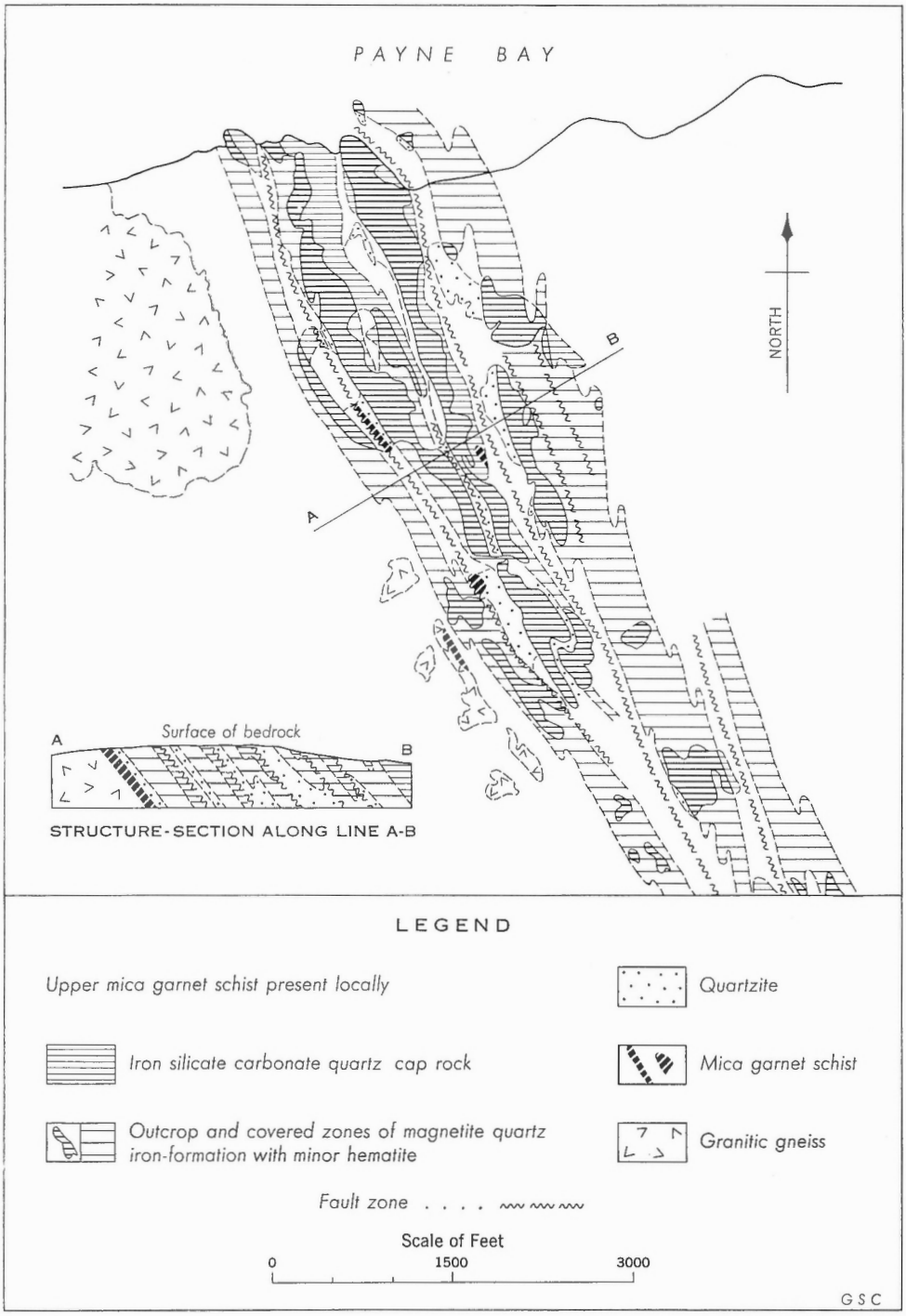


Figure 5. ***A geological plan and section of the shore outcrop area in the Payne Bay ore zone. (Based on information supplied by Oceanic Iron Ore of Canada Limited.)***

Payne Bay Ore Zone

The Payne Bay iron range, including the shore outcrop and the Black area described above, extends southeast from Payne Bay for several miles. More than 71,300,000 tons of potential ore grading 23.85 per cent recoverable iron that can provide a concentrate grading 66.32 per cent iron has been indicated by diamond-drilling completed by Oceanic Iron Ore of Canada Limited.

Morgan Lake Iron Range

The Morgan Lake syncline is about 15 miles south of Payne Bay and about 15 miles west of the west coast of Ungava Bay. It forms a prominent northwesterly trending range of hills composed of younger trough rocks surrounded by granite gneiss. Iron-formation is well exposed around the perimeter of this syncline which is about 8 miles long and 3 miles wide. The syncline plunges southeast with iron-formation on the west limb dipping gently east towards the centre of the basin and on the east limb dipping steeply west. International Iron Ores Limited holds claims covering most of the east limb and northwest part of the syncline and Oceanic Iron Ore of Canada Limited holds the southwest part of the west limb.

The main ore zone in the southwest part of the Morgan range, explored by Oceanic Iron Ore of Canada Limited, is oval-shaped in plan, and metataconite is well exposed over a plateau area 15,000 feet long and 1,700 feet wide. The higher grade metataconite is about 100 feet deep on an average and is underlain by about 30 feet of leaner material. The metataconite consisting of thin-banded mixtures of magnetite, iron silicates, and quartz is nearly flat lying in the western part of this plateau and much of it is well exposed or covered by thin layers of siliceous cap rock towards the northeast. Granitic rocks are exposed in the central part of this plateau and iron-formation in the eastern part beyond the area of indicated ore is largely concealed by overburden. Company engineers report that 350 million tons of potential ore grading 24.56 per cent iron that can be beneficiated to give a concentrate grading 63.3 per cent iron have been indicated by diamond-drilling in a 3-mile-long section, and that 181 million tons of potential ore grading 16.88 per cent iron that can provide a concentrate grading 65.4 per cent iron are indicated below the higher grade metataconite.

Metataconite in the northwest and east limbs of the Morgan syncline explored by International Iron Ores Limited is composed of thin-banded mixtures of magnetite, iron silicate, and quartz with very little hematite. The iron-formation is well exposed along a strike length of 12 miles and on the basis of surface sampling and geological mapping the company reports 25 million tons of metataconite grading 32.4 per cent iron and 0.7 per cent manganese which can be easily concentrated. There are other indications of further ore potential in this range.

Area North of Payne Bay

International Iron Ores Limited has an exploration permit from the province of Quebec for a 443 square mile tract of land around the north border of the

Ungava geosyncline north of Payne Bay. Late in 1952 Ross Toms staked a large number of claims covering the iron-formation, and International Iron Ores Limited acquired this ground in 1953 and commenced a geological-mapping, diamond-drilling, and sampling program. Intensive field work was carried out in four different parts of the property under the direction of P. E. Auger, R. Béland, and J. F. White. By the end of 1957 geological maps on a scale of one inch equal to one half mile had been completed for the whole property and more detailed maps had been prepared for four selected areas. Three of these areas were tested by diamond-drilling seventy-one holes with a total length of 8,465 feet.

Iron-formation is exposed intermittently around the perimeter of the geosyncline belt for 123 miles. On the basis of work to date company engineers estimate that more than 800 million tons of metataconite averaging 36 per cent iron is mineable from well-exposed iron-formation along 58 miles of strike length. Considerably more metataconite is present below shallow overburden or thin layers of cap rock.

Five areas that are particularly favourable for development because of their substantial reserves of potential ore and location are:

(1) The Kyak zone on the east limb of the syncline and extending northwest from Payne Bay for 6 miles.

(2) The Igloo Lake zone on the east limb of the geosyncline directly east of Roberts Lake.

(3) The Hump zone on the east limb of the geosyncline 6 miles northwest of Roberts Lake.

(4) The Yvon Lake zone 4 miles northwest of Roberts Lake on the west limb of the geosyncline.

(5) The Synclinal zone near the west and southwest shore of Roberts Lake.

Kyak Bay zone. The metataconite in this zone consists of banded mixtures of magnetite, hematite, and quartz that is underlain by a thin band of iron silicate and overlain by spotted carbonate-quartz cap rock. Most of the metataconite beds dip vertically or steeply west in this zone and the iron-formation is thickened and repeated numerous times by complex doubly plunging isoclinal folds and thrust faults. Some of the beds that dip gently west are overturned and are apparently parts of recumbent folds.

Roberts Lake zones. The four zones around Roberts Lake have not been examined as thoroughly as the Kyak zone. The metataconite is thin banded and consists predominantly of magnetite with hematite in granular quartz. Where examined by the writer in the Yvon Lake area it is 80 to 100 feet thick and is underlain by quartzite and grunerite-rich schists and overlain by carbonate quartz cap rock.

CONCLUSIONS

All the known iron deposits in this northern part of the Ungava geosyncline are of metataconite type, and consist of selected zones of metamorphosed iron-formation that can be concentrated to give high-grade iron ores. The stratigraphic successions in the various localities that include the iron-formation are similar in their major features, but the extent to which different facies of iron-formation are developed in each area varies considerably. Facies of iron-formation consisting of mixtures of magnetite, hematite, and quartz form the major ore zones throughout the region. Metamorphism has affected zones of iron ore to a variable degree, and iron-formations from zones of high-rank metamorphism are generally coarser grained than those in less metamorphosed zones; the iron minerals in the former zones can usually be concentrated more easily.

The region has been carefully prospected and the general distribution of the iron-formation as revealed by outcrops is shown on the accompanying map. It is possible that other bands of iron-formation are present outside of the areas indicated but that they are concealed by overburden or thin sheets of barren rock that have been thrust over iron-formation along low-dipping fault planes.

The potential ore proven in this region to date is all well exposed and will require the removal of a very small amount of overburden or waste rock material. Very large tonnages of potential ore are indicated in zones adjacent to the proven orebodies where the ratio of waste rock to ore increases to two to one or greater. Extensive amounts of ore may be inferred in many known iron-formation bands that have not been fully explored.

SELECTED BIBLIOGRAPHY

AUGER, P. E.

1954: The Stratigraphy and Structure of the Northern Labrador Trough, Ungava, New Quebec; *Trans. Can. Inst. Min. Met.*, vol. 57, pp. 327-330.

1958: Ungava Iron Ores Company: Geological Report on Atlantic Iron Ores Limited and International Iron Ores Limited; Unpub. rep. in files of Geol. Surv., Canada.

BÉLAND, R., and AUGER, P. E.

1958: Structural Features of the Northern Part of the Labrador Trough; *Trans. Roy. Soc. Can.*, ser. 3, sec. 4, vol. 52, p. 5.

BÉRARD, JEAN

1957: Preliminary Report on Bones Lake Area, New Quebec; *Dept. Mines Quebec,* P. R. No. 342.

1958: Preliminary Report on Finger Lake Area, New Quebec; *Dept. Mines Quebec,* P.R. No. 360.

1959: Preliminary Report on Leaf Lake Area, New Quebec; *Dept. Mines Quebec,* P.R. No. 384.

BERGERON, ROBERT

1954a: Preliminary Report on Gérido Lake Area, New Quebec; *Dept. Mines Quebec,* P.R. No. 291.

1954b: Iron Formation of the Labrador Trough; Quebec, Laval Univ., D.Sc. thesis (unpub.)

1955: Preliminary Report on Thévenet Lake Area (West Part), New Quebec; *Dept. Mines Quebec,* P.R. No. 311.

1956: Preliminary Report on Harveng Lake Area (West Half); *Dept. Mines Quebec,* P.R. No. 320.

1957a: Preliminary Report on Brochant-De Bonnard Area, New Quebec; *Dept. Mines Quebec,* P.R. No. 348.

1957b: Important Low Grade Iron Deposits of the Province of Quebec; from paper presented at the 25th Ann. Conv. of the Prospectors and Developers Assoc. of Canada, March 1957.

DE ROMER, HENRY S.

1956: The Geology of the Eastern Border of the Labrador Trough, East of Thévenet Lake, New Quebec; Montreal, McGill Univ., M.Sc. thesis (unpub.).

FAHRIG, W. F.

1955: Lac Herodier, New Quebec; *Geol. Surv., Canada,* Paper 55-1.

1956a: Lac Herodier (East Half), New Quebec; *Geol. Surv., Canada,* Paper 55-37.

1956b: Cambrian Lake (West Half), New Quebec; *Geol. Surv., Canada,* Paper 55-42.

GÉLINAS, LÉOPOLD

1958a: Preliminary Report on Gabriel Lake Area (West Half), New Quebec; *Dept. Mines Quebec,* P.R. No. 373.

1958b: Preliminary Report on Thévenet Lake Area (East Half), New Quebec; *Dept. Mines Quebec,* P.R. No. 363.

GRIFFIS, A. T.

1957: The Rio Tinto Story, Oceanic Iron Ore of Canada Limited; *Precambrian Mining in Canada,* October 1957, p. 62.

GROSS, G. A.

1959: Metallogenic Map for Iron in Canada; *Geol. Surv., Canada,* Map 1045 A-M4.

JANES, T. H., and ELVER, R. B.
1958: A Survey of the Iron Ore Industry in Canada during 1957; Mineral Res. Div., Dept. Mines Tech. Surv., Canada, Min. Inf. Bull. MR 27.
1959: Survey of the Canadian Iron Ore Industry during 1958; Mineral Res. Div., Dept. Mines Tech. Surv., Canada, Min. Inf. Bull. MR 31.

LINDEMAN, E., and BOLTON, L. L.
1917: Iron Ore Occurrences in Canada; *Mines Branch, Canada,* vols. 1 and 2, No. 217.

LOW, A. P.
1895: Report on Explorations in Labrador Peninsula, along the East Main, Koksoak, Hamilton, Manicouagan Rivers; *Geol. Surv., Canada,* Ann. Rept., vol. 8, pt. L.
1896: Report on a Traverse of the Northern Part of the Labrador Peninsula from Richmond Gulf to Ungava Bay; *Geol. Surv., Canada,* Ann. Rept., vol. 9, pt. L.
1898: Report on an Exploration of the South Shore of Hudson Strait and of Ungava Bay; *Geol. Surv., Canada,* Ann. Rept., vol. 11, pt. L.

MARTIN, W. C.
1929: Reconnaissance, part of Payne Bay, Ungava Bay, for the Nipissing Mining Company Limited, 1929; MS. rept. in files of Dept. Mines Quebec.

MCGERRIGLE, H. W., and GIRARD, H.
1950: Special Report on the Iron Deposits of the Province of Quebec; *Dept. Mines Quebec,* P.R. No. 262.

OWENS, O. E.
1955a: The Geology of Part of the "Labrador Trough" South of Leaf Lake, New Quebec; Montreal, McGill Univ., Ph.D. thesis (unpub.).
1955b: Abstract—*Can. Min. J.,* vol. 76, No. 10, p. 96.

ROSCOE, S. M.
1957: Cambrian Lake (East Half), New Quebec; *Geol. Surv., Canada,* Paper 57-6.

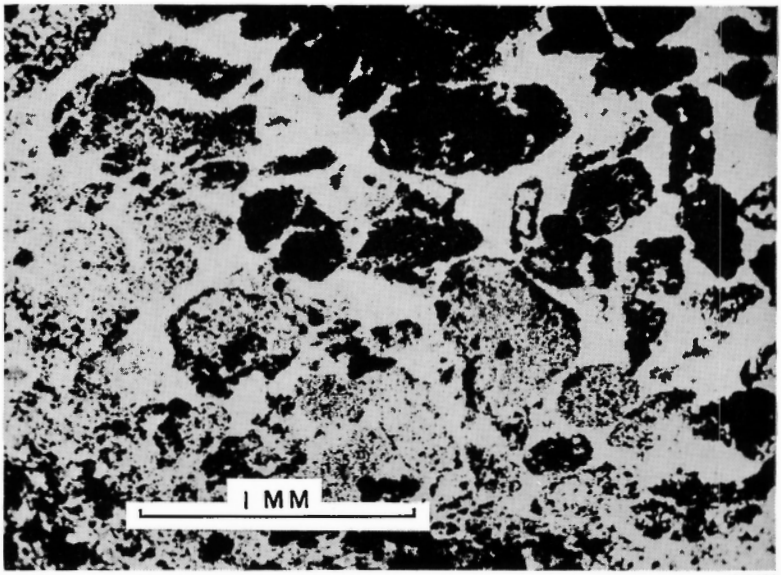
SAUVÉ, PIERRE
1955: Preliminary Report on Gérido Lake Area (East Half), New Quebec; *Dept. Mines Quebec,* P.R. No. 309.
1956a: Preliminary Report on Leopard Lake Area (East Half), New Quebec; *Dept. Mines Quebec,* P.R. No. 325.
1956b: Preliminary Report on De Freneuse Lake Area (West Half), New Quebec; *Dept. Mines Quebec,* P.R. No. 332.
1957a: Preliminary Report on De Freneuse Lake Area (East Half), New Quebec; *Dept. Mines Quebec,* P.R. No. 358.
1957b: The Geology of the East Half of the Gérido Lake Area, New Quebec, Canada; Baltimore, Maryland, John Hopkins Univ., Ph.D. thesis (unpub.).
1959: Preliminary Report on Leaf Bay Area, New Quebec; *Dept. Mines Quebec,* P.R. No. 399.

SHEPHERD, NORMAN
1957: The Mineralogy of a Metamorphosed Iron Formation from Payne Bay, Ungava, New Quebec; Univ. of Toronto, M.A. thesis (unpub.).

SLIPP, R. M.
1957: Base Metal Deposits in the "Labrador Trough" between Lake Harveng and Lac Aulneau, New Quebec; Montreal, McGill Univ., Ph.D. thesis (unpub.).

WADDINGTON, G. W.
1960: Iron Ore Deposits of the Province of Quebec; *Dept. Mines Quebec,* P.R. No. 409.

WHITE, C. E.
1958: Cyrus Eaton Operations are Most Northerly in Quebec-Labrador Trough; *Precambrian Mining in Canada,* October 1958.
1959: The Ungava Project; *Western Miner and Oil Rev.,* vol. 32, No. 11, p. 48.



110422

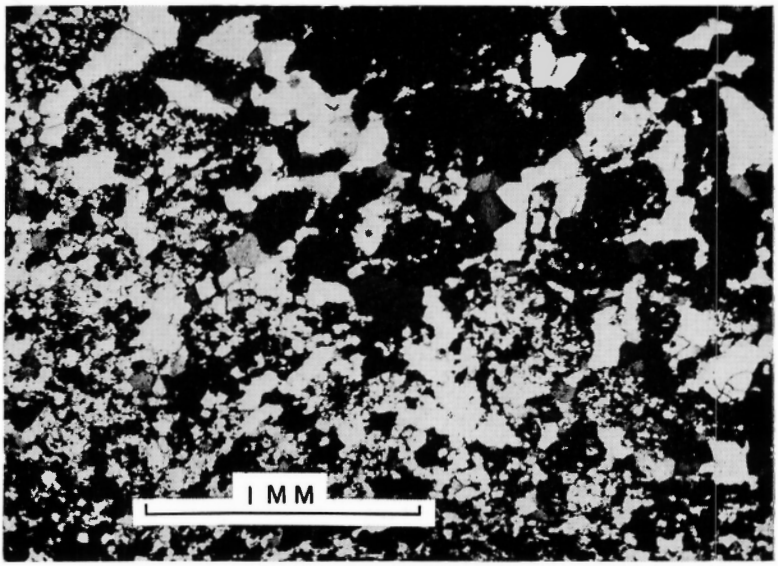
A. *Shows thin section with transmitted light. Mixtures of hematite and magnetite are black; quartz is white. Note relict granules and degree of recrystallization of iron minerals.*

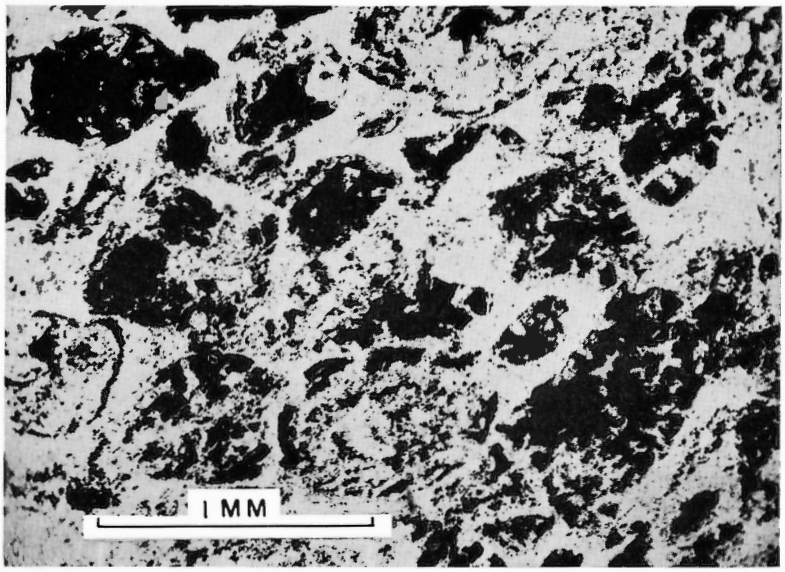
Plate I

Texture of specular hematite-magnetite-quartz iron-formation from North Finger Lake zone.

B. *View of IA with transmitted light and nicols crossed. Note cherty texture of quartz forming relict granules surrounded by a coarse-grained quartz matrix.*

110422





110421

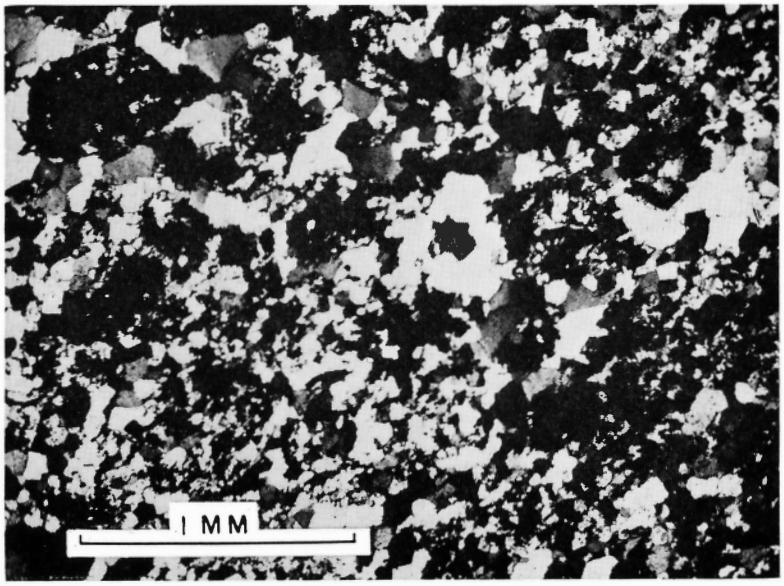
A. Shows thin section with transmitted light. Black is mixtures of hematite and magnetite; white is quartz. Note well-preserved granular to oolitic texture.

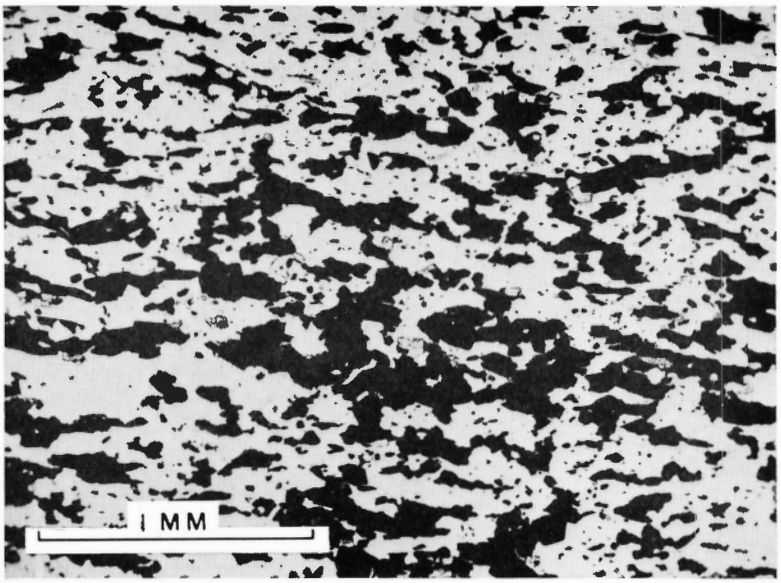
Plate II

Texture of magnetite-hematite-quartz iron-formation from North Finger Lake zone.

B. View of IIA with nicols crossed. Note cherty granules and recrystallized coarse-grained quartz matrix.

110421





110416

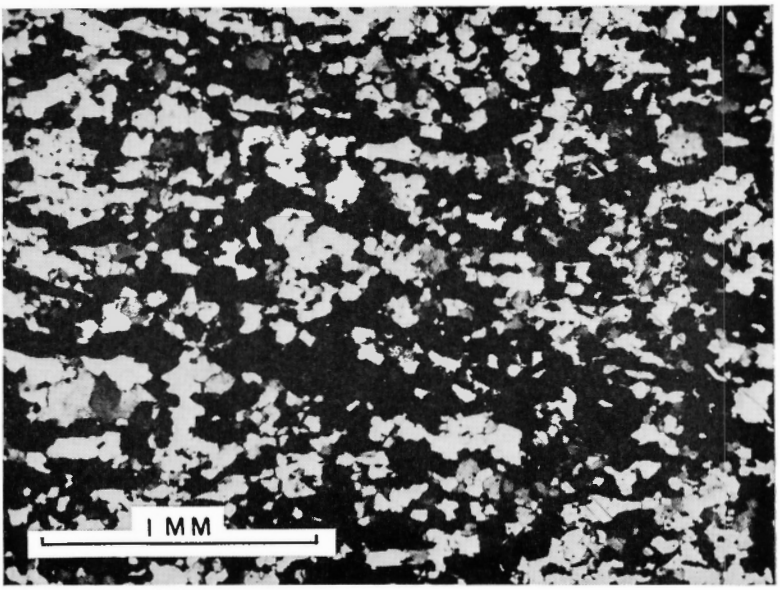
A. Shows thin section with transmitted light. Mixtures of specular hematite and magnetite are black; quartz is white. Note vague outlines of relict granules and distinct iron oxide grain clusters.

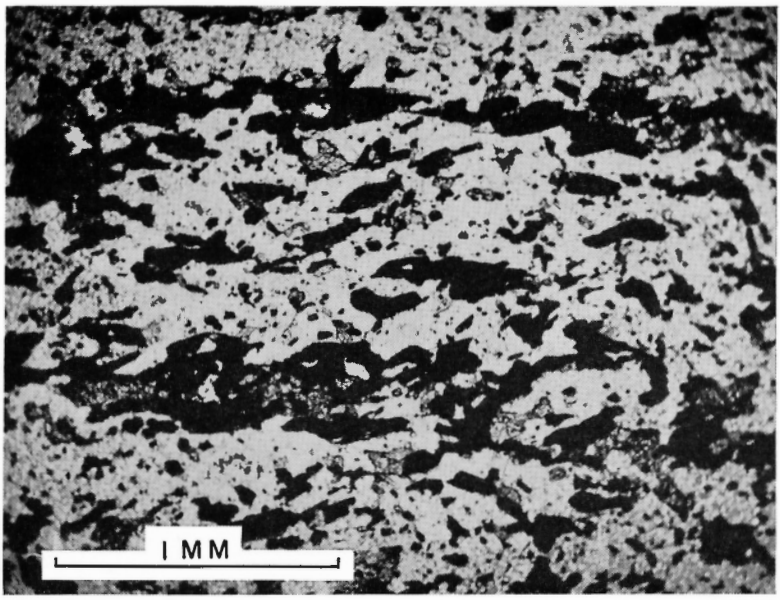
Plate III

Texture of hematite-magnetite-quartz iron-formation from Castle Mountain zone.

B. View of IIIA with crossed nicols. Note more uniform granularity of quartz.

110416





110415

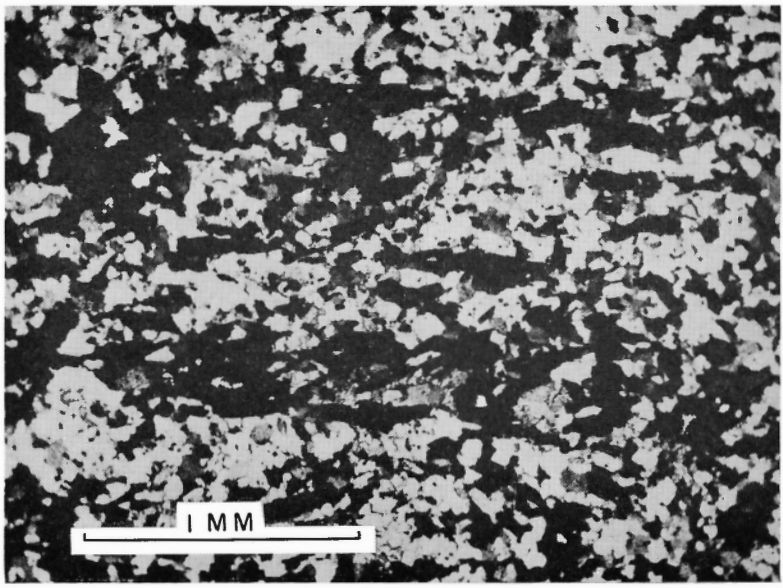
A. *Shows thin section with transmitted light. Platy specular hematite grains are black; fine-grained carbonate grains are medium grey with mottly relief; quartz is lighter grey. Note relict granules.*

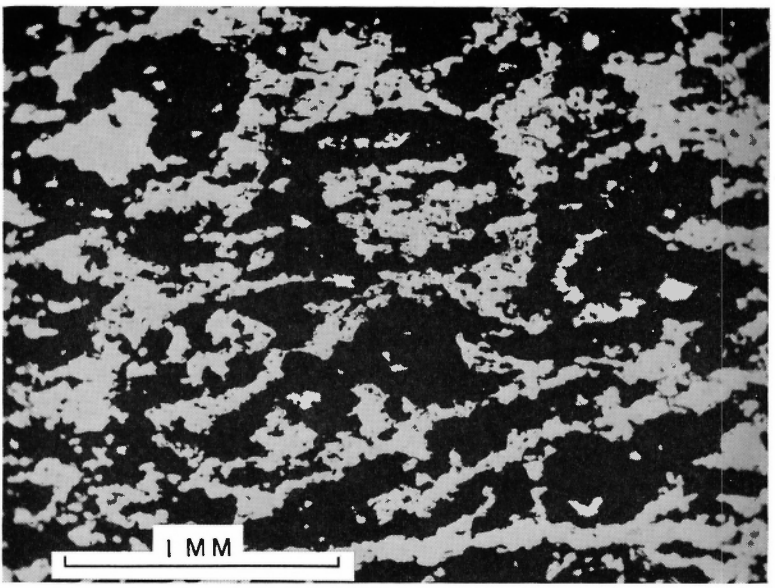
Plate IV

Texture of hematite-quartz iron-formation from Castle Mountain zone.

B. *View of IVA with nicols crossed. Note texture of recrystallized granular quartz.*

110415





110414

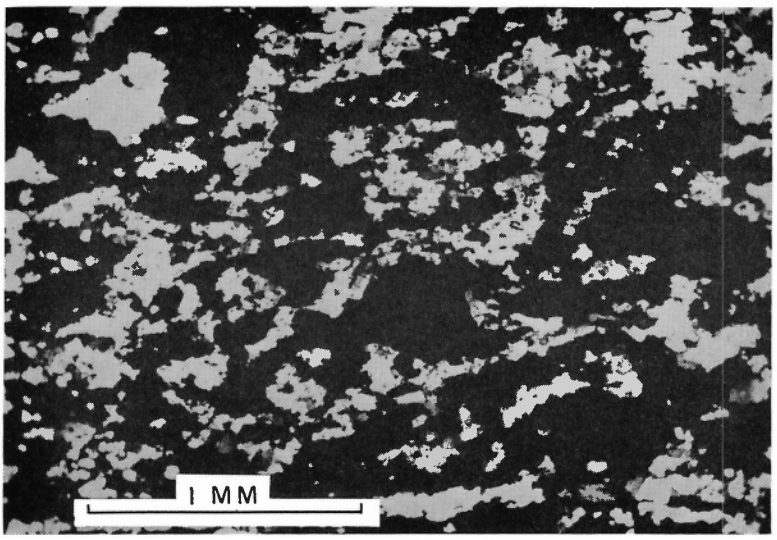
A. Shows thin section with transmitted light. Mixtures of magnetite with minor hematite are black; quartz is white. Note relict granules and well-defined iron oxide grain clusters.

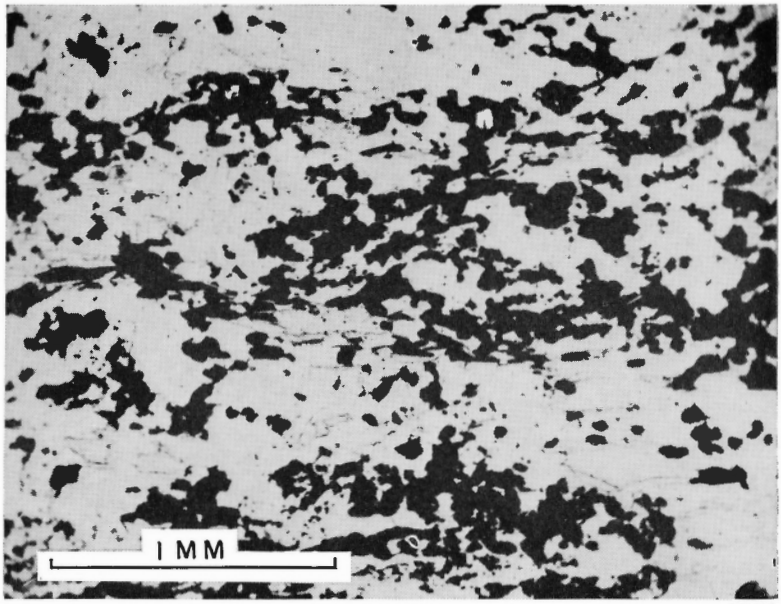
Plate V

Texture of specular hematite-magnetite-quartz iron-formation from Payne Bay zone.

B. View of VA with crossed nicols, showing coarse granular quartz.

110414





110418

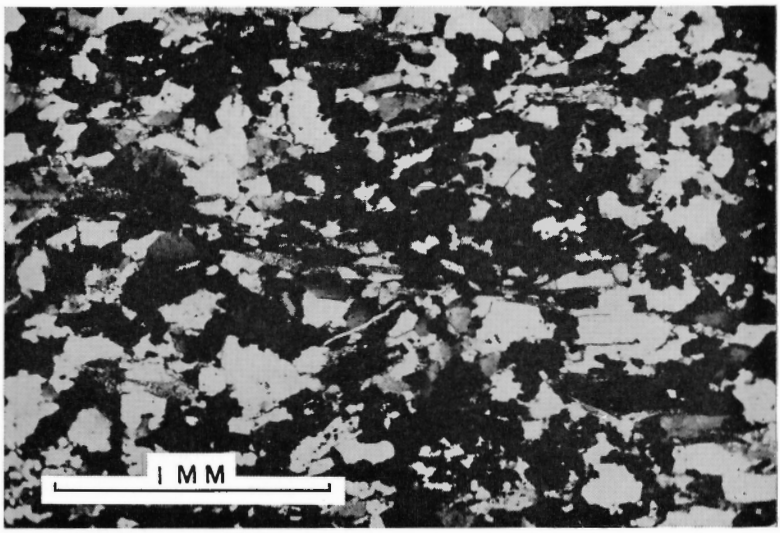
A. *Thin section with transmitted light. Magnetite with minor hematite is black; platy grains of muscovite, actinolite and grunerite are medium grey; quartz is white.*

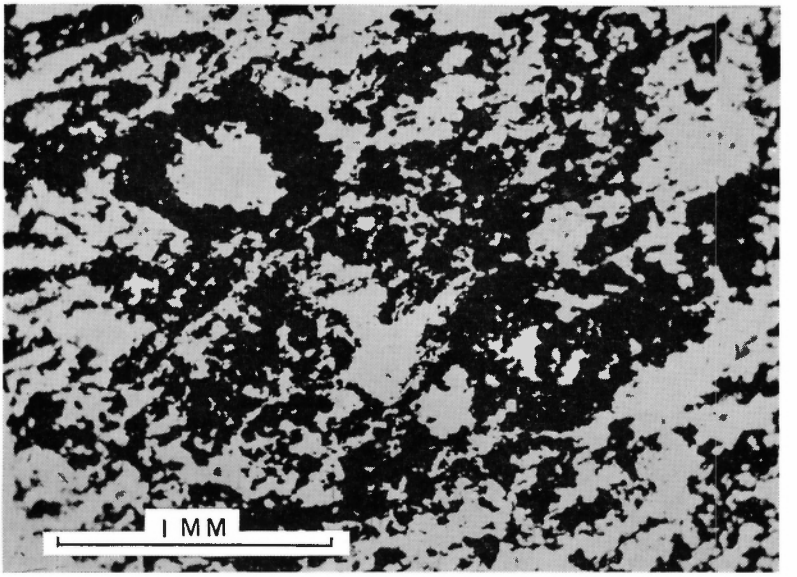
Plate VI

Texture of hematite-magnetite-quartz iron-formation from Payne Bay zone.

B. *View of VIA with nicols crossed. Note mosaic texture with oriented silicate minerals in coarse-grained quartz.*

110418





110417

A. Shows thin section with transmitted light. Mixtures of magnetite and hematite are black; quartz is white. Note relict granules and distinct iron oxide grain clusters.

Plate VII

Texture of hematite-magnetite-quartz iron-formation from Yvon Lake zone.

B. View of VIIA with nicols crossed showing granularity of quartz.

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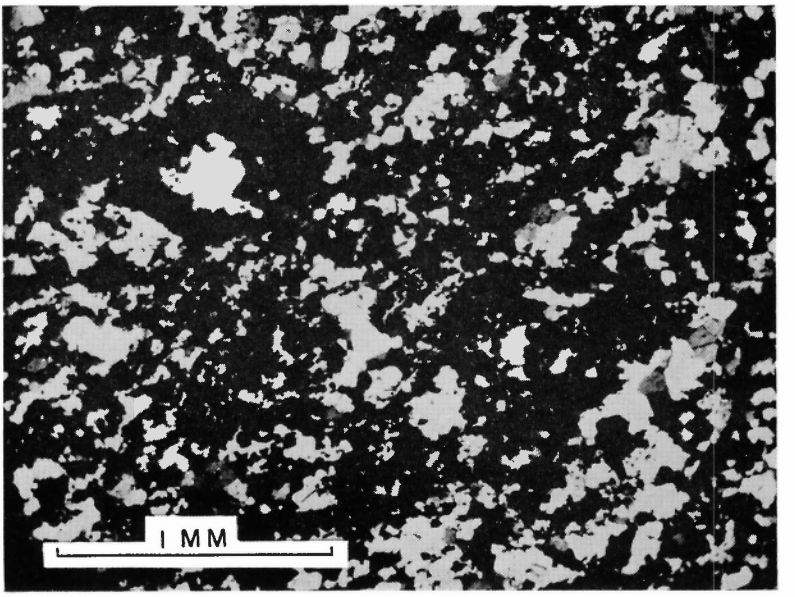

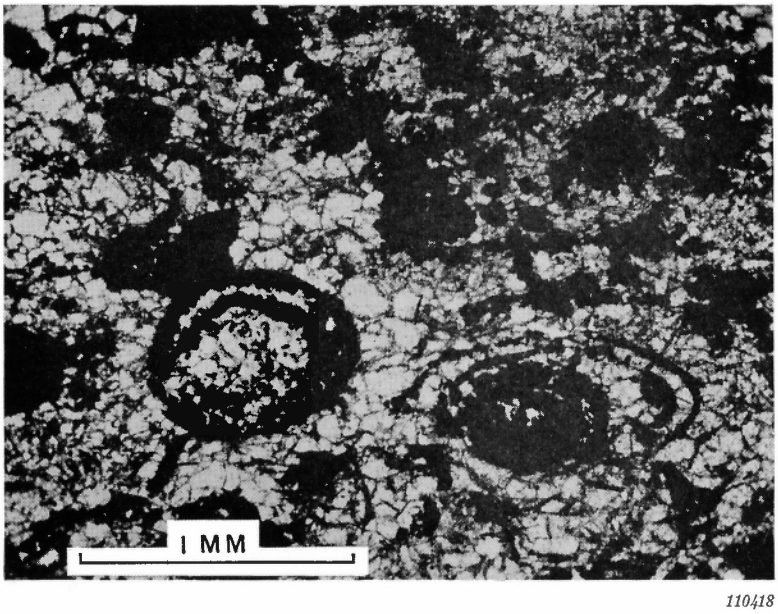

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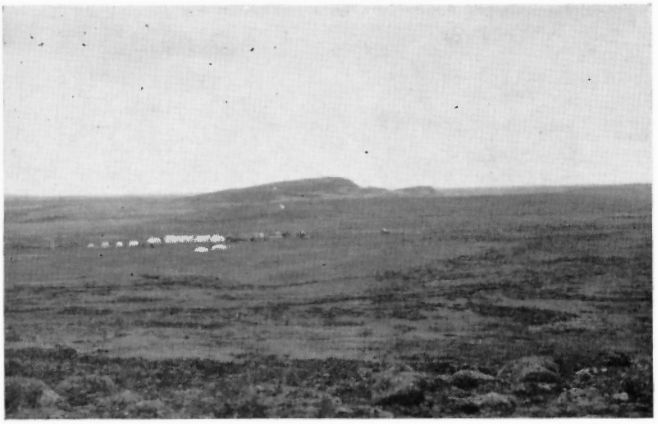
Plate VIII. ***Photomicrograph of hematite-magnetite-quartz iron-formation from Yvon Lake zone. From thin section with transmitted light showing magnetite with minor hematite in black; quartz is mottly grey. Note relict oolites in recrystallized granular quartz.***



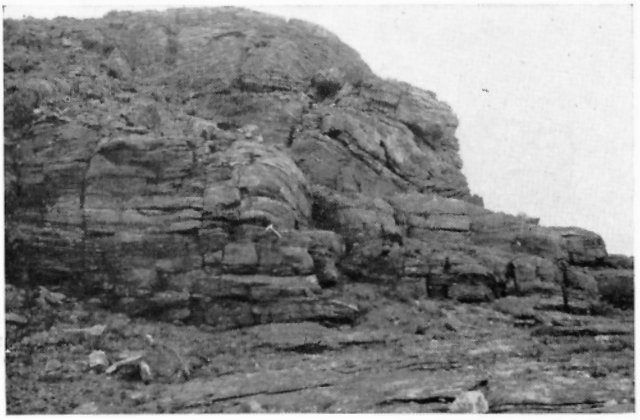
G.A.G. 4-2

A. *View southeast from Payne Bay to the Black area—which forms the hill in the background—and to the 1957 camp of Oceanic Iron Ore of Canada Limited.*

Plate IX

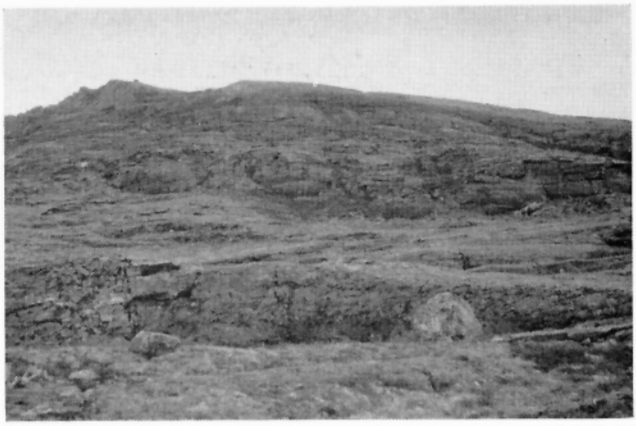
G.A.G. 4-3

B. *View west along the north shore of Ford Lake from Castle Mountain zone to numbers 4 and 5 zones, and to the 1957 camp of Atlantic Iron Ores Limited.*



G.A.G. 4-5

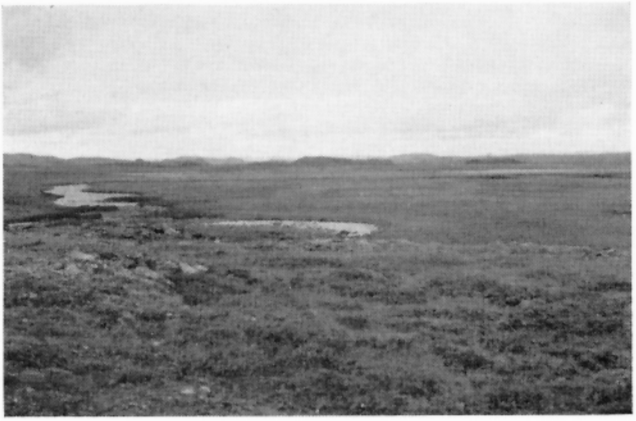
C. *Magnetite-hematite-quartz iron-formation capped by thin wavy banded iron silicate-magnetite iron-formation near the top of Castle Mountain zone east of Ford Lake.*



G.A.G. 4-6

A. View east towards bluffs of magnetite-hematite-quartz iron-formation on Castle Mountain zone in the Ford Lake area.

Plate X



G.A.G. 8-4-57

B. View north towards Leaf Lake across the coastal plane east of the Leaf Lake iron range.

G.A.G. 4-7-57

C. Hummocks of tightly folded and faulted iron-formation on the coastal plane east of the main Leaf Lake iron range, which is shown to the north in the background.