A STUDY OF PART OF THE KANIAPISKAU SYSTEM NORTHWEST OF ATTIKAMAGEN LAKE, NEW QUEBEC

by

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A STUDY OF PART OF THE KANIAPISKAU SYSTEM
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INTRODUCTION

GENERAL STATEMENT

This report is based on field work by the writer during the summers of 1948 and 1949, and on subsequent laboratory investigations at McGill University. The map-area forms part of a concession in New Quebec granted to the Hollinger North Shore Exploration Company Limited. The concession includes part of the "Labrador Trough" which contains a folded and faulted assemblage of Precambrian sedimentary and volcanic rocks (Figure 1). The first part of the report deals with the general character of the country and the regional geology. The second part is concerned with a detailed study of part of the Kanispiskau system (Late Precambrian) northwest of Attikamagen Lake, and in particular with the iron-formation and the iron ore deposits which occur within it.

The field work consisted of detailed mapping in the vicinity of several iron ore occurrences which lie to the northeast of the main ore zone in the Labrador Trough (Figures 2 and 3). Mapping was done by plane-table on the scale one inch equals 200 feet and orientation was maintained from known azimuths of the sun. In addition, a few short pace and compass traverses were made to complete the local geology. Two tri-angulation stations were erected so that the survey could be tied into the main triangulation system farther west.

Accompanying the report are two maps of the local geology on the scale one inch equals 1000 feet. The contours are based on assumed elevations of 1725 feet for Snow and Bruin lakes. This figure was chosen as the altimeter in the plane showed minus 175 feet relative to the assumed datum of 1900 feet for the seaplane base at Knob lake (Figure 2).

LOCATION AND AREA

The map-area comprises approximately 20 square miles within the region bounded by latitudes 55° 03' north and 55°13' north, and by longitudes 66°50' west and 67°07' west (Figure 2). It forms part of the New Quebec concession of the Hollinger North Shore Exploration Company Limited. The boundary between New Quebec and Labrador occurs a few miles to the east and south.

ACCESS, TRANSPORTATION AND COMMUNICATION

The chief means of access is by plane, either chartered or operated by Hollinger Ungava Transport Limited, a private company incorporated to service the interests of Hollinger Consolidated Gold Mines Limited. The planes operate from airbases at Mont Joli and Seven Islands, Quebec. The Canadian National railways passes through Mont Joli, and in summer there is regular boat service to Seven Islands from Rimouski and Matane. Personnel and supplies are transported in Douglas C-47 aircraft to Knob Lake landing strip, an interior airbase 432 miles north of Mont Joli or 317 miles north of Seven Islands, and located in New Quebec

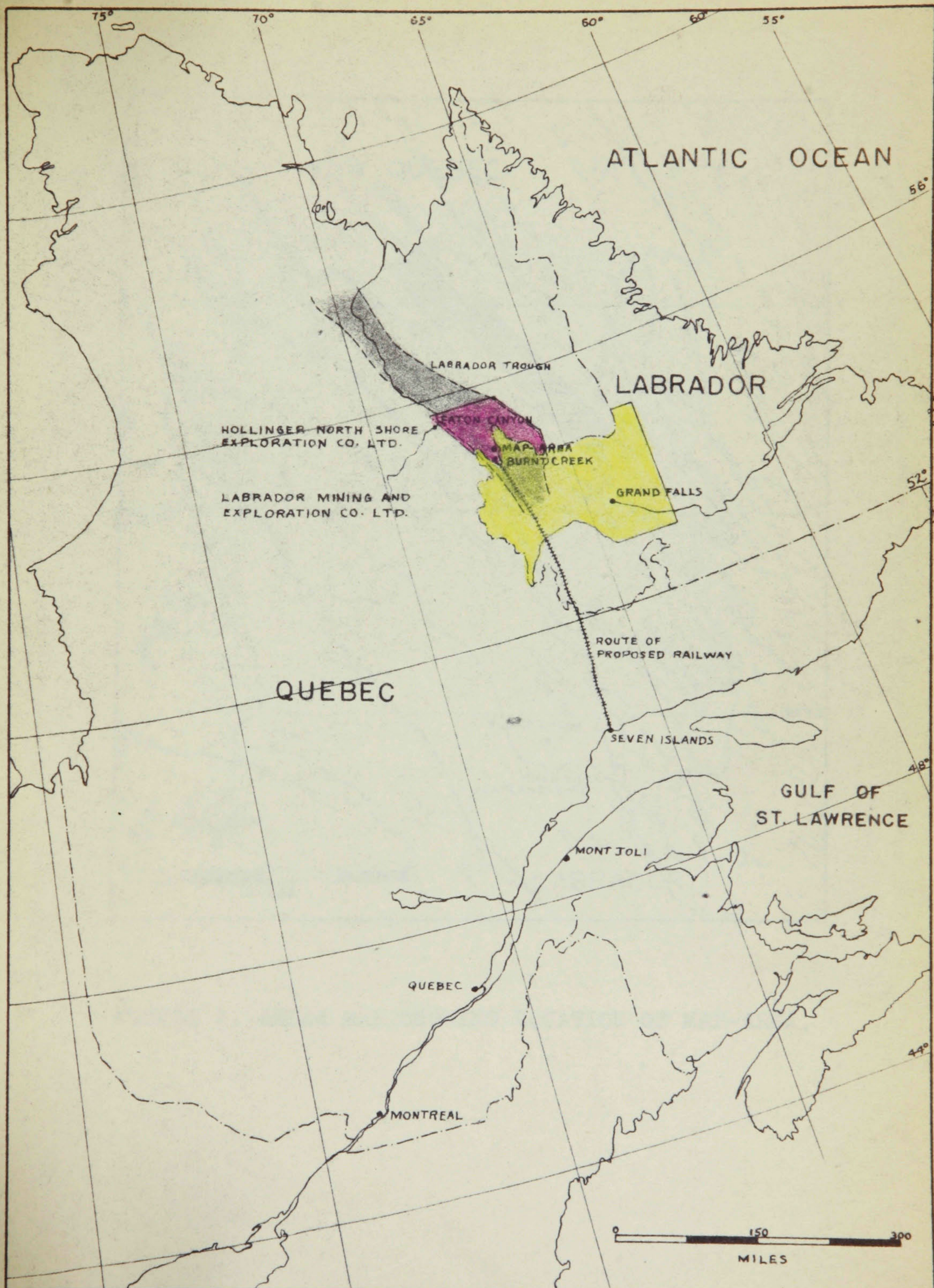

FIGURE 1. INDEX MAP SHOWING LOCATION OF CONCESSIONS AND THEIR RELATION TO LABRADOR TROUGH.

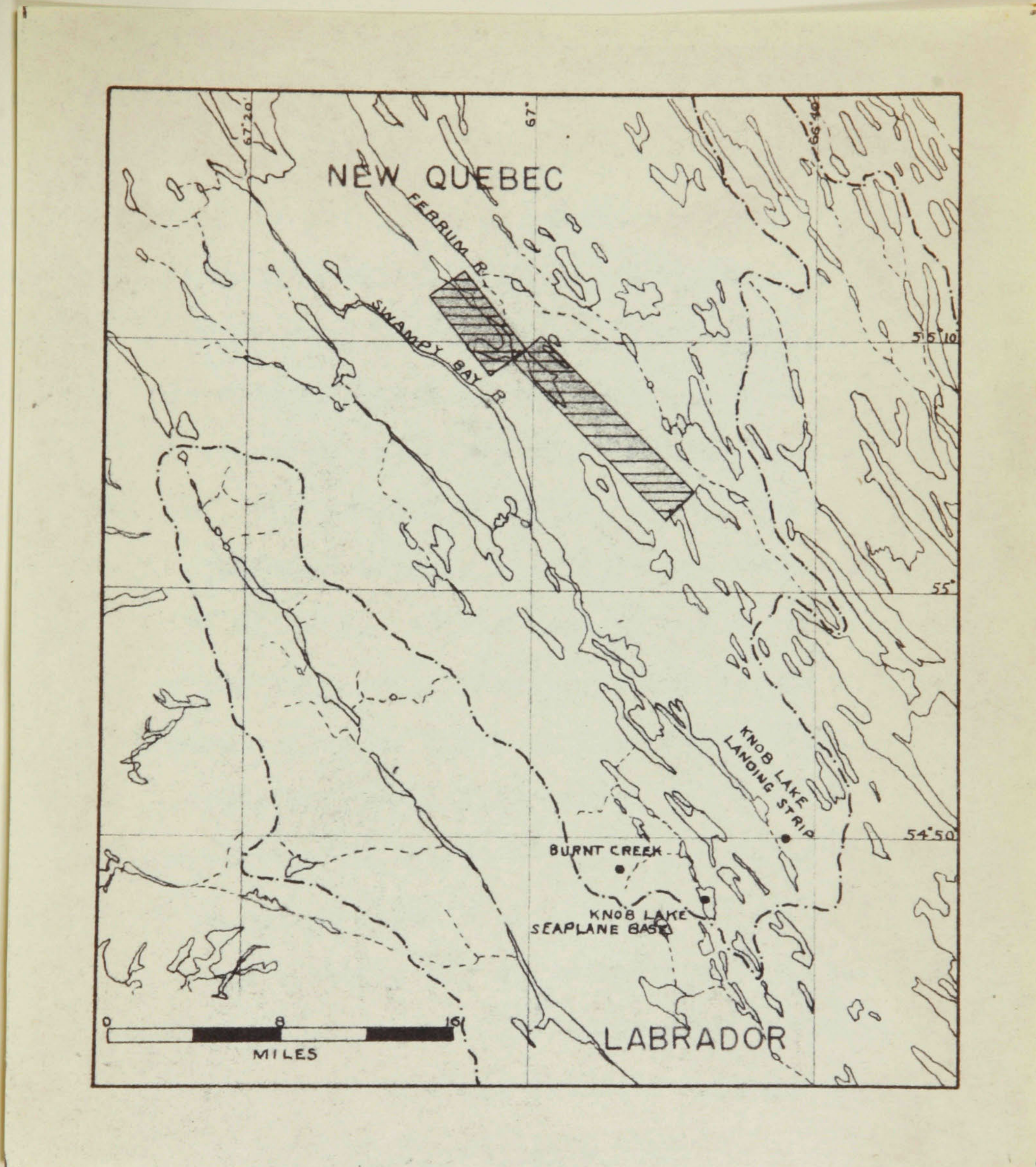

FIGURE 2. INDEX MAP SHOWING LOCATION OF MAP-AREA.

at approximately latitude 54° 50' north and longitude 66° 40' west. The base at Burnt Creek is about eight miles west of the landing strip.

Although access by canoe along any one of the main river systems is feasible, the distances, and the presence of numerous rapids and falls make this method impractical. Indian trappers from Seven Islands, who ascend the Moise river, take about a month to complete the trip.

Fifty miles of secondary road permits transportation by truck and jeep among the landing strip, base and iron deposits. The road extends northwestward from Burnt Creek for 30 miles and at the nearest point, is about 12 miles from the map-area. Transportation beyond the road is by Norseman aircraft based at Knob Lake, which is five miles west of the landing strip.

Communication is by radio from stations at the landing strip and Ashuanipi lake.

A railway location survey between Seven Islands and Burnt Creek is now in progress. This work is directed by the Quebec North Shore and Labrador Railway Company.

HISTORY AND PREVIOUS WORK

The earliest geological work in the central part of the Labrador peninsula was by A.P. Low, who, in 1893 and 1894, made a rapid reconnaissance survey along the main watercourses (Low, 1897). At this time, Low roughly outlined the "Labrador Trough" and reported on the occurrence of iron-formation (erroneously called iron ore) within it. As a result, in 1929 W.F. James and J.E.Gill investigated the iron ore potentialities and during the course of the work discovered iron ore near Ruth lake, in the vicinity of the present development. The name "Kaniapiskau Series" was given to the sedimentary, and associated igneous, rocks. In 1933, Gill, Bannerman and Tolman (1937) investigated reports of gold discoveries around lake Shabogamo, which lies at the south end of the Trough.

Labrador Mining and Exploration Company was incorporated in 1936 to prospect and develop a concession of about 20,000 square miles lying entirely in Newfoundland-Labrador and located in the upper basins of the Hamilton and Nashaupi rivers (Figure 1). Field work was directed by McKay (Quebec) Exploration Limited until 1942, when Hollinger Consolidated Gold Mines Limited acquired control. In the same year, Hollinger North Shore Exploration Company Limited was incorporated to explore and develop a concession of about 3,900 square miles in New Quebec. The concession lies northwest of the northwestern part of the Labrador concession and includes the upper basin of the Swampy Bay river and part of the upper basin of the Whale River.

Although iron ore had been discovered within the Labrador concession as early as 1929 and in New Quebec by 1938, the chief object of the early exploration was the search for gold and base metals. However, results from trenching and test-pitting carried out in 1945, indicated the potentiality of the region as a source of iron ore. At the end of 1946, thirty-six iron ore occurrences were known and by the end of 1948, surface drilling had proven the presence of at least three hundred million long tons of iron ore.

Field work within the concessions, under the direction of the Labrador Mining and Exploration Company Limited, has been in progress since 1936. The general distribution of the rock types is roughly known but a large portion is as yet unmapped. A reconnaissance survey along the Ferrum river between latitudes 54° 55' north and 55° 15' north, and including the present map-area, was made by W.G. Johnston in 1946. The results are contained in a private report (Geology of the Ferrum River area) and includes a map on the scale two inches equal one mile.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation to Dr. J. E. Gill of the Department of Geological Sciences of McGill University for his assistance, suggestions and constructive criticism of this report. In addition, the writer is indebted to Drs. A.E. Moss and J.E. Retty of Labrador Mining and Exploration Company Limited for information related to the regional geology of the Labrador Trough and for the results of several analyses.

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GENERAL CHARACTER OF THE COUNTRY

GEOMORPHOLOGY

Regional

The "Trough" Kaniapiskau system forms part of the Labrador peninsula, a region predominantly of crystalline rocks of Precambrian age, which was peneplained, recently uplifted and glaciated, and is now undergoing dissection by rivers. The uplift was accompanied by warping and the general elevation of the eastern and southern margins of the peninsula is greater than that of the central portion. Inland from the St. Lawrence river, the terrane rises rapidly and forms a rugged barrier, deeply dissected by fast-running streams which have cut canyons as much as 1,000 feet deep. A range of hills having a maximum elevation of about 3,200 feet crosses the country in an east-west direction approximately 50 miles north of Seven Islands, Quebec. From here, the surface gradually slopes northward and 100 miles inland, the general elevation is about 1,800 feet and the topography relatively flat.

In the Dyke Lake area (Figure 3), the "Trough" forms part of an interior upland 1,500 to 2,000 feet high, broken by numerous northwestward-striking ridges and chains of hills with local elevations from 100 to 1,000 feet above the surrounding country. The topography shows a close adjustment to rock structure, the details having been determined by differential resistance to erosion. The ridge and valley system must have been defined in its broader form by river erosion in Tertiary time. Glaciation, which followed, has produced many local modifications. The ridges are generally underlain by quartzose members or igneous rocks. Intervening areas are hummocky or flat, and are normally drift covered or occupied by lakes and muskegs.

Low (1897, p. 117L) gives the following description of the topography near Cambrian lake on the Kaniapiskau river (latitude 56° 30' north):

> "The general dip of the rocks is towards the north-east, and, in consequence, the mountains which they form show steep cliff-faces towards the west, with long gentle slopes on the opposite side. These beds run in ridges roughly parallel to one another and to the general strike of the rocks, that is, from south-east to north-west. They rise from 800 to 1500 feet above the surface of the lake, which is about 400 feet above sea-level, and on the western side often have perpendicular cliffs over 500 feet high, with a great talus of broken rocks at the bottom."

The present drainage of the Labrador peninsula reflects a Pliocene drainage pattern modified by glaciation. By the Pleistocene epoch the streams, rejuvenated by uplift during the Miocene, had reached a stage of late youth or early maturity. This stream pattern was disorganized by glaciation and today only here and there can deep and well-defined valleys that represent pre-glacial drainage channels be recognized. Elsewhere, the drainage consists largely of lake-filled depressions separated by short stretches of river displaying rapids or falls.

The southern part of the Trough is drained by the Swampy Bay river, which flows northward into the Kaniapiskau-Koksoak River system, and the Ashuanipi river, which is part of the Hamilton River system. The region is marked by extensive, shallow expansions of water, and is frequently referred to as a "lake plateau". It is typical of a post-glacial drainage pattern.

Local

Within the map-area, the most pronounced topographic feature is the parallel arrangement of the ridges, valleys and lakes, all of which strike about N.40° W., that is, appoximately parallel to the regional strike of the bedrock (Plate 1). In general, the ridges are underlain by iron-formation, quartzite or chert, whereas shale, slate and limestone occupy the lower areas. The tops of the ridges are normally from 150 to 250 feet above the surrounding lakes but near Hook and Bruin lakes, some rise as much as 385 feet above the lakes.

Glaciation

Low (1897,p.290L) calculated that the centre of accumulation of the last ice sheet was "about midway between the east and west coasts of the peninsula, and between latitudes 53° and 55°," that is, in the vicinity of lake Kaniapiskau. With respect to glacial striae in the upper basin of the Hamilton river, Low (p.293L) reports:

> "Along the Ashuanipi Branch, as far as Dyke Lake, the direction of flow continues towards S.45° E. Here an older set of striae towards N.60°E. is found, at first imperfectly seen beneath those first noted, but in the course of a few miles becoming much better developed as those of the other set gradually die out. About Lake Petitsikapau, only the N.60°E. set is found, even on the high hills (420 feet) about the north side of the lake. On the small area between Dyke and Astry Lakes, the ice-movement appears to have been somewhat erratic, and sets of striae having S., S.50°W. and S.50°E. directions are found. About Astray Lake and along the river above to the Menihek Lakes, the direction is again constant and towards S.50°E."

Apart from Low's work, little information on ice-movements has been compiled and most of it is conflicting. The lack of data is, in part, the result of the poor development of striae in most areas. It is evident that glaciation was extensive and removed most of the pre-glacial surface material. The main ice-movement was probably in an easterly to southerly direction but, locally, was influenced by bedrock structure. It seems probable that near the end of the Wisconsin, the ice-sheet broke up into several small, active glaciers. This would account for local variations in the direction of the striae.

Only a few striae were found within the map-area and these vary in direction from S.50°E. to S.40°E., that is, approximately parallel to the regional strike. Chatter marks indicate the movement was from the northwest. Four to five miles farther east, the direction of movement is reported to be towards S.40°E. (W.G.Johnston, 1946). A few erratics of chert breccia indicate an easterly movement, as this rock is found only in the main ore zone to the west.

In general, glacial deposits throughout the region are thin and are confined to the lower areas, the ridges commonly being bare. These deposits consist principally of till, including boulders, gravel, sand and clay. A few eskers and drumlin-like forms are found in the northern and southern parts of the region. These generally strike northwestward. A more common glacial feature is abandoned beaches, several of which have been reported. Within the map-area, a few poorly-developed, discontinuous beach terraces are found along the hillsides, at heights as much as 200 feet above the general elevation of the country. They consist of sand and gravel. These beaches indicate the presence of former large lakes, probably formed by ice-damming.

CLIMATE

The accompanying table of meteorological observations (Table 1) taken at the Dominion Meteorological Station at Sandgirt lake (latitude 53°55'north, longitude 65°20'west), has been supplied by Professor F.K. Hare of the Geography Department, McGill University, and affords specific data as to the climate of the interior. The minimum temperatures given in the table are probably slightly higher than those which would be recorded within the map-area as Sandgrit lake is 100 miles southeast of this locality. Break-up is about the middle of June and freeze-up, towards the latter part of October.

No permafrost has been reported from the region although, in places, frozen ground was encountered in pitting during the field season. Normally it extends from two to three feet below the surface but may be as much as six feet or more. It appears to depend on several factors including drainage, character of overburden, and location.

FLORA AND FAUNA

White and black spruce, and tamarack are the principal trees in the region. Although fair stands of timber are found in some sheltered valleys, in general, the quantity suitable for lumber is limited as the trees are normally sparsely distributed, short and branching. A few dwarf birch are present on the hills and balsam fir is found in several of the low areas.

Caribou moss is abundant wherever the terrane is well drained, and commonly it is the only vegatation on the tops of the hills. Labrador tea is also abundant especially along the hillsides. Some alders and willows occur but are not common.

Game is scarce although the lakes and streams are generally well stocked with fish, including speckled and lake trout, pike and pickeral. Animals present include a few woodland caribou, ptarmigan, ducks, geese,rabbits,and porcupines. The fur-bearing animals are represented by the muskrat, mink, otter, fox and bear. However, with the exception of the ptarmigan, the quantity of wild life is very limited.

Month	Temperature								Precipitation					
	Mean daily range	Daily mean	Mean of daily		Mean of monthly		Absolute		Average monthly fall	Rain inches	Snowfall inches	Days		
	°F	°F	Maximum °F	Minimum °F	Maximum °F	Minimum °F	Highest recorded °F	Lowest recorded °F				Total	Rain ≥ 0.1 ins.	Snow ≥ 0.1 ins.
January	19	-7	2	-17	31	-43	37	-55	1.92	-	19.2	14	-	14
February	21	-3	8	-13	31	-41	37	-45	3.01	-	30.1	14	-	14
March	25	6	19	- 6	39	-30	47	-33	1.45	-	14.5	12	--	12
April	22	19	30	8	48	-23	55	-30	1.81	0.16	16.5	13	2	12
May	15	34	42	27	60	7	70	-12	2.98	1.76	12.2	17	10	9
June	18	46	55	37	76	27	84	21	3.06	2.96	1.0	15	15	2
July	18	57	66	48	84	36	87	31	3.97	3.97	-	15	15	-
August	16	55	63	47	78	35	85	31	3.75	3.75	-	18	18	-
September	15	46	53	38	71	26	76	20	3.45	3.40	0.5	15	15	1
October	11	32	38	27	56	13	59	8	2.18	1.54	6.4	15	9	Lost
November	14	16	23	9	43	-15	49	-23	2.33	0.48	18.5	12	2	12
December	16	-2	6	-10	25	-39	30	-45	3.50	-	35.0	14	-	14
Annual		26					87	-55	33.41	18.02	153.9			

Table 1. Meteorological observations, Sandgirt lake, Labrador (latitude 53°55' north, longitude 65°20' west) for the years 1942 to 1948. Observations taken by the Canadian Meteorological Service.

WATER POWER

Grand falls on the Hamilton river, one of the larger undeveloped water power sites in the world, is located within the Labrador concession, about 140 miles southeast of the iron-ore area. A preliminary survey indicates a potential of 1,250,000 horsepower. In Quebec, Eaton canyon on the Kaniapiskau river (Figure 1) is also a large possible source of power having a maximum indicated potential of 500,000 horsepower.

REGIONAL GEOLOGY[1]

INTRODUCTION

The "Labrador Trough" contains a folded and faulted assemblage of little-metamorphosed, Precambrian sedimentary and volcanic rocks which lie upon an older, eroded igneous and gneissic basal complex. The assemblage is cut by a few sills, dikes and stocks which are predominantly of basic composition. The Trough is at least 350 miles in length and within the Dyke Lake map-area (Figure 3) ranges from 30 to 60 miles in width. The northwestern and southeastern limits are as yet unknown.

The accompanying table of formations and the Dyke Lake map summarize the known geological data concerning the Labrador Trough within this region. They were compiled by Dr. A.E. Moss, Geologist, Labrador Mining and Exploration Company Limited, from private reports of the Company. The field work on which these reports are based has been done by several geologists, including the writer, but principally by Drs. A.T. Griffis, A.E. Moss and J.A. Retty.

Although some of the interpretations of the stratigraphic relationships as shown in the table of formations are as yet tentative, the succession from the base of the Hamilton River series to the top of the Sokoman iron-formation may be accepted as essentially correct. The main ore zone,

1 Data largely taken from a private report by Dr. A.E. Moss, Geologist, Labrador Mining and Exploration Company Limited.

FIGURE 3. GEOLOGICAL MAP OF DYKE LAKE AREA.

Table of Formations

	Pleistocene		Till, gravel, sand and minor clay		
PRECAMBRIAN	Montagnais Intrusives		Diorite, gabbro, pyroxenite and related rocks; serpentinite; granite and syenite		
	Kaniapiskau (Huronian-type)	<u>Point Series</u> (Upper Huronian or possibly Keweenawan?) -unconformity?	Menihek slate Sawyer-Nimish group	<u>Howse Group</u> Principally argillaceous and arenaceous rocks	<u>Doublet Group</u> Principally lavas; minor clastic rocks
		<u>Ferriman Series</u> (Middle Huronian?) -unconformity?	Sokoman iron-formation Nimish volcanics Ruth slate Wishart quartzite Fleming chert breccia	Note: Relative age of Howse Doublet, Murdock, and Laporte groups is unknown. Correlation based on lithology only.	
		<u>Hamilton River Series</u> (Lower Huronian?)	Denault dolomite Nimish volcanics Attikamagen shale Seward grits		
	Walsh Intrusives			Syenite, granite, diorite, felsite porphyry	
	Nachikopi (Keewatin?)			<u>Murdock Group</u> Chloritized pyroclastic and clastic rocks	<u>Laporte Group</u> Biotite-rich an chloritized sedimentary rocks
	Ashaunipi Group		Orthogneiss, paragneiss, intrusive rocks of acidic to basic composition		

where most of the detailed mapping has been done, is underlain by these rocks. The position of the Howse, Doublet, Murdock and Laporte groups, and the associated intrusive rocks, is much less certain, as all these groups, with the possible exception of the Laporte, are bounded by faults. For this reason, the groups are of necessity correlated only on the basis of their lithology and, in the table of formations, are therefore placed in subsidiary columns. The Murdock and Laporte are considered to be "Keewatin-type" and are placed below the Kaniapiskau. The relatively less-altered Howse and Doublet are correlated with the Point series, although all four groups may be of comparable age.

STRATIGRAPHY

Ashuanipi Group

This group forms the "basement complex" upon which the sedimentary and volcanic rocks within the Labrador Trough were deposited. It is normally separated from the Kaniapiskau system along the western edge of the Trough by a major unconformity but, in places, the contact is a thrust-fault. In contrast, most, if not all, of the eastern margin of the Trough is bounded by a fault, so that the age relationship of the Ashuanipi group and that of the Murdock and Laporte groups in particular, is actually unknown.

The Ashuanipi group consists principally of orthogneiss and paragneiss intruded by rocks of acidic to basic composition including granite, syenite, diorite, gabbro, anorthosite and pyroxenite.

Murdock Group

The Murdock group is exposed in the northeastern part of the Trough. Reconnaissance mapping indicates that these rocks are in a strip bounded by faults so that their age relations are unknown. They are much more highly altered than either the Howse group to the west, or the Doublet group to the east, and are considered, therefore, to be older than either and possibly to underlie the Kaniapiskau system.

The group consists principally of pyroclastic and clastic rocks that are characteristically chloritized so that, in places, the rocks are altered to chlorite schist. The pyroclastic rocks range from finely laminated tuffs to thick-bedded agglomerates containing fragments as much as two feet in diameter. Distributed through the pyroclastic rocks are lenticular beds of greywacke, quartzite, slate and conglomerate. The beds are generally not more than a few tens of feet thick. The boulders in the conglomerates are formed of diorite, gabbro, intermediate and basic lavas, and granitic rocks.

Laporte Group

A few exposures of well-bedded, biotite-rich greywacke and of green schist have been observed east of Laporte lake along the eastern margin of the Trough. The relation of these rocks to the adjacent Doublet group is unknown but they resemble the rocks of the Murdock group.

Walsh Intrusives.

These intrusive rocks include syenite, granite, diorite and felsite porphyry, forming stocks and dikes. They are generally well foliated and could actually be called gneisses. An intrusive relation with the Murdock group is proved by exposures at Walsh lake (latitude 55°10' north) but a similar relationship to the Laporte group has not been observed.

Hamilton River Series and Ferriman Series

Introduction

These series, together with the Menihek slate (Point Series), underlie the western two-thirds of the Dyke Lake map-area. The rocks are folded and faulted and the distribution of each series is too complicated to show at the scale of the accompanying map. In addition, a large part of the area has not been mapped in sufficient detail. The Hamilton River series is absent at the extreme western edge of the area, the absence being the result of a sedimentary overlap of the Ferriman series upon the "basement complex".

Seward Grits

The type section of the Seward grits is exposed along the eastern margin of the Trough (latitude 54° 27' north) and is reported to be several hundred feet thick. The predominating rock consists of rounded to subangular, glassy quartz fragments, averaging about one-eighth inch in diameter, in a fine-grained matrix of feldspar, kaolin, sericite and quartz. Crossbedding is normally well developed. The section also includes massive quartzite, minor greywacke bands, and in places, chert lenses and chert conglomerate.

This formation has not been observed within themain ore zone. It may represent a near-shore facies and may be, in part, equivalent in age to part of the Attikamagen shale.

Attikamagen Shale.

The principal rock type is green, grey, red or black shale. The formation has a wide distribution except in the western part of the Trough, where it is absent.

Denault Dolomite

The type rock is a massive, very fine-grained dolomitic limestone, cream or white in colour on fresh surfaces, yellowish brown or buff on weathered surfaces. In places, chert and flint form irregular masses and nodules distributed throughout the limestone. Quartz veinlets are present along joint surfaces.

The Denault dolomite is absent in some areas as the result of either erosion or non-deposition. Present data indicate that a disconformity separates the dolomite and overlying chert breccia, and it is suggested that the chert fragments of the breccia were derived from weathered dolomite.

Fleming Chert Breccia

The chert breccia consists of angular to subangular fragments of chert in a fine to medium-grained, quartzitic matrix. The fragments are generally one-half inch to two inches in diameter but fragments as much as 18 inches in diameter have been recorded. In places, they have a concentric structure and scalloped edges. The colour is grey, white or not uncommonly black and that of the matrix, light grey to white.

The chert breccia appears to have a limited distribution, being restricted to the main ore zone. In all observed outcrops, it is underlain by the Denault dolomite.

Wishart Quartzite

The principal rock type is a massive, medium to coarse-grained, white or light grey quartzite. It is normally thick-bedded but locally thin beds or crossbedding may be well developed. Associated rocks include chert, greywacke, arkose and grit. The chert, where present, forms a massive bed five to fifty feet thick at the top of the quartzite.

Locally along the main ore zone, a bed of chert conglomerate, two to ten feet thick, has been observed at the base of the Wishart quartzite. Where it is present, the dolomite and chert breccia are absent, and it rests directly on the Attikamagen shale. It may be equivalent in age to the chert breccia and mark an unconformity although no structural discordance has been reported.

The quartzite formation is distributed throughout the western two-thirds of the Trough. Because of this, as well as its resistance to erosion, it serves as an excellent marker horizon.

Ruth Slate

The slate, though normally less than 75 feet thick and rarely exceeding 150 feet in thickness, is remarkably persistent throughout the main ore zone and has been observed at Sawyer lake, about 100 miles to the south. However it may be absent at several intervening localities. It generally contains at least ten per cent iron, and in places, abundant chert, so that it might locally be classed as iron-formation. Nevertheless, because of its persistence, definite limits, and high alumina content, it is separated from the iron-formation.

The slate is commonly black, but the fresh surface may be brown, red or grey. It weathers brown.

Sokoman Iron-Formation

The formation outcrops extensively throughout the western two-thirds of the Labrador Trough. It is discussed in some detail in connection with the geology of the map-area (page 42).

Nimish Volcanics

The volcanic rocks within the Kaniapiskau system are lithologically similar and are grouped under the term "Nimish volcanics" although they are obviously of different ages. Flows of this type are known to occur above the Attikamagen shale and Ruth slate, and to form part of the Sawyer-Nimish group. However, the stratigraphic position in many cases is unknown and volcanic rocks may occur at other horizons in the Kaniapiskau system. Therefore, until detailed mapping establishes the several periods of extrusion, it does not seem constructive to give separate names. The occurrence suggests prolonged, intermittent volcanic activity resulting in interlayering and interfingering of the volcanic and sedimentary rocks.

Pillowed andesites are common in the northern part of the Labrador concession. No extrusive rocks have been observed in the main ore zone but are abundant along a parallel belt which lies just east of the map-area. Associated with the andesites are massive, fine to medium-grained greyish green rocks, termed "greenstones". No flow structures are recognizable and they may be of extrusive origin or possibly sills. However, most of the "greenstones" are considered to be extrusive as, in places, they have been traced into pillowed flows. Some amygdaloidal lavas and a few narrow bands of flow breccia are present.

Point Series

Introduction

The Sawyer-Nimish group comprises a thick series of extrusive and sedimentary rocks that outcrop in the eastern and central part of the Trough in the vicinity of Sawyer lake (latitude 54° 26' north). This group may overlie the Ferriman series unconformably, as at Sawyer lake Nimish volcanics were extruded onto the Sokoman iron-formation, whereas farther north, the rock above the iron-formation is the Menihek slate. However, it is possible that the Sawyer-Nimish group is equivalent in age to all or part of the Hamilton River - Ferriman series but was deposited under somewhat different conditions, in proximity to a centre of volcanism.

Sawyer-Nimish Group

No detailed mapping of these rocks has as yet been done so that the stratigraphy within the group is unknown. However, the group comprises a thick series of volcanic and sedimentary rocks. Part of the volcanic rocks is similar in lithology to the Nimish volcanics, but porphyritic lavas are common and a great variety of pyroclastic rocks is present, varying from thinly bedded tuffs to coarse agglomerates. A common rock type consists of abundant fragments of jasper in a "greenstone" matrix. Interbedded with the volcanic rocks are iron-formation and narrow beds of shale, greywacke, quartzite and conglomerate.

Several iron-formation members may be present or the interlayering may represent a continuous period of deposition with simultaneous volcanism.

Menihek Slate

This rock is normally a black or grey, well-laminated slate or shale which lithologically cannot be separated from the Attikamgen shale. It appears to be several hundred feet thick and to form the uppermost part of the Kaniapiskau system.

Large areas of the Menihek slate are found in the Howells River valley and southeastward along Menihek lake at the west edge of the Trough, and in the vicinity and south of Petitsikapau lake in the central part. In addition, smaller areas are underlain by this rock to the north in the New Quebec concession.

Howse Group

The Howse group lies in the east-central part of the Trough, and extends from Marion lake (latitude 54°48' north) in the south, northwestwards to beyond the northern edge of the Dyke Lake map-area. It is separated from the Murdock group to the east and probably from the Hamilton River - Ferriman series to the west by faults and is tentatively correlated with the Point series. A fault along the western margin is assumed as near Marion lake the Hamilton River - Ferriman series dips westward and appears to truncate the Howse group, whereas, along the contact to the north, both rock groups dip eastward with the Howse apparently the younger. These conditions are explained by assuming a major fault along the contact.

The principal rocks are of sedimentary origin, namely shale, slate, greywacke, quartzite and conglomerate. A few pillowed lavas are present and one narrow band of iron-formation has been reported. Although the combined thickness of the sedimentary and volcanic rocks is only a few thousand feet, the group outcrops over a width of several miles. The increase in thickness is the result, at least in part, of the intrusion of these rocks by thick gabbro sills.

Doublet Group

The Doublet group underlies a large area along the northeastern margin of the Trough. It consists predominantly of extrusive rocks which are principally well-pillowed flows although some flow breccia, pyroclastic rocks and "greenstones" are present. Several bands of grey quartzite and shale occur.

The Doublet group of rocks is bounded by faults and the age relationship is unknown. Tentatively it is correlated with the Point series. It is possible that a major unconformity rather than a fault separates the Doublet and Ashuanipi groups in the extreme northern part of the map-area but insufficient data are available to prove or disprove this.

Montagnais Intrusives

Dikes, sills and bosses of predominantly basic composition cut the rocks of the Kaniapiskau system. The principal rock types are diorite and gabbro. They commonly resemble the "greenstone" flows and, as over 90 per cent occur as sills, it is difficult to separate them from the flows in mapping.

Other intrusive rocks include "feldspathic diorite", diabase, serpentinite, and minor pyroxenite, granite and syenite. The feldspathic diorite is identified by the presence of aggregates of saussuritized plagioclase in a coarse-grained groundmass. The so-called serpentinite is a massive, black or greenish black rock that weathers cocoa-brown. It is generally fine grained, but medium and coarse-grained varieties are not uncommon. The serpentinite forms thick sills within the Doublet group.

STRUCTURE

The rocks within the Labrador Trough are folded and thrust-faulted. The fold axes and thrust-faults strike in a northwesterly direction; the thrust-faults and axial planes of the folds generally dip northeastward. In mapping, one finds characteristically, northeastward dipping strata which are repeated at intervals, with some omissions, across a line at right angles to the strike, usually in the same order, but occasionally in reverse. Field work indicates that the rocks were originally folded, then faulted, with the elimination of the northeast limbs of most of the synclines.

Some faults have been observed on surface, others were penetrated in drilling, but the majority are inferred because without them a reasonable interpretation of the stratigraphy is impossible. The known faults dip at 60° or more northeastward. Dip separations produced by them range from 200 to 1,500 feet.

GEOLOGY OF THE AREA

STRATIGRAPHY

Introduction

All the consolidated rocks within the map-area are of Late Precambrian age and form part of the Kaniapiskau system. Their lithology resembles that of the Huronian rocks of the Lake Superior region and they are generally considered to be approximately equivalent in age.

Table of Formations

Quaternary	Pleistocene	Till	Feet
Late Precambrian (Kaniapiskau)	Point series	Slate	300+
	Unconformity?		
	Ferriman Series	Iron-formation	350-400
		Ferruginous slate	0- 40
		Chert	3- 20
		Quartzite	125-175
		Shale	0- 50
	Unconformity?		
	Hamilton River series	Limestone	0-250+
		Slate	200+

Lower Slate

Exposures of the lower slate are found between Bruin and Trough lakes, and east of Snow lake. The fresh surfaces are jet-black and the rock weathers flat-white or, where slightly stained by iron hydroxides, yellowish grey. The rock is generally well laminated although beds as thick as 0.4 inch occur. Where flow cleavage is not well developed, joints spaced about an inch apart are common.

Although the predominant rock type is slate, the formation includes shale and argillite. The beds consist of dark grey to black argillaceous material. No minerals could be identified in thin section.

Interbedded with the slate are beds of grey to black chert generally 0.2 inch to two inches thick but rarely as much as two feet. The thinner beds are commonly discontinuous, the chert forming irregular, aligned lenses averaging about an inch in diameter and 0.1 to 0.2 inch thick.

The mode of occurrence of the lenses of chert suggests that originally they were ellipsoidal to spheroidal globules of gelatinous silica formed by the precipitation of colloidal silica, preceded and followed by the deposition of argillaceous material, and then the whole indurated, with consequent flattening of the globules and crystallization of the silica. Only where the deposition of the silica was insufficient to form a continuous layer would lenses of chert be formed.

The fact that, not uncommonly, the slate adjacent to the chert is stained reddish brown by iron hydroxide indicates that some iron, probably as ferrous carbonate, was deposited along with the chert. A similar occurrence is found at the base of the iron-formation exposed near Hook lake. There is no evidence that the iron hydroxide was transported by solutions descending from the iron-formation for it is limited to within an inch of the chert beds and is lacking in most cases.

Limestone

Overlying the lower slate conformably is a dolomitic limestone member. It is a dense, dark grey, very fine-grained rock that weathers to a light grey or, less commonly, a rusty brown. The beds range in thickness from a fraction of an inch to two feet. Staining and refractive index determinations indicate that the prevalent mineral is dolomite and that many beds are pure dolomitic limestone. Primary black chert is distributed throughout some of the strata but its occurrence is not common. Silica is also present as veinlets of quartz along joints.

An exposure to the west of Snow lake consists of fragments of grey dolomitic limestone in a dark grey, fine-grained matrix of clastic limestone and quartz (Plate 2A). The fragments are generally about one inch in diameter but some are as much as a foot. About 20 per cent of the matrix consists of angular to subrounded quartz grains, 0.1 to 0.6 millimeter in diameter. Crystals and globules of marcasite occur in the quartz and between the grains. The principal cementing material is carbonate although some silica and argillaceous material are present. North of Trough lake, part of the limestone exposed has a brecciated appearance. It consists entirely of angular fragments of dolomitic limestone, as much as a foot in diameter, cemented by carbonates. The phenomenon is best seen on the weathered surface where slight differences in colour serve to outline the fragments. East of Snow and Johnston lakes the limestone is interbedded with grey to black shales and is, in general, more calcitic than average.

Limited exposure of the limestone prohibits the determination of the stratigraphic relations within this member. The rusty-weathering variety, which probably contains some ferrous iron replacing the magnesium, is interbedded with the purer dolomitic limestone. There is no apparent difference in the composition of the brecciated and neighbouring non-brecciated limestone, the brecciation suggesting merely the breaking up of previously deposited beds with later cementation of the fragments. Exposure, mechanical weathering, and redeposition along with other detritus, would explain the formation of the clastic limestone exposed to the west of Snow lake.

Dolomitic limestones are present in every geologic system, including a wide distribution in the Precambrian, and although numerous studies of them have been made, the theories relating to their origin are still conflicting. The most widely held theory is that dolomitic limestone is the result of replacement of calcium carbonate by magnesium carbonate and that the replacement took place in marine waters before the sediments were completely lithified (Van Tuyl, 1914, pp. 397-406). It is assumed that the magnesium carbonate unites with calcium carbonate to form dolomite and that a chemically equivalent quantity of calcium carbonate passes into solution. A highly concentrated sea would facilitate the transfer but Skeats (1905, p.134) and Blackwelder (1913, p.623) have shown that the concentration of magnesia was probably not more than two to three times that in the present oceans.

The theory that dolomitic limestone is the result of primary precipitation by inorganic chemical processes cannot be disregarded for, although laboratory experiments have failed to indicate these processes, field evidence suggests that dolomites, at least on a small scale, have been so formed (Van Tuyl, pp. 318-324). Daly (1909, p. 163) has suggested that in Precambrian time when the scavenger system of the ocean was not yet developed, the seas must have been depleted in lime and magnesia due to the precipitating effect of ammonium carbonate generated from decaying organisms on the sea floor. However, because ammonium carbonate would be ineffective as a precipitant of magnesium carbonate unless the oceanic water was free of all calcium salts, calcium carbonate would be precipitated first, followed slowly by possibly the hydrous carbonate of magnesium, which then might unite with the calcium carbonate to form dolomite. Nevertheless, as Van Tuyl (p. 306) notes, the fact that the two carbonates are found by experiment to come down separately, with the calcium carbonate much in advance of the hydrous magnesium carbonate, is not sufficient evidence to wholly exclude the theory of direct chemical deposition of large masses of dolomite. Under favourable conditions the double carbonate may be precipitated directly, the dolomite molecule being continuously formed in solution while deposition proceeds.

Shale

No natural exposure of shale was found but fragments are common in the vicinity of Snow and Hook lakes, and bedrock was exposed in two pits near Snow lake. The chief characteristics of this rock are its light colour and well-developed bedding. The fresh surface is coloured pale shades of red, yellow and green which weather to rose, dull yellow and light grey. The thicknesses of the strata range from 0.01 to 0.3 inch.

The colour and the fact that the rock is soft and porous suggest that it originally may have been a carbonaceous or calcareous shale which, at least near the surface, has been leached by meteoric waters. It consists of very fine-grained argillaceous material.

The shale and the overlying quartzite were not seen in contact but structural data indicate a conformable relation. Neither was the underlying limestone and slate found in proximity to the shale. It is absent south of Hook lake.

Quartzite

Near Snow lake the quartzite is a massive, fine-grained rock consisting of subangular to rounded grains of quartz plus, in places, rounded grains of grey to black chert and fragments of microcline. The top two to three feet are medium-grained and feldspathic. Except where stained by iron hydroxides, the weathered surface is white or light grey.

South of Hook lake, pure quartzite is less common. Biotite, chlorite, argillaceous material, and some feldspar and white mica, are abundant constituents although quartz grains generally form 50 per cent or more of the rock. Fragments of chert are also present. Chlorite is the principal mafic mineral and occurs with argillaceous material between angular and subangular quartz grains. Some of the chlorite is secondary after argillaceous material and some has formed from the alteration of biotite. The feldspar is chiefly relatively fresh microline, although well-saussuritized feldspar fragments occur. The amount of feldspar never exceeds five per cent.

Fresh surfaces are light grey to greenish grey to black. All are fine-grained. The weathered surface is grey to greenish grey except where stained by iron hydroxide, in which case it is various shades of yellow or brown. In places narrow bands of shale or slate occur.

Much of the quartzite is in massive beds, although the more impure varieties are generally thin-bedded, the thickness of the beds averaging 0.1 inch. Visible grain gradation is rare and no clearly identifiable crossbedding was seen. Where both bedding and jointing are present, one set of joints is parallel to the bedding, and two other less perfect sets occur at approximately 90 degrees to it.

The precentage of ferromagnesian minerals and argillaceous material generally decreases towards the top of the quartzite although local exceptions are found.

Chert

At the top of the quartzite is three to twenty feet of light grey to black, massive chert which serves as an excellent marker horizon. Where folding is open, as at Hook lake, the chert forms extensive exposures. It consists of microcrystalline quartz that commonly contains a few minute inclusions of colourless to pale green minnesotaite and/or carbonate.

The contact between the quartzite and chert is well defined although slightly irregular.

Iron-Formation [1]

Introduction

The iron-formation forms the most extensive outcrops within the map-area. It is probably about 400 feet thick but no completely exposed section was found. Although several types of iron-formation can be differentiated in the field, their mineralogy is similar. The mineral constituents are quartz, carbonate, minnesotaite[2], magnetite, hematite, goethite, limonite, and, in places, riebeckite. Granules are common in the upper part of the iron-formation, and average about one millimeter in diameter.

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1 Iron-formation is used as a general term for a bedded rock consisting essentially of quartz and iron-bearing silicates, carbonates, oxides, or hydroxides.
Chert as used here is restricted to crystallized masses of interlocking quartz crystals, the individual crystals of which average about 0.01 millimeter in diameter.
Granule is used to refer to the spheroidal, ellipsoidal or more irregular forms that are found in parts of the iron-formation. There is no implication as to composition or internal structure.
Limonite refers to unidentified yellow, brown or reddish brown iron hydroxide. Posnjak and Merwin (p.311) indicate that most of the limonite is goethite with adsorbed and capillary water.

2. Minnesotaite is an iron-bearing silicate with the structure of talc. Gruner (1946,p.9) gives the empirical formula as $(OH)_{22}(Fe'',Mg)_{22.3}(Si_{30.4}(Al,Fe''')_{1.4})O_{74}$ as compared to a theoretical formula of $(OH)_{16}Fe_{24}Si_{32}O_{80}$. The optical properties include parallel extinction; positive elongation; $N_\gamma - N_\alpha = 1.615 - 1.580 = 0.035$; weak pleochroism with Z and Y = pale green, X = colourless.
The optical determinations were checked by an X-ray powder photograph taken by Mr. Cyrille Dufresne at the University of Minnesota.

Unfortunately, the iron-formation is generally altered and this makes difficult a reasonable determination of the original composition. For this reason, a description of the less-altered iron-formation in the vicinity of Heluva lake (Figure 5) is included under the subtitle "The Iron-Formation of the Heluva Lake Area". This area was mapped by the writer during the summer of 1949. There, in places, nearly flat-lying, relatively undisturbed iron-formation occurs along the west edge of the Labrador Trough.

The iron-formation within the Snow-Trough Lakes map-area was divided megascopically into several clearly discernable types. These are as follows:

1. Ferruginous slate
2. Cherty carbonate iron-formation
3. Ferruginous chert
4. Cherty metallic iron-formation
5. Jaspery iron-formation
6. Cherty minnesotaite-carbonate iron-formation
7. Amphibole-bearing iron-formation

Ferruginous Slate

A black slate forms the base of the iron-formation at Hook and Bruin lakes. The rock is not strictly a slate as, although fissility is marked, this is generally parallel to the bedding. The fresh surface is black and the weathered surface yellowish to reddish brown, or black. A conformable contact with the underlying chert is exposed at the east side of Bruin lake.

In thin section, the rock is seen to consist principally of dark grey to black argillaceous material and microcrystalline quartz. Some clastic quartz and chert occur but some of the quartz grains simulate, by form and cleavage, fragments of feldspar, and some resemble in shape flakes of chlorite or biotite. There is no evidence as to the time of replacement but it is assumed to be simultaneous with deposition. A few shreds of altered biotite are present. Iron hydroxide occurs, chiefly as an alteration product of rhombohedral crystals of carbonate.

The slate does not form a separate unit, but is interbedded with non-clastic iron-formation. The best exposures are found along the east arm of Hook lake where interbedded slate, chert and cherty carbonate iron-formation form a thickness of as much as 120 feet. The slate is more prevalent at the base and exposures indicate a maximium thickness of about 40 feet. However, at the southern end of the peninsula, the slate is not more than 15 feet thick.

Cherty Carbonate Iron-Formation

The cherty carbonate iron-formation is a massive, dark grey, fine-grained rock which weathers dark brown or reddish brown. It consists of about equal proportions of irregular, interlocking crystals of quartz, averaging about 0.05 millimeter in diameter, and carbonate (Plate 2B). The carbonate occurs as patches and individual rhombohedrons scattered throughout the rock. In thin section, it is dusty grey in colour with a colourless, or rarely, very pale green, calcite border. Tests indicate the centres to be now chiefly ankerite. One or two per cent of magnetite is present as minute octahedra or as dusty grains apparently replacing the carbonate. Near the weathered surface, the carbonate alters to brownish yellow, dark brown or reddish brown limonite. Pseudomorphs of limonite after carbonate are common. A few minute fibres of yellow limonite and pleochroic, greenish yellow to dark grey, iron silicate (?) are visible at high magnifications. They form considerably less than one per cent of the slides.

Magnetite and carbonate in a relationship similar to that noted above is described by Grunner (1922, p.411) who states:

> "In many places magnetite seems to have replaced carbonate, and it appears to be least abundant where much siderite is present. This suggests that in places, magnetite is formed by partial oxidation of siderite."

Associated with the slate and cherty carbonate iron-formation are beds of grey to black chert generally 0.2 to one inch thick but rarely as much as 18 inches. The chert weathers grey with a reddish brown tinge or flat-white. It consists of crystalline quartz, averaging 0.5 millimeter in diameter, and from less than one to four per cent carbonate. Commonly, the slate adjacent to chert beds is stained reddish brown by iron hydroxide.

The cherty carbonate iron-formation contains, in part, aligned, spheroidal, ellipsoidal or irregular forms of black chert which range from 0.2 to one inch in diameter. In general, the smaller chert forms are spheroidal or ellipsoidal, whereas the larger are irregular in plan and roughly lenticular in section, the thickness ranging from 0.1 to 0.3 inch. Some chert, however, is irregular in shape both in plan and section. The chert consists of microcrystalline quartz and three to four per cent carbonate, that is, it is identical in composition to the interbedded chert. The cherty carbonate rock and chert differ only in the percentage of carbonate present.

Where the weathering agents have peretrated the bands, the broken surface shows residual patches of dark grey cherty carbonate rock and "fragments" of chert in a reddish brown to dark brown matrix the whole simulating a conglomerate.

The mode of occurrence of the chert, which also is found in the lower slate (page 35), suggests that originally it was precipitated as ellipsoidal to spheroidal globules of gelatinous silica. Simultaneous deposition of silica and carbonate, interrupted at intervals by the almost complete cessation of that of the carbonate, would result in an interbedded chert and cherty carbonate rock similar to that described. If, during the non-deposition of carbonate there was insufficient silica precipitated to form a continuous layer, the globules of silica, isolated and, in part, flattened by subsequent deposition of carbonate and silica, would form separate lenses.

Ferruginous Chert

The ferruginous chert is characteristically well bedded, the thicknesses of the beds ranging from 0.05 to one inch and averaging 0.2 inch. They consist of yellow to brown to brownish red ferruginous chert, and grey to black chert which weathers grey to flat-white. The microcrystalline quartz forming the chert commonly contains very minute, colourless to pale green minnesotaite and, in places, dusty black particles which may be graphite.

Under the microscope, the ferruginous chert is seen to be either an altered cherty carbonate iron-formation or an altered iron-bearing silicate rock. The former consists of quartz, and yellow to brown to brownish red limonite in the form of patches, bands, or commonly, pseudomorphic after rhombohedral carbonate crystals (Plate 3A). The altered silicate rock consists of microcrystalline quartz, and yellow to brown, fibrous limonite which as fibres averaging about 0.05 millimeter in length crisscrosses to form irregular mats (Plate 3B) or, as shorter fibres, is distributed throughout the quartz. Depending on the percentage of limonite present, the fresh and weathered surfaces are yellow to dark brown. The assumption that these beds are an altered iron-bearing silicate rock is based on the fibrous nature of the limonite and the similarity to altered cherty minnesotaite-carbonate iron-formation found elsewhere.

Opaques occur as discontinuous bands about 0.1 millimeter thick, parallel to the bedding, and as grains scattered throughout the beds. In thin section, their outlines resemble the grouping of euhedral grains of magnetite. However, magnetite is not common and where present is partially altered to martite (Figure 4). Generally, the grains now consist of goethite containing patches, and bordered by selvages, of hematite (martite). The goethite is commonly slightly magnetic suggesting the presence of residual submicroscopic grains of magnetite.

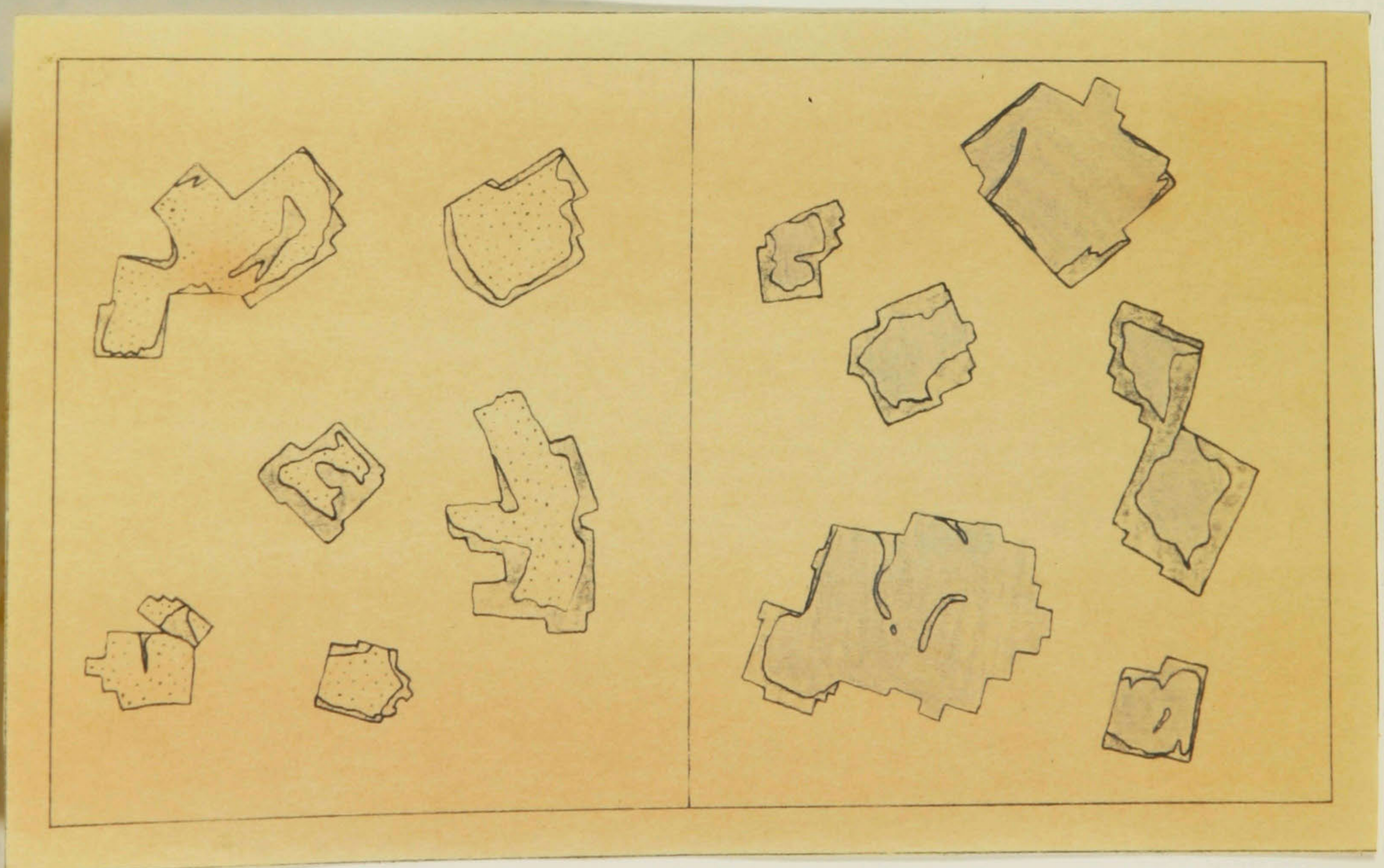

Figure 4
Relation of martite to magnetite and to goethite.
(composite of camera lucida drawings, 420X)
Left - Octahedral grains of magnetite rimmed by martite.
Right - Octahedral grains of goethite rimmed by, and containing patches of, martite.

Stippled: magnetite; shaded: martite; grey: goethite

Cherty Metallic Iron-Formation

Cherty metallic iron-formation consists principally of chert and iron oxides. The colour of the fresh and weathered surfaces is dark brownish grey to metallic bluish black. It occurs in beds normally ranging in thickness from 0.1 to one inch, but in places the thickness is as much as 12 inches.

The mineral constituents are quartz, hematite, magnetite, goethite and limonite. The quartz occurs as irregular interlocking crystals, averaging about 0.01 millimeter in diameter, which generally contain a few minute, colourless to pale green inclusions, probably minnesotaite. Some ribbon quartz may be present or the quartz crystals may be slightly elongated, with a preferred orientation parallel to the bedding. The hematite occurs as irregular blebs either singly (averaging 0.01 millimeter in diameter) or in clusters (Plate 4B), or rarely, as flat rhombohedrons. The magnetite generally forms well-developed grains, commonly as individual octahedra averaging about 0.1 millimeter in diameter, or as larger masses formed by their union. Partial or complete alteration of magnetite to martite is common. The martite forms rims around the magnetite and proceeds inward along either irregular lines or octahedral planes (Figure 4). Goethite occurs either pseudomorphic after magnetite grains or in more irregular form. The goethite pseudomorphs are generally rimmed by martite. In places, the martite predominates and the octahedral grains consist of martite containing patches of goethite (Plate 10B).

Yellow to brown limonite is present as sheaves and radiating fibres, and as fibres roughly parallel to the bedding. Its presence gives the chert a brownish colour. The limonite is probably the result of the alteration of an iron silicate such as minnesotaite. In places, tiny holes on the weathered surface of the rock indicate that at least minor carbonate was originally present.

Not uncommonly, the rock has a granule texture. However, it is more common in the jaspery iron-formation and is described under that rock type.

Jaspery Iron-Formation

The jaspery iron-formation has characteristically a dull red colour from dusty particles of hematite distributed throughout crystalline quartz. It is mineralogically similar to the cherty metallic iron-formation, but the hematite is present as finer particles in the jaspery iron-formation and there is less of it. The jaspery and cherty metallic varieties of the iron-formation are generally interbedded. In places they grade into one another both along the strike and the dip.

The jaspery iron-formation commonly has a granule texture (Plate 6A). In section, the granules can be seen to be outlined partially or completely by opaque grains, partially or completely by concentric shells of dusty opaques, or a combination of the two. The size of the granules is generally just under one millimeter, but some are as much as two millimeters in diameter. They are spherodial, ellipsoidal or more irregular in form. The centres consist of opaques, quartz, jasper or rarely minnesotaite, or combinations of these. Complete granules of jasper are also present. The surrounding medium is jasper, chert, or chert and metallic minerals.

Beds, with or without a granule texture, are mineralogically similar. The diameters of the quartz crystals within the granules are generally somewhat less than average (0.01 millimeter). Sheaves and radiating fibres of minnesotaite are present both inside and outside the granules but the amount is limited. The minnesotaite is normally altered to fibrous limonite. Magnetite and hematite commonly occur together in the granules and at least part of the hematite is actually martite.

In general, thin beds (0.1 to 0.5 inch) of jaspery or cherty metallic iron-formation do not have a granule texture. However, it is normally present in the thicker beds.

<u>Cherty Minnesotaite-Carbonate Iron-Formation</u>

The fresh surface of the rock is greenish grey to yellowish brown in colour and weathers yellowish to dark brown, reddish brown or brick-red. Bedding is well developed, the thichnesses of the beds ranging from 0.1 inch to two inches Megascopically, a granule texture is rare, although it can be recognized where the granules are outlined by magnetite.

Thin sections of the rock show varying proportions of quartz, minnesotaite, carbonate, magnetite and limonite (Plates 7 and 9A). Even in section, it is not common to see a granule texture and where present, with the exception of those outlined by magnetite, the granules are generally indistinct and they constitute only a small part of a slide. They are spheroidal, ellipoidal, or more irregular in shape and average 0.8 millimeter in diameter, although ranging from 0.2 millimeter to 1.3 millimeters. Successive beds vary somewhat in the ratio of carbonate to minnesotaite, so that the rock type includes cherty minnesotaite iron-formation with no appreciable carbonate, cherty carbonate iron-formation with as little as 15 per cent minnesotaite, and gradations between.

The minnesotaite occurs as sheaves and radiating fibres that average about 0.05 millimeter in length. In general, the length of the fibres within the granules is somewhat less than average although, in places, longer fibres (0.15 millimeter) extend from the margins into the surrounding chert. The alteration of the minnesotaite to limonite is marked by a change in colour from pale green to yellow, and on completion, the rock is better termed a ferruginous chert. The carbonate is principally siderite which is dusty grey in thin section. In places, fibres of minnesotaite extend into the siderite. The magnetite, generally as euhedral grains, outlines or partially fills some of the granules, or is distributed throughout the rock, or rarely, it is concentrated in beds about 0.1 inch thick.

Amphibole-Bearing Iron-Formation

Fibrous riebeckite ($Na_6''Fe_6''Fe_4'''Si_{16}O_{46}(OH)_2$) has formed in connection with bedding slippage within the iron-formation exposed along the east arm of Hook lake. The greater concentration of the amphibole is along bedding surfaces but it is also distributed throughout the rock which consists of jaspery and cherty metallic iron-formation with or without a granule texture. A few fibres of riebeckite are found within the granules but this is not common. Megascopically, the riebeckite is greyish blue and in thin section, strongly pleochroic with X = medium blue, Y = purple and Z = greenish yellow.

The fibres transect the minnesotaite but not the opaque minerals and some sheaves contain euhedral grains of magnetite, their relationship indicating that the magnetite, in part, was formed at the same time as, or later than, the riebeckite. The fibres are inclosed by quartz, much of which shows a ribbon structure. Introduced quartz is common along the bedding surfaces.

The opaque minerals are magnetite and hematite, with the former generally partially converted to martite. An exception is the magnetite that appear to be related to the development of the riebeckite. These grains show only slight alteration to martite, the alteration having proceeded along octahedral planes.

As fibrous riebeckite (crocidolite) is a stress mineral and most of the elements necessary for its development are present, its occurrence is not at variance with the events, although the probable initial deficiency of sodium in the iron-formation would explain why it is not more common. The writer has identified it at Hook lake, east of Trough lake, and also east of Heluva lake (1949). In all cases, the containing rock (iron-formation) has undergone close folding or shearing, and introduced quartz is present. It is possible that some sodium was contained by the iron-formation on deposition, either by colloidal adsorption or in entrapped sea water. The iron silicates are another possible source. However, riebeckite contains slightly in excess of eight per cent of Na_2O, whereas analyses give a much lower content for the iron silicates, for example (Gruner 1946, p.10), minnesotaite - - 0.08 per cent of Na_2O, and stilpnomelane $((OH)_4(K,Na,Ca)_{0-1}(Fe,Mg,Al)_{7-8}Si_8O_{23-24}.2\text{-}4H_2O)$. 0.03 to 0.27 per cent of Na_2O. Also, the assumption that sufficient sodium was present in the original sediments does not explain the predominating occurrence of the riebeckite along the bedding surfaces of otherwise normal iron-formation, that it is relatively rare, nor the general association with quartz. It seems a logical assumption that the sodium and quartz were introduced during deformation and that the riebeckite formed as a direct result of the combination of sodium, silica and iron under stress conditions. The source of sodium could be either magmatic or from leaching of the underlying argillaceous rocks.

A comparable occurrence of fibrous riebeckite (crocidolite) is found in the asbestos deposits of South Africa. There, (Du Toit, 1946) conformable seams of crocidolite are present in the banded ironstones and jaspers of the Transvaal system (Late Precambrian). The country rock, where fresh, is a shale, siltstone, or cherty to calcareous sediment which were originally (p. 163) "Colloidal, semi-colloidal and finely granular materials of widely varying composition" and which, generally, are rich in iron, the iron being deposited as ferrous silicate and as carbonate. By oxidation, hydration and silicification, the rock has been changed to banded ironstones and jaspers. However, the crocidolite, according to Du Toit, has developed as a result of dynamic metamorphism from the strata in which it is found, and approximates in composition the material replaced. Aggregates of magnetite commonly flank the crocidolite seams and indicate that (p.193) "the material transformed must have held an excess of iron over that needed for such conversion". The necessary water was probably present either in combined form or cognate, and the soda, by colloidal adsorption or as a soda-lime zeolite.

Stratigraphy of the Iron-Formation

The best section of the iron-formation is exposed at Snow lake. It is divisible as follows:

Jaspery and cherty metallic iron-formation with or without a granule texture	thick-bedded	205 feet
	thin-bedded	85
Ferruginous chert		60
		350

The ferruginous chert conformably overlies the chert member at the top of the quartzite (Table of Formations, page 34). Ferruginous slate forms the base of the iron-formation at Hook and Bruin lakes but is absent at Snow lake, and south of Bruin lake. However, an outcrop of ferruginous chert overlying the slate conformably was observed just north of Bruin lake.

The division between the ferruginous chert and the overlying thin-bedded intermediate iron-formation is arbitrarily taken as the lower limit of the jaspery iron-formation. Thus the first ten feet of the intermediate division consists of jaspery iron-formation interbedded with ferruginous chert and some cherty metallic beds.

The division between the thin and thick-bedded iron-formation is also arbitrary. The thicknesses of the beds in the lower division range from 0.1 to one inch, whereas in the upper part, the thickness is generally 0.5 inch to two inches and beds 10 to 12 inches thick are common. The rock consists of jaspery iron-formation and cherty metallic iron-formation. A granule texture is found only towards the top of the intermediate division but is common in the upper division.

A good section of the lower part of the iron-formation is exposed at Hook lake. The section is divisible as follows:

Thick-bedded jaspery and cherty metallic iron-formation with a granule texture....	155 feet
Thin-bedded jaspery and cherty metallic iron-formation	95
Cherty minnesotaite-carbonate iron-formation	20
Cherty carbonate iron-formation	80
Ferruginous slate	40
	390

South of Hook lake incomplete exposures and subsidiary folding complicate the determination of the section. However, there is a definite gradual change in the upper part of the iron-formation in that cherty minnesotaite-carbonate rocks are more numerous south from Syncline lake to Johnston lake, and the upper thick-bedded member thins southward.

The base of the iron-formation is ferruginous chert. Overlying it is cherty minnesotaite-carbonate iron-formation and cherty metallic iron-formation with the relative proportion of the latter gradually decreasing towards the south. The upper part of the formation is thick-bedded jaspery and cherty metallic iron-formation.

A section, from scattered outcrops, is as follows:

Jaspery and cherty metallic iron-formation	
thick-bedded...	100 feet
thin-bedded ...	20
Cherty minnesotaite-carbonate iron-formation.	80
Ferruginous chert	190
	390

The sequence within the iron-formation may be summarized as follows:

Jaspery and cherty metallic iron-formation with or without a granule texture	
thick-bedded...	100-205 feet
thin-bedded....	20- 95
Cherty minnesotaite-carbonate iron-formation.	0- 80
Ferruginous chert	60-190
Cherty carbonate iron-formation	0- 80
Ferruginous slate	0- 40
	350-400

The Iron-Formation of the Heluva Lake Area

The rocks in the vicinity of Heluva lake (Figure 5) were mapped by the writer during the summer of 1949, and a description of the iron-formation there is here included as this area forms part of the main ore zone and also, nearly flat-lying, relatively undisturbed iron-formation occurs along the edge of the Labrador Trough to the west of the lake. These rocks are less altered than those at Snow-Trough lakes and apparently approximate more closely the original sediments.

Table of Formations

Quaternary	Pleistocene	Till	Feet
Late Precambrian (Kaniapiskau)	Point series	Shale	40+
	Unconformity?		
	Ferriman Series	Iron-formation	270-350
		Shale and argillite	30- 45
		Chert	15- 30
		Quartzite	50-200
	unconformity?		
	Hamilton River Series	Limestone	0- 50
		Shale	0-700+

The iron-formation is divisible into the following

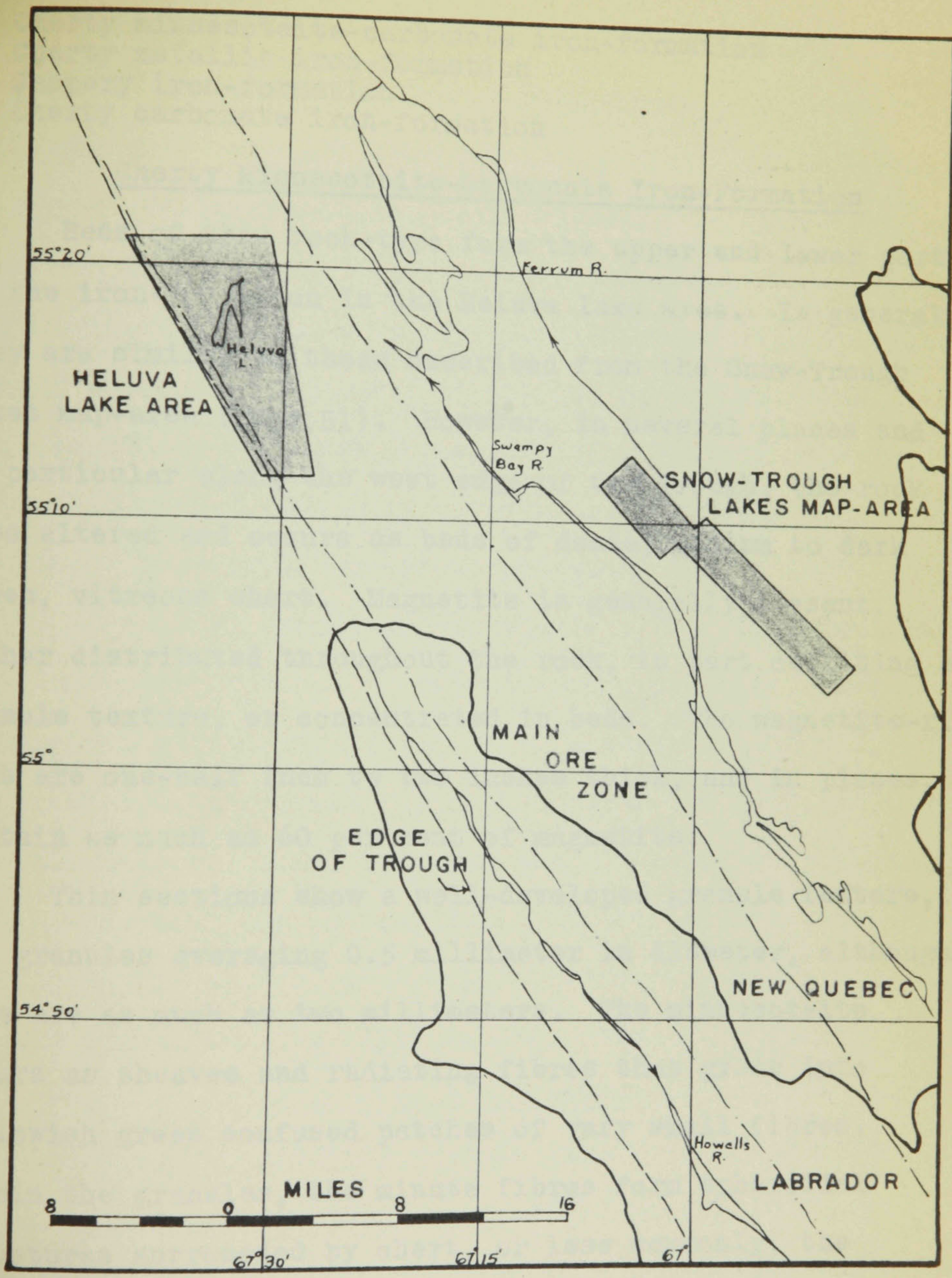

Figure 5. Index map showing location of Heluva Lake area and the relation to the Snow-Trough Lake map-area.

rock types:

1. Cherty minnesotaite-carbonate iron-formation
2. Cherty metallic iron-formation
3. Jaspery iron-formation
4. Cherty carbonate iron-formation

Cherty Minnesotaite-Carbonate Iron-Formation

Beds of this rock-type form the upper and lower part of the iron-formation in the Heluva lake area. In general, they are similar to those described from the Snow-Trough Lakes map-area (page 51). However, in several places and in particular along the west edge of the Trough, the rock is less altered and occurs as beds of dense, medium to dark green, vitreous chert. Magnetite is generally present, either distributed throughout the rock, in part outlining a granule texture, or concentrated in beds. The magnetite-rich beds are one-half inch to two inches thick, and in places, contain as much as 60 per cent of magnetite.

Thin sections show a well-developed granule texture, the granules averaging 0.5 millimeter in diameter, although some are as much as two millimeters. The minnesotaite occurs as sheaves and radiating fibres that grade into yellowish green confused patches of very small fibres. Within the granules, the minute fibres form spheroidal structures surrounded by chert, or less commonly, the relations may be reversed (Plate 8 A). Dusty grey carbonate is normally associated with the minnesotaite.

The magnetite generally forms well-developed grains, either individual octahedra averaging about 0.1 millimeter in diameter, or larger masses formed by their union. The grains partially outline some granules, are scattered throughout some granules, or occupy most of others. Although the grouping of the magnetite grains roughly conforms with the shape of the granules, particularly noticeable where the granules are flattened or irregularly shaped, the individual grains commonly transect the outlines of the granules. In the magnetite-rich beds, octahedra of magnetite form large scattered grains and long narrow groupings which parallel the bedding. A granule texture is absent.

In places, graphite occurs associated with minnesotaite but it is not common. In thin section, one band showed spheroidal structures of graphite in chert (Plate 8B). Minnesotaite is present. Also, a few of the granules contain some yellowish brown, weakly pleochroic, confused patches of what may be the iron silicate, stilpnomelane[1], although this mineral is strongly pleochroic where the minute plates or needles are similarily oriented.

<u>Cherty Metallic Iron-Formation</u>

The cherty metallic iron-formation is similar to that of the map-area (page 49). However, it occurs in thicker beds which average about eight inches in thickness but range

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1. Gruner (1946,p.11) gives the empirical formula of stilpnomelane as $(OH)_4(K,NA,Ca)_{0-1}(Fe,Mg,Al)_{7-8}Si_8O_{23-24}$ $\cdot 2\text{-}4H_2O$. The structure approximates that of mica or chlorite without being a mixture of the two. It is commonly associated with minnesotaite in the iron-formation of the Mesabi range.

from one inch to 12 inches. In addition, carbonate is more abundant. The weathered surfaces are commonly pitted where the carbonate has been leached out. The pits range in size from that of a pin-hole to as much as one inch in diameter and average about one-eighth inch. They are normally lined with limonite. The carbonate is greyish brown to brown in colour and the principal constitueht is siderite.

The magnetite and hematite are closely associated and at least part of the hematite is secondary after the magnetite, although the metallic grains outlining and filling some granules are entirely hematite. The magnetite is commonly rimmed by, or contains patches of, hematite (Plate 9B). In many cases, the metallic grains are irregular in shape, and the contacts between the hematite and magnetite give no indication of the age relationship (Plate 10A). The age relation is further complicated by the presence here and there, of blades of hematite, some of which have magnetite forming part of the margins (Figure 6). The occurrences suggest that, in part, the magnetite and hematite may have crystallized simultaneously, and that some hematite was possibly reduced to magnetite.

Jaspery Iron-Formation

This rock is similar to the thick-bedded jaspery iron-formation in the map-area (page 50). Both normally have a well-developed granule texture. However, carbonate is more abundant in the Heluva Lake area.

Figure 6

Relation of magnetite to blades of hematite,
in jaspery iron-formation. A similar relation
is found in the cherty metallic iron-formation.
(Camera lucida drawing 95X)
stippled: magnetite; grey: hematite; matrix: jasper

Cherty Carbonate Iron-Formation

Cherty carbonate iron-formation is not common and forms no large unit such as found at Hook lake. However, the rocks are similar even to having associated chert beds. Also, beds of cherty carbonate rock are found interbedded with the argillaceous member which underlies the iron-formation proper.

Stratigraphy

The succession within the iron-formation at Heluva lake is as follows:

state that "…. the original constituents of the iron-bearing formations were dominantly cherty iron carbonate and iron silicate (greenalite) with minor amounts of hematite and magnetite….". Gruner (1946,pp.14-17) from X-ray data considers greenalite to have a serpentine structure and gives the formula as $(OH)_{6-x}(Fe'',Mg)_{6-x}Fe'''_xSi_4O_{11+x}\,H_2O$ where x signifies the ionic amount of trivalent iron replacing divalent iron. Although greenalite may have been an original constituent of the Sokoman iron-formation, it has not as yet been definitely recognized in any of the members.

Minnesotaite

Tyler (1949,pp.1102-1105) in discussing the Lake Superior region considers minnesotaite and stilpnomelane to be low grade metamorphic minerals formed from a cherty carbonate and greenalite rock, the minerals of which were original precipitates or produced by diagenesis. Metamorphism of these rocks is the result of "deep burial with associated high temperatures and pressures", and, locally, is related to small intrusive bodies. More intense metamorphism is found adjacent to large intrusive masses, such as the Duluth gabbro, and the mineral grunerite ($(OH)_2Fe_7(Si_4O_{11})_2$) has formed. Regarding the transformation, Tyler (p.1105) states:

> "Iron-rich silicates formed at low temperatures may take on more silica from the chert during metamorphism to form secondary silicates with a lower iron content. Thus greenalite which contains about 39 per cent iron may be observed in thin sections in all stages of alteration to minnesotaite. Chert is eliminated in this process.

> We may consider a facies of the original iron formation which consisted essentially of siderite and chert. If stilpnomelane - 21 to 29 per cent iron - or minnesotaite - 27.5 per cent iron-forms, the chert may be changed completely to iron silicates with an original iron-content as low as 20 to 23 per cent. Chert in excess of that required to form iron silicates recrystallizes to form sugary quartz."

More information is available regarding the formation of stilpnomelane than that of minnesotaite but as these two minerals are commonly associated, occurring together in many granules and, in places, with greenalite, the data can be assumed to be applicable in part to the minnesotaite. The association was first described by Gruner (1944,p.363) in the Mesabi and Cuyuna ranges and later by Tyler (1949,p.1103) who states:

> "Minnesotaite was identified by the author from the Ironwood and Negaunee formations on the eastern Gogebic and Marquette ranges, where it occurs in association with stilpnomelane and magnetite. This association indicates that the mineral probably forms in a low-grade metamorphic facies under conditions similar to stilpnomelane."

Present study of the Sokoman iron-formation indicates that the mineral stilpnomelane is not common. If minnesotaite and stilpnomelane are both products of low-grade metamorphism, the relative scarcity of the latter must be explained by some other reason than that of the degree of metamorphism. Gruner (1946, p.13) states:

> "All analyses of stilpnomelane ever made contain from about 4 to 7% Al_2O_3 and 2 to 9% of MgO. For this reason it is thought that Al and Mg are essential constituents for the stability of this structure."

As shown in the following tabulation of analyses taken from Gruner (1946,p.10), the Al_2O_3, CaO and K_2O contents of minnesotaite are low in contrast to that of stilpnomelane.

	Minnesotaite	Stilpnomelane		
SiO_2	51.29	46.85	44.77	45.24
Al_2O_3	0.61	4.64	6.32	6.73
Fe_2O_3	2.00	11.60	20.79	25.34
FeO	33.66	20.00	12.83	3.45
MgO	6.26	5.75	4.01	7.67
MnO	0.12	0.33	0.21	0.60
CaO	Nil	0.94	0.10	1.91
Na_2O	0.08	0.27	0.07	0.03
K_2O	0.03	2.07	3.31	1.67
TiO_2	0.04	0.15	0.04	0.33
H_2O	5.54	5.77	5.64	6.72
H_2O	0.24	1.80	1.96	.76
	99.87	100.17	100.05	100.45

Thus the less common occurrence of stilpnomelane relative to minnesotaite is probably the result of a deficiency of alumina, and possibly also of lime and potash, in most parts of the iron-formation. Two analyses of iron-formation (dried) are shown below. The first (1) is representative of the section within the map-area and the second (2), that of the Heluva Lake area. It should be noted also, that very little of

	1	2
SiO_2	49.64	54.80
Al_2O_3	0.29	0.16
Fe	31.9	29.1
MgO	0.86	1.26
Mn	0.30	0.24
CaO	0.28	0.60
P	0.038	0.015
S	0.019	0.009
Loss on ignition	3.06	0.85

Analyses by The M.A. Hanna Company, Iron River, Michigan the observed part of the Sokoman iron-formation is unoxidized. Stilpnomelane may well have been present, especially in those members of the ferruginous chert associated with the underlying Ruth slate, which is high in alumina, but, if so, oxidation has destroyed all evidence of it.

It is generally agreed that stilpnomelane is normally a low-grade metamorphic mineral. Tyler (1949,p.1103) states:

> "Stilpnomelane is extensively developed in iron formation and slates, adjacent to basic dikes and sills, quartz-adularia pegmatite veins, quartz-tourmaline veins, and quartz veins on the eastern Gogebic, the Marquette range, and in the Crystal Falls district."

Hallimond (1924,p.193) describes its occurrence in a metamorphic facies of iron formation, adjacent to greenstone dikes in North Wales, and Turner and Hutton (1935,p.7) discussing the origin in greywacke schists of New Zealand, state:

> "Thus in the schists of Western Otago stilpnomelane has crystallized as a stable product of low-grade metamorphism, in which shearing stress at low temperature, aided to an unknown extent by the action of dilute aqueous solutions, has been the dominant controlling factor."

However, Gruner (1946,p.12) postulates that stilpnomelane and minnesotaite, along with greenalite, may be primary constituents of the iron-formation in the Mesabi range, forming from a colloidal gel.

> "As stilpnomelane forms from, let us assume, a colloidal gel, it will take the ions in its neighborhood which are most convenient and of the necessary charge. If it cannot find any more it will stop growing. The leftover gel material, then, may be

of the proper composition to form minnesotaite or greenalite, or quartz and siderite, if CO_2 is available in considerable concentration. This illustration should suffice to show why these silicates can show so many variables in otherwise definite crystal structures. It also sheds light on the bewildering arrangements the minerals, particularly the silicates, may take with respect to shapes, grain sizes, textures, and even bedding and banding without very material changes in the chemical composition of the taconite as a whole."

The minnesotaite within the Sokoman iron-formation normally occurs as sheaves, radiating fibres or fibres arranged in a grid pattern. A granule texture is generally in evidence in the minnesotaite-bearing rocks, although commonly indistinct, apparently having been partially destroyed, and in places obliterated, by the growth of the fibres and the development of a new texture. Furthermore, the mineral has a talc structure. The writer concludes that the minnesotaite in its present form, is a low-grade metamorphic mineral. However, there is still the problem of the source of the constituents forming the minnesotaite. Three possible sources are suggested, namely, greenalite, colloidal material of a suitable composition, and crystalline quartz and carbonate.

There is no evidence that greenalite is or was a common mineral in the Sokoman iron-formation. It has not yet been observed even in the least-altered specimens studied. If a transformation from greenalite to minnesotaite is general, there should be some evidence of residual greenalite, especially in the cherty minnesotaite-carbonate iron-formation exposed west of Heluva lake. Certainly the association of greenalite and minnesotaite is not uncommon in the Biwabik iron-formation of the western Mesabi district.

It is more likely that most of the minnesotaite formed directly from colloidal gel, and, on crystallization or recrystallization, under the influence of diagenesis and low-grade metamorphism, developed its present fibrous form. The composition of the colloidal material is problematical but probably varied from place to place. With slightly different conditions of deposition, diagenesis and metamorphism, varied mineralogical facies might well result.

The transportation and deposition of iron was studied by Moore and Maynard. From their investigations they concluded (1929,p.302) that the iron was transported principally as a ferric oxide hydrosol, stabalized by organic matter. This conclusion is not wholly applicable to the cherty minnesotaite-carbonate iron-formation, although in agreement with data concerning the jaspery and cherty metallic rocks. It is possible that a minor amount of minnesotaite may have formed from a precipitate of hydrous ferric oxide, silica and organic matter. The iron in minnesotaite is predominantly in the ferrous state, thus necessitating reduction of the iron, as well as combination of the iron and silica. However, it does not explain the wide distribution of the minnesotaite-bearing members, nor the fact that of two adjacent beds, one may be cherty minnesotaite-carbonate iron-formation whereas the other is jaspery or cherty metallic iron-formation. It seems necessary to conclude that the original precipitates were different.

It is probable that the cherty minnesotaite-carbonate rocks originally consisted essentially of hydrous ferrous silicate and silica. The carbonate may have formed by a reaction between ferrous silicate and organic matter, or between ferrous silicate and calcium carbonate. If the precipitate was high in alumina and magnesia, stilpnomelane might result on crystallization.

Concerning the Gunflint iron-formation, Gill (1925,p.727) concluded that the original precipitate consisted "sometimes of hydrated ferrous silicate and silica, sometimes of hydrated ferric oxide and silica, and more rarely, of all three of these substances". Hayes (1917,p.75) considers the hydrous aluminous silicates in the Wabana iron ore to have been precipitated as such. Gruner (1946,p.9) in describing granules of minnesotaite in the Biwabik formation states:

> "There are also many definite granules which are still darker - about the colour of green olives in these sections which are so fine grained that only smooth green areas can be made out even with high magnification. These differ from greenalite only by their mottled appearance and aggregate polarization between crossed nicols."

The third possible source of the constituents forming the minnesotaite is crystalline quartz and carbonate. In this connection, the relationship at Hook lake is of interest in that, lying directly above the cherty carbonate iron-formation, is 20 feet of cherty minnesotaite rock which in turn is overlain by jaspery and cherty metallic iron-formation. Both the carbonate and minnesotaite members are massive, whereas, within 35 feet of the latter, the jasper and metallic iron-formation has undergone bedding slippage and fibrous riebeckite is well developed along the bedding planes. Minnesotaite is only a minor constituent in the upper member and is absent in the cherty carbonate rock except for a few minute inclusions in the quartz. In contrast, no carbonate was found in the cherty minnesotaite member. Thus, the minnesotaite could have developed from a cherty carbonate rock as a result of dynamic metamorphism and/or through the action of the dilute solutions which were active in the formation of the riebeckite. However, the cherty carbonate member contains beds and lenses of chert and these are absent in the cherty minnesotaite rock.

In summary, it is probable that most of the minnesotaite in the Sokoman iron-formation developed directly from colloidal material, and, on crystallization or recrystallization, under the influence of diagenesis and low-grade metamorphism, developed its present fibrous form. The composition of the colloidal material probably varied slightly from place to place but consisted essentially of hydrous ferrous silicate and silica. Transformation of carbonate and silica into minnesotaite after initial crystallization is not unlikely, but there is no evidence that it occurred. If the original precipitate was rich in alumina and magnesia, the resulting mineral would have been stilpnomelane.

On alteration, the minnesotaite, in so far as could be studied in thin section, becomes yellowish green in colour and eventually changes to yellowish brown or dark brown limonite (goethite) which retains the fibrous form of the minnesotaite. However, Tyler (1949, p.1110) believes that the alteration of the silicates in the iron-formations of the Gogebic and Marquette ranges produces soft red hematite on a far more extensive scale than goethite. In this connection, Gruner (1946,p.97) states:

> "When the silicates, minnesotaite and stilpnomelane, break down they form at first a dirty green to yellowish soft earthy material which may have the shape of original needles. A number of X-ray photographs of these needles give a few poor lines which coincide with equally poor lines of montmorillonite or nontronite. As nontronite is a very poorly crystallized ferric silicate with much H_2O and a layer structure similar to minnesotaite and stilpnomelane such a transition from fresh silicates to goethite by way of nontronite is not at all surprising."

and (p.100)

> "Minnesotaite and greenalite, also a part of the stilpnomelane, alter to goethite, which is brownish-yellow in the ore. Siderite in some places becomes

hematite, in other, goethite. A part of the stilpnomelane, particularly in the Intermediate Slate, alters to hematite and kaolinite."

Iron Oxides and Hydroxides.

Among the many problems concerning iron-formation is that of the origin of the iron oxides, hematite, magnetite and martite. With respect to the Sokoman iron-formation, any acceptable hypothesis must include or explain the following data:

1. West of Heluva lake, massive jaspery iron-formation overlies and is overlain by cherty minnesotaite-carbonate iron-formation. The contacts are well defined and the relations suggest an abrupt change in the type of sediments deposited or the conditions under which they were deposited. Although these members, and in particular the lower two, have a wide distribution, nowhere is the sequence interrupted nor is there any gradation of one rock into another along the strike.

A similar relationship was noted in the Snow-Trough Lakes map-area but it is not as well defined because of folding and limited exposure.

2. The jaspery and cherty metallic iron-formation contains variable, although not abundant, amounts of carbonate and minor occurrences of minnesotaite.

3. Minnesotaite, in all specimens studied in thin section, alters to fibrous limonite (goethite). Generally the carbonate also alters to limonite but, in places, the

alteration product is soft red hematite, and at Hook lake, minute grains of magnetite appear to have formed from the carbonate.

4. No hematite was found in the cherty minnesotaite-carbonate iron-formation although magnetite is normally abundant.

5. The magnetite generally forms well-developed grains either as individual octahedra or as masses formed by their union. Alteration of the magnetite to martite is common in parts of the jaspery and cherty metallic iron-formation (page 49) and in the ferruginous chert (page 47). Octahedral grains of magnetite are rimmed by, or contain patches of, martite (Figure 4,Plate 9B). Where the rock is highly weathered, the magnetite is also altered to goethite. The result is octahedral grains of goethite rimmed by, and containing patches of, martite (Figure 5), or, martite containing patches of goethite (Plate 10B).

6. The relations of the magnetite and hematite in the jaspery and cherty metallic iron-formation suggest that, in part, the magnetite and hematite may have crystallized simultaneously, and that some hematite was possibly reduced to magnetite (page 61).

It was concluded that most of the minnesotaite in the Sokoman iron-formation formed directly from colloidal material, and as a result of diagenesis and low-grade metamorphism, was crystallized into its present fibrous form. Magnetite is the only iron oxide present in the minnesotaite-bearing rocks. Some granules are partially outlined by the magnetite grains, some contain scattered grains, and others are almost completely formed of magnetite. The grouping of the grains of magnetite roughly conforms with the shapes of the granules. However, individual grains commonly transect their outlines. The close association of the minnesotaite and magnetite indicates a similar origin for the two minerals. It is probable that they formed at approximately the same time and under similar conditions. The strong crystallizing force of magnetite would explain the euhedral grains transecting the outlines of some granules.

The writer postulates that, in general, the martite found in the Sokoman iron-formation formed as a result of the action of hydrothermal solutions, whereas, under intense weathering, the normal alteration product of magnetite is goethite. The relations between the magnetite, martite and goethite (summarized page 74) are most easily explained by this hypothesis.

It had been generally assumed that the abundant occurrence of martite in the iron-formations of the Lake Superior region was the result of weathering (Gruner,1922, pp.2,3). However, of recent years, more geologists have favoured the idea that the martite has formed as the result of hydrothermal solutions. It is known that magnetite is extremely stable under surface conditions, as proven by the presence of fresh grains in many sediments. In addition, alteration to martite is rare if account is taken of the wide distribution of magnetite. In all occurrences, other than that of the Lake Superior region, the transformation is considered to be the result of hydrothermal solutions. Thus, Newland (1922, pp. 299-302) points out that the magnetite of the Arnold Hill district in the Adirondacks is altered to martite only where hydrothermal solutions were active and concludes that "under surface conditions one would expect the product to be limonite rather than hematite".

Gilbert (1925,p.595) after studying the relationship of magnetite and hematite concluded:

> "It is common in oxidized specimens to see magnetite crystals with their borders replaced by hematite and their interiors by limonite. It is easy in such cases to assume that both hematite and limonite are supergene, but as a rule a more reasonable explanation is that the limonite is replacing the magnetite selectively."

In the Mesabi range, Broderick (1919,p.365) reports that in the vicinity of the iron ore the magnetite is altered by surface water to limonite rather than hematite. Gruner (1930,p.851) notes that "the discovery of whole martite ore bodies to a depth of 900 feet in the ores suggests that martite is due to thermal oxidation".

The only recent writing supporting the surface oxidation hypothesis is by Wienert (1933,p.71). He considers the martite in the Marquette district of Michigan to have resulted from surface oxidation as a study of drill core showed a progressive decrease of martite with depth. However, the iron-formation of the Marquette district is cut by intrusives and Wienert mentions that one drill hole intersected a diorite dike near surface. It is suggested that the martite formed as a result of the activity of hydrothermal solutions related to the period of intrusion. Tyler (1949, p.1123) supports the idea of hydrothermal solutions and considers that Wienert must have made an error in his conclusions.

If hydrothermal solutions penetrated part of the Sokoman iron-formation, minor amounts of iron and silica would probably be dissolved and later redeposited. In this connection, metallic hematite locally veins and replaces the iron-formation. Secondary quartz is generally present. In addition, patches of specular hematite and quartz crystals have been observed by the writer.

It is generally assumed that rocks similar to the jaspery and cherty metallic members, are the result of the alteration of cherty silicate or cherty carbonate material. Van Hise and Leith (1911,p.187) consider the source minerals as greenalite and/or a cherty carbonate rock. However, Gruner (1922,p.416) states:

> "In the Biwabik formation we find hematite and greenalite together. Hematite is commonly taken to be an alteration product of greenalite......There is no reason, then, why hematite (or a ferric hydroxide), where associated with greenalite, could not have been an important primary mineral in the Biwabik formation."

Tyler, (1949,p.1111) postulates that such rocks were derived from a metamorphic facies of the iron formation, consisting of chert and secondary iron silicates. However, he assumes that the principal alteration product of the iron silicates is hematite and this is not true for the Sokoman iron-formation where even in jaspery beds, the silicates alter to fibrous goethite. Nor would such an hypothesis explain the wide distribution and consistent relation of the jaspery and cherty metallic iron-formation and the cherty silicate members. If remnants of one type of rock were present in the other, there would be some basis for such an assumption.

It is concluded that, with the exception of the martite, most of the hematite found in the jaspery and cherty metallic iron-formation formed from hydrated ferric oxide. Subsequent to precipitation, it was dehydrated to anhydrous ferric oxide, crystallized and possibly recrystallized, and probably altered in part, to magnetite. The association of hematite with carbonate and minnesotaite is unlikely if the hematite is a general alteration product of these minerals. Hayes (1915,p.73) in discussing the Wababa iron ores of Newfoundland describes granules composed of alternate concentric layers of the hydrated iron silicate, chamosite and hematite, in which the hematite is probably mostly primary. The general conclusion of original hematite does not preclude the probability that some hematite has formed from iron silicates and cherty carbonate material but this source is of secondary importance. Regarding hematite granules in the red basal taconite of the Gunflint iron-formation, Gill (1927,p.699) states:

> "The original precipitates from which these granules developed probably consisted of gelatinous silica and hydrated ferric oxide."

and (p.702):

> "Within a few feet above and below (the red basal taconite), almost equally persistent beds of greenalite taconite appear and it is difficult to see how one part of the series could have suffered alteration, whereby hematite was developed from original greenalite, while the beds above and below escaped entirely. Unless the change is considered to have occurred almost contemporaneously with deposition. In some instances, such contemporaneous alteration may have occurred, but in general, such an assumption introduces an unnecessary complication, since hydrated ferric oxide may form as a direct chemical precipitate just as readily as ferrous silicate."

Moore and Maynard (1929,p.302) as a result of a detailed investigation of the solution, transportation and precipitation of iron and silica state:

> "It is concluded that the iron going to make up large sedimentary iron formations was transported principally as a ferric oxide hydrosol, stabalized by organic matter."

Upper Slate

The upper slate is exposed along the east shore of Bruin lake and west of Syncline lake. Depending on the location, the rock could be called a slate, shale or argillite as the cleavage is not always pronounced and fissility is lacking in some exposures. The thicknesses of the beds range from 0.1 inch to four inches, with the average about 0.3 inch. On the fresh surface, the rock is black, grey or greenish grey and weathers grey, greenish grey or dull rose. The microscope shows nothing except extremely fine-grained argillaceous material.

The iron-formation and slate were not found in contact but appear to be structurally conformable.

Pleistocene

Till consisting of clay, boulders, sand, and gravel forms a thin mantle over most of the bedrock. The thickness of the till on the higher ground is normally less than ten feet, and the larger exposures are found here. The boulders are generally less than a foot in diameter but some as much as four feet in diameter were seen. Erratics occur throughout the area, and are present even on the higher hills.

No glacial deposits such as eskers or drumlins were found.

STRUCTURE

Unconformities.

The quartzite and limestone are probably separated by an unconformity. East of Syncline lake, the quartzite lies directly above the lower slate, whereas, farther south, the underlying rock is limestone. Also, the shale below the quartzite at Snow lake is absent south of Hook lake. In all of these instances, there is no visible structural discordance.

These relations indicate that, following the deposition of the limestone, the rocks were uplifted and partially eroded. Slight disturbances are suggested by the occurrence of fragmental limestone. This interpretation is supported by evidence of an unconformity at the same horizon within the main ore zone to the west. There, locally, a thin chert conglomerate underlies the Wishart quartzite. Where it is present the dolomite and chert breccia are absent, and it rests directly on the Attikamagen shale. Mapping along the western edge of the Labrador Trough indicates that following the deposition of the Hamilton River series, the margin of the basin of sedimentation shifted westward resulting in a sedimentary overlap of the Ferriman series upon the Ashaunipi basal complex.

It has been suggested tentatively that an unconformity separates the Sokoman iron-formation and overlying Point series near Sawyer lake (Figure 3, latitude 54°26' north). There the iron-formation is overlain by extrusive rocks of the Sawyer-Nimish groups, whereas farther north, the overlying rock is the Menihek slate which is definitely younger than the volcanics. It is known from drilling that these volcanic rocks overlie in one place a rock of iron-ore grade, thus also suggesting the presence of an unconformity. Within the Snow-Trough Lakes map-area, the upper slate and iron-formation were not found in contact, but they appear to be structurally conformable and there is no evidence of the existance of a disconformity; neither has the writer been able to find evidence for such a break within the main ore zone. It may be that this unconformity, if it occurs, is limited to the southern part of the Trough.

Folding and Faulting

A large, open anticline is the predominant structure near Snow lake, whereas, the prominent ridge extending southeastward from Snow lake to Hook lake is formed by a syncline with subsidiary folds on the limbs (see maps in pocket). Near the north end of Hook lake, the east limb flattens out and then steepens to form an anticline, which plunges northwestward. The symmetry of the anticline is broken by bedding slippage within the iron-formation exposed along the east arm of Hook lake. The orientation of riebeckite fibres and of striae indicate a dip-slip movement. The displacement is apparently not great but serves to emphasis the probability of a regional fault extending through Snow and Hook lakes.

Near Bruin lake this assumed regional fault separates the two limbs of an asymmetrical syncline, the north limb of which dips steeply southward. As much as 150 feet displacement along cross-faults is indicated by exposures of chert. A subsidiary fault probably extends through the north arm of Bruin lake but nowhere is it, or the assumed fault farther east,exposed.

The western part of the Bruin-Snow area is underlain by limestone which forms an open, northwestward-striking anticline. There probably is an anticline to the east as well, but data are lacking. The association of faulting, and open and closed folding, as is present north of Syncline lake, is not uncommon in the main ore zone.

Along the west side of Syncline lake, the rocks are folded into an anticline with associated crumpling. Near the north end of the lake, the west limb is overturned and crumpling of the east limb and the upper slate is pronounced. On the small peninsula at the south end of Syncline lake, the greywacke is intricately crenulated and the massive quartzite broken by numerous joints. At the west side of Trough lake, the rocks probably form the overturned west limb of an anticline. Crossfaults with as much as 70 feet displacement occur and jointing in the quartzite suggests subsidiary folds.

Although chert and quartzite overlie the iron-formation west of Syncline and Trough lakes, the sequence is interpreted as being overturned. The interpretation is based on the following data:

1) If no overturning is assumed, thin-bedded ferruginous chert forms the top of the iron-formation and, in places, jaspery and cherty metallic iron-formation the bottom. This is the reverse of the sequence noted elsewhere.

2) Large blocks of limestone, mapped as debris, outcrop above the quartzite at one point along the west edge of Trough lake.

3) The chert is identical with the chert member.

4) The quartzite near Trough lake is a massive light grey, fine-grained rock similar in appearance to the upper part of the quartzite member. However, no greywacke is present.

CORRELATION

Local

There is no difficulty in correlating the rocks within the map-area with the Kaniapiskau system. Although not all the formations are represented, the succession is similar, as shown below.

	Point Series	Menihek slate 500+ feet	Upper slate 300+ feet
		Sawyer-Nimish group	
	unconformity?		
Late Precambrian	Ferriman series	Sokoman iron-formation 250-700	Iron-formation 350-400
		Nimish volcanics	
Kaniapiskau		Ruth slate 0-150	Ferruginous slate 0-40
		Wishart quartzite 40-250	Chert 3-20 Quartzite 125-175 Shale 0-50
		Fleming chert breccia 0-300	
	unconformity?		
		Denault dolomite 0-300	Limestone 0-250+
	Hamilton River series	Nimish volcanics	
		Attikamagen shale 0-1000+	Lower slate 200+
		Seward grits 0-3000	

The absence of the Nimish volcanics was expected as they are not present within the main ore zone to the west, although pillowed flows and "greenstones" occur about four miles northeast of the map-area. Reconnaissance mapping of these rocks indicates that they overlie the lower (Attikamagen) shale and were presumably extruded following erosion of the limestone formation and probably part of the shale. However, as the limestone is absent in the area examined by the writer, and the shale and flows were not found in contact, the igneous rocks may actually represent a period of extrusion preceding the deposition of the limestone.

The Wishart quartzite around Burnt Creek camp, in the main ore zone, is normally purer than the quartzite mapped, but greywacke is not rare, especially farther northwest. In addition, a chert member, similar to that in the map-area, commonly forms the top of the quartzite. The thickness of the shale at the base of the quartzite is unknown but its distribution appears to be limited and it is considered to be a member of this formation.

A detailed study is only now being made of the succession within the iron-formation exposed along the main ore zone. However, mapping by the writer in the vicinity of Burnt Creek camp indicates that a cherty minnesotaite - carbonate rock or a ferruginous chert overlies the Ruth slate and forms the base of the iron-formation, although the greater thickness consists of thin-bedded to massive, jaspery and cherty metallic iron-formation. At Heluva lake, approximately 50 miles to the northwest but still in the main ore zone, the succession within the iron-formation is as follows:

Upper cherty minnesotaite-carbonate iron-formation	40- 50 feet
Jaspery and cherty metallic iron-formation	200-250
Thin-bedded jaspery iron-formation	0- 50
Lower cherty minnesotaite-carbonate iron-formation	30- 50
	270-350

This may be compared with the succession within the Snow-Trough Lakes map-area:

Jaspery and cherty metallic iron-formation	
thick-bedded	100-205 feet
thin-bedded	20- 95
Cherty minnesotaite-carbonate iron-formation	0- 80
Ferruginous chert	60-190
Cherty carbonate iron-formation	0- 80
Ferruginous slate	0- 40
	350-400

A detailed comparison of sections of the iron-formation in different localities within the Trough must await further mapping and petrographic study. However, in general, the divisions into which the formation may be divided are probably similar although the sequence and thickness will vary somewhat.

Regional

Although considerable reconnaissance mapping for several companies has been done along the Labrador Trough to the north of the Dyke Lake map-area, with the exception of the traverse by Low, no data have been published. Low (1897,p.262L) gives the following section for the sedimentary rocks along the Koksoak river (the divisions are those of the writer):

Menihek slate	1. Rusty-weathering,black, micaceous shales.............	600 feet
Sokoman iron-formation	2. Dark-gray,ferruginous cherts.......................	200
	3. Dark-gray,ferruginous cherts,together with beds of jasper and magnetite......	500
	4. Fine-grained, dark-gray, ferruginous chert,somewhat calcareous and blotched with siderite...............	150
Ruth slate	5. Light-pink,very compact, brecciated limestone,often very siliceous..............	20
	6. Light-green, siliceous shales.......................	30
	7. Black,carbonaceous,graphic shales.......................	100
Denault dolomite	8. Massive,cherty,dark-blue dolomite....................	10
Attikamagen shale	9. Pearly-green shales, with cherty dolomite beds, showing ripple marks.........	40
	10. Coarse, gray sandstone.........	3
	11. Greenish-gray, calcareous shale, with occasional bands(6 in. to 15 in.) of fine-grained, dark-blue dolomite, weathering yellow..	30
Seward grits	12. Fragmental, violet-pink, calcareous chert............	200
	13 Red calcareous sandrock.........	200
	14. Medium-grained red-sandstone, and thin beds of red felsitic shales.............	10
	15. Bands of red and gray sandstone, separated by beds of red felsitic shales..........	425
		2518

Regarding the section, Low states:

"This section is constructed from several broken sections taken along the river. No. 15 rest unconformably upon the Laurentian granite. No. 14 represents the lowest beds of another cliff-face, and perhaps may be the upper part of No.15.

> There is a break in the section between No.11 and No.12, with probably a few beds missing. From No.4 to No.11 the section is continuous, while the upper measures are added by estimation, from the various exposures seen along the river, and are only an approximation of the thickness of the iron-bearing cherts, shales and limestones."

Until such time as reports on the intervening rocks are published, there seems little hope of a close correlation of the rocks along the Koksoak river and those within the Dyke Lake area. The Wishart quartzite, which is an excellent horizon marker in the south, is absent farther north according to the above division. Furthermore, Low does not mention any possible unconformity within the series, although number 12 may represent a break. A further complication is the fact that towards the south the Hamilton River series is absent along the western margin of the Trough and the Ferriman series rest directly on the Ashaunipi basal complex. Thus, the section given by Low may be comparable to only the upper part of the Kaniapiskau as the lowest member rests unconformably on granite.

For the rocks in the vicinity of lake Shabogamo which lies about 60 miles south of the southern edge of the Dyke Lake area, Gill, Bannerman and Tolman (1937,p.571) give the following section:

Basic intrusives	Olivine gabbro and diabase
Acid intrusives	Biotite and biotite-hornblende granite; microcline granite; pegmatite, aplite, and porphyritic granite dikes

Basic Intrusives	Diorite, gabbro
Wapussakatoo series	White quartzite
	Schistose grit
	Iron-bearing formation
	Mica schists and gneisses, injected gneiss
Duley Lake series	Marble
	Gneisses, schists, and iron-bearing quartzite

It seems probable that the Wapussakatoo and Duley Lake series are the metamorphosed equivalent of the Kaniapiskau. The iron-formation, marble, quartzite and grit are all represented farther north, and the sedimentary schists and gneisses of the Duley Lake series are probably, in part, the equivalent of the argillaceous rocks. If this correlation is correct, the intrusive rocks and the Montagnais intrusives would be of comparable age.

It is possible that part of the Labrador Trough swings southwestward and extends as far as Mistassini lake. It is interesting to note that Low (1897,p.242L) in describing a traverse north of lake Mouchalagen, reports schist, gneiss, limestone and iron-bearing rocks. Support of this possibility will have to await further mapping.

Sedimentary rocks, lithologically similar to the Kaniapiskau and also presumably of Late Precambrian age, occur along the eastern coast of Hudson bay and on adjacent islands. The assemblage is best developed around Richmond gulf, and on the Nastapoka and the Belcher islands. It includes iron-formation, arkose, sandstone and quartzite, argillite, shale, and slate, and dolomite and limestone, Associated with the sedimentary rocks are basic igneous rocks in the form of flows, sills and dikes. The beds strike north and generally dip westward at angles which seldom exceed 15 degrees. However, on the Belcher islands, the rocks form north-striking, broad,open folds.

Moore (1918,p.438) describes the iron-formation as consisting of "jasper, chert, hematite, magnetite, siderite, and green granules regarded as the iron silicate, greenalite." However, from the description of the iron silicate, and also that of Young (1922,p.22), it seems probable that it is, in part at least, minnesotaite. The detailed study of the iron-formation as reported by Young (1922) indicates that it is not dissimilar to the Sokoman iron-formation. However, although non-clastic material predominates, it contains a considerable amount of clastic quartz and feldspar.

Leith (1910, pp.234-236) postulates that the assemblage is divisible into two groups, a lower Richmond Gulf group and an upper Nastapoka group, which are separated by an unconformity, principally erosional but in part structural. The iron-formation forms the upper part of the Nastapoka group, and although about 400 miles separate these rocks from those of the Labrador Trough, if the unconformity is assumed to be equivalent to that separating the Hamilton River and Ferriman series, the position of the two iron-formations is comparable. The occurrence of these rock groups along the eastern coast of Hudson bay indicates, at least, that sediments were being deposited in another basin under conditions similar to those that existed for the Kaniapiskau and probably at about the same time.

In compiling the table of formations, the practice of giving each division within the rock assemblage a local name has been followed. However, on the basis of lithology and structure, an attempt was made to correlate the succession with that in other parts of the Precambrian shield and especially that of the Lake Superior district. Although the basis of the correlation is questionable, the Kaniapiskau and Lake Superior Huronian are not dissimilar as may be seen in the following comparison of the section for the Marquette district as given by Leith, Lund and Leith (1935) and that of the Dyke Lake area.

Marquette District	Dyke Lake Area
Upper Huronian	Point series
Michigamme slate	Menihek slate
Clarksburg volcanics	Sawyer-Nimish group
Greenwood iron-formation	
Goodrich quartzite	
------unconformity------	------unconformity?------
Middle Huronian	Ferriman series
Negaunee iron-formation	Sokoman iron-formation
	Nimish volcanics
Siamo slate	Ruth slate
Ajibik quartzite	Wishart quartzite
	Fleming chert breccia
------unconformity------	------unconformity?-------
Lower Huronian	Hamilton River series
Wewe slate	
Kona dolomite	Denault dolomite
	Nimish volcanics
	Attikamagen shale
Mesnard quartzite	Seward grits

ORIGIN OF THE SOKOMAN IRON-FORMATION

INTRODUCTION

The origin of the Sokoman iron-formation is principally a problem of sedimentation, including the source of the iron and silica, their transportation and subsequent deposition. In addition, any hypothesis must take into account the fact that banded iron-formations have world-wide distribution, and are commonly of great extent and thickness. Thus, within the Labrador Trough, iron-formation has been reported over a distance of 300 miles, and in the Dyke Lake area, the average thickness is probably at least 300 feet.

The Sokoman formation closely resembles the iron-formations of the Lake Superior region, but even here where considerable detailed work has been accomplished, there is no unanimity of opinion regarding the origin. However, it is generally agreed that most are chemical or in a small part biochemical sediments. Nevertheless, this is not necessarily applicable to all banded iron-formations. Dunn (1941,pp.369,370) considers that part of the iron-formation found in India was "originally deposited as fine-bedded ferruginous tuffs (which became oxidized), and more normal ferruginous sediments, and that surface and subsurface silicification of these, more or less contemporaneous with their deposition, under the action of solutions, partly magmatic in origin, gave rise to the banded jaspers and cherts."

Stark (1929,p.528) reports that locally the Agawa iron-formation in northwestern Minnesota is a tuff in which the iron oxides have been concentrated into bands by gravity and reworking, the whole simulating typical banded iron-formation. In addition, there is the Itabirite (iron-formation) of Brazil that consists of alternating beds of quartzite and iron oxides, or, not uncommonly. a mixture of the two (Harder, 1914, p.101).

Study of the Sokoman iron-formation indicates that, in the map-area and main ore zone at least, it consists essentially of chert and iron silicates, carbonates, oxides or hydroxides. With the exception of the ferruginous slate exposed at Hook lake, which is stratigraphically equivalent to the Ruth slate that underlies the iron-formation proper, no clastic sediments were observed. Neither is there any evidence that the iron-formation was originally, either partially or wholly, a ferruginous tuff. It may well be that clastic sediments and tuffaceous material do form part of the iron-formation farther south, but data are insufficient to support this possibility.

The following discussion of the origin of the Sokoman iron-formation is restricted to a sedimentary rock consisting essentially of microcrystalline quartz and iron-bearing minerals. The composition, extent, continuity of bedding, and the general association with normal sediments, precludes any possibility other than that the formation is a sedimentary rock.

DIFFERENT HYPOTHESES

There is general agreement that iron-formations are chemical or in small part biochemical sediments. The principal differences of opinion have to do with the source. The dominant early hypothesis of origin was that the material was derived from the weathering and erosion of old land surfaces and deposited in nearby basins or seas of shallow water. However, Van Hise and Leith (1911, pp.499-529), after studying the iron-formations of the Lake Superior region, suggested that direct and indirect contributions from contemporaneous lavas were of prime importance. They concluded (p.516):

> "Ordinary processes of weathering, transportation, and deposition of iron salts from terranes of average composition were as effective in the pre-Cambrian of the Lake Superior region as in other times and places, but these processes account for only thin and relatively unimportant phases of the iron-bearing rocks.......................
> For the derivation of the unique thick and extensive iron-bearing formations of the Lake Superior region it is necessary to appeal to some other agency. This is believed to be furnished by the large masses of contemporaneous basic igneous rocks. The association of sedimentary iron-bearing formations and basic igneous rocks is known in many localities outside of the Lake Superior region. The iron salts have been transferred from the igneous rocks to the sedimentary iron-bearing formations partly by weathering when the igneous rocks were hot or cold, but the evidence suggests also that they were transferred partly by direct contribution of magmatic waters from the igneous rocks and perhaps in small part by direct reaction of the sea waters upon the hot lavas."

Gruner (1922,pp.446-457) has shown that a direct contribution hypothesis involves serious chemical difficulties. Furthermore, there is no evidence of volcanism during the deposition of the Biwabik iron-formation of the Mesabi range, whereas, although extrusion of basic rocks reached a maximum during Keewatin time, the greatest development of iron-formation is in the Huronian. This suggests that these lavas were the source of iron-bearing sediments not so much during the time of their extrusion, as during their exposure to weathering much later. Gruner (p.459) concludes:

> "During Upper Huronian[1] time there existed large land areas in North America which were covered with greenstone and basalts. It is probable that fresh extrusive rocks and volcanic tuff and ash were deposited on parts of the land, as well as in the sea basins then existing. The climate of the continent was humid and probably tropical or subtropical. Vegetation of a low form was abundant and aided in the rapid decay of the rocks. Under these conditions iron, which usually is one of the most stable elements in weathering, went into solution to a large extent, but only in waters with organic colloids was it stable for any length of time in the zone of oxidation. Silica was also dissolved on a large scale. Both iron and silica were carried to the sea by rivers rich in organic matter."

The Gunflint iron-formation in Ontario is a continuation of the Biwabik iron-formation of the Mesabi range. Gill (1927,pp.726,727) from a study concerned with the origin of

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(1) The Biwabik iron-formation is now considered to be Middle Huronian.

the Gunflint, concluded:

> "During the Animikie period, continental weathering proceeded much as it does today. A landmass of low or moderate relief in a temperate or tropical climate was subjected to deep decay. Amongst other substances, iron and silica were carried to the sea by rivers, principally as colloids stabilized by protective agents. The usual clastic sediments were deposited near the river mouths, but the sols retained their stability long enough to be carried relatively long distances by off-shore currents to areas of shallow or moderate depth, in which fine, suspended particles were deposited rarely and only during brief periods. These conditions, maintained for a much longer time than in most other periods in the earth's history, resulted in the formation of an exceptionally thick series of sediments consisting almost wholly of iron compounds and silica.
>
> Volcanism occurred, particularly during the latter half of the iron-formation period. Some silica and iron may have been contributed directly by magmatic springs or by submarine lava flows, but the total quantity supplied in this way is believed to be relatively small."

In contrast to Gruner and Gill, Aldrich (1929,pp.143,144) considers that a magmatic source is necessary to explain the iron-formation of the Gogebic range, Wisconsin.

> "Either the silica and iron were dissolved in a solution and the solution was poured into this surface basin, or there were deliveries of molten lava at the surface, and sea water or meteoric waters extracted the silica and iron salts from these hot masses."

In 1929 Moore and Maynard studied the solution, transportation and precipitation of iron and silica with reference to the origin of iron-formation. From their experiments, they concluded (1929,p.524):

> "Assuming an abundance of organic matter in pre-Cambrian formations, it is possible for cold water to have extracted and transported sufficient iron and silica from the great areas of igneous rocks

exposed in pre-Cambrian time to build up large deposits of banded iron and silica. The iron would be dissolved and carried as a ferric oxide hydrosol and the silicas as colloidal silica, the two being stabilized by organic matter which kept them from mutually precipitating one another until thrown down by the electrolytes in the sea. The banding in the deposits, as shown by experiment, could be due to the differential rate of precipitation of the iron and silica combined with the influence of seasonal changes causing varying quantities of these substances to be brought into the basin of deposition at different periods throughout the year.

Concerning early Precambrian iron-formations, Moore (p.525) states:

> "The senior writer has for years adhered to the idea that practically all the pre-Cambrian iron-formations have been formed as the result of normal processes of weathering and chemical sedimentation. However, field work in recent years, followed by the laboratory experiments herein described, have led to a belief in Leith's contention that hot waters have played a more important role in the deposition of the highly siliceous formations associated with igneous rocks than was formerly admitted."

In 1935, Leith, Lund and Leith restudied the geology of the Lake Superior region, incorporating the information available since the earlier study by Van Hise and Leith (1911). They state (1935,p.23):

> "Study of the origin of the iron-formations since publication of Monograph 52 has not appreciably modified the conclusion therein reached - namely, that both weathering and igneous processes have played a part in bringing the iron salts together and that both chemical and organic processes have caused their precipitation. The quantitative ranges of the different processes are still conjectural....
>
> The conclusion cannot be avoided that the iron-formations of the pre-Cambrian, not only of the Lake Superior region but of the world, were the

unique result of some special combination of conditions that has not since been repeated."

GENERAL REMARKS

Experiments show that the granule texture found in the Sokoman iron-formation is not uncommon in colloidal precipitates, and that an assumption of organic processes is unnecessary to explain it. This work is summarized by Gill (1927, pp.692-694). However, it is established also that certain bacteria deposit iron in considerable quantities (Harder,1919). Gruner (1922,pp.413-420) considers that organisms were active in the precipitation of the Biwabik iron-formation of the Mesabi range. He describes bacteria, bacilli and algae, and ascribes groups or chains of minute concentric rings (cell structures) found in the iron-formation to microörganisms. Cell structures, although rare, do occur in the Sokoman formation (Plate 8). However, Hawley (1926,pp.441-461) has shown how forms similar to many of those described by Gruner may be reproduced by inorganic processes. It may be concluded that there is no direct evidence for or against the possibility that organisms played a part in the deposition of the Sokoman iron-formation.

The investigations related to the origin of iron-formation are well summarized by Moore and Maynard (1929,p.272). The principal points are as follows:

1. At present, most of the large rivers of the world are transporting sufficient silica to form large sedimentary formations. In addition, many of the rivers carry considerable quantities of iron. In this connection, Gruner (1922,p.455) calculated that with three parts iron per million, the Amazon river would transport an amount of iron equal to the iron content of the Biwabik formation, in 176,000 years.

2. Cold, carbonate waters are capable of dissolving sufficient iron and silica from a basic terrane to form large sedimentary deposits.

3. The iron is transported principally as a ferric oxide hydrosol; the greater portion of the silica, as a silica hydrosol.

4. Mixed hydrosols of iron oxide and silica, stabilized by a small amount of organic matter, can be transported for long distances in natural waters. However, when acted on by electrolytes of the composition and concentration of sea water, they are precipitated.

It is necessary to assume the existence of plant life in the Precambrian to explain the transportation of the iron as a ferric oxide hydrosol, and also, the occurrence of ferrous carbonate. The evidence for such an assumption is summarized by Moore and Maynard (1929,pp.522-524) who conclude:

> "If land vegetation did not exist there is no doubt marine and fresh water plants did exist, and that they must have been exceptionally abundant to give the little evidence that is now preserved."

It was concluded (page 71) that most of the minnesotaite-bearing iron-formation developed from a colloidal gel consisting essentially of hydrous ferrous silicate and silica. Thus, although the iron was probably deposited principally as hydrous ferric oxide, in places it occurred as a hydrous ferrous silicate.

Large masses of basic extrusive rocks are associated with the Sokoman iron-formation in the southern part of the Labrador Trough. It may be that minor amounts of iron and silica were contributed directly by submarine lava flows or magmatic springs. However, the association is not widespread, and no extrusive rocks have been observed in the main ore zone. Furthermore, it seems unnecessarily forced to appeal to magmatic sources if weathering is capable of supplying sufficient iron and silica.

The actual source rocks are unknown but probably have been destroyed by erosion. There is no reason why the sediments could not have been supplied from both sides of the Trough. However, it is assumed that the greater proportion came from a landmass to the east. The formations of the Kaniapiskau system appear to thicken and become coarser grained eastward. It is suggested that the rocks of the Murdock and Laporte groups are remnants of this landmass.

Chemical weathering predominated during deposition of the iron-formation. Clastic sediments probably reached the Trough but were deposited near the margins, whereas, the colloidal material retained its stability long enough to be carried out towards the centre.

CONCLUSIONS

In the Huronian period, a basin of deposition existed within the present Labrador peninsula. Normal clastic sediments were deposited within it during most of the period. Intermittent but prolonged volcanism resulted in local interlayering of flows and pyroclastic material with sedimentary rocks. Although detritus probably was derived from both east and west of the basin, the predominant source of the sediments was a landmass to the east.

The basin of deposition was probably a shallow epicontinental sea. As such, it would favor the development of the Denault dolomite. In addition, crossbedding within most of the formations suggests that shallow conditions prevailed. Data indicate intermittent uplifts and at least one major withdrawal of the sea, followed by erosion, during the existence of the basin.

By the time of the deposition of the iron-formation, the landmass had been reduced to low or moderate relief. A tropical or subtropical, humid climate would favor deep decay and the release of iron and silica, but a temperate climate may have prevailed. The iron and silica were transported principally as ferric oxide hydrosol and silica hydrosol, stabilized by organic matter. Although most of the iron was deposited as hydrous ferric oxide, in places, the precipitate consisted essentially of hydrous ferrous silicate and silica. Minor amounts of iron may have been contributed from a magmatic source.

Organisms were not essential for precipitation but may have played some part.

Subsequent to deposition, the hydrated ferric oxide was dehydrated to anhydrous ferric oxide, crystallized and possibly recrystallized, and altered in part, to magnetite. Cherty minnesotaite-carbonate iron-formation developed from hydrous ferrous silicate and silica. The carbonates may have formed by a reaction between the ferrous silicate and organic matter, or between ferrous silicate and calcium carbonate. All the silica now occurs as microcrystalline quartz.

At the end of the period, the rocks within the basin were subjected to great stresses. At first, a large synclinorium formed but on continuation of the stress, faults developed and the synclinal structure was destroyed.

IRON ORE

GENERAL DESCRIPTION

Introduction

The iron ore of the Dyke Lake area is predominantly a soft ore, that is, it contains a high percentage of fines. On the basis of appearance, it is divisible into brown, blue and yellow ores. The greater proportion is brown ore and consists essentially of goethite together with minor hematite and soft limonite(1). The blue ore consists essentially of hematite together with some goethite and limonite, and, not uncommonly, minor magnetite. Although yellow, limonitic ore occurs in places, it is relatively unimportant. In general, the limonitic ore has a high content of water and is of lower grade, whereas, the highest grade ore is blue. Where a high percentage of manganese is present in the ore, the color is black.

Chemical Composition

On the basis of chemical composition, the ore is divided into bessemer, non-bessemer and manganiferous ores. Non-bessemer ore contains 0.045 per cent or more (dried analysis) of phosphorus. Manganiferous ore contains three per cent or more of manganese. To the end of 1948, drilling has indicated

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(1)The term limonite is used to imply goethite with adsorbed and capillary water. Some hydrated hematite may be present.

324 million long tons of ore of which 57.7 per cent is bessemer, 30.6 per cent non-bessemer, and 11.7 per cent manganiferous. The weighted analysis for each type of ore and the combined grade are given below.

X	(1)	(2)	(3)	(4)	(5)
Fe	60.7	57.8	50.2	58.6	31.0
Mn	0.30	0.56	7.68	1.25	0.27
P	0.028	0.112	0.102	0.062	0.145
SiO_2	8.58	7.84	7.75	8.25	42.02
CaO	0.09	0.12	0.10	0.10	0.15
MgO	0.05	0.06	0.06	0.05	0.09
Al_2O_3	0.57	1.34	1.25	0.89	6.42
S	0.012	0.014	0.013	0.013	0.027
Loss on ignition	3.07	6.38	6.89	4.54	5.98

X Based on dried analyses by The M.A. Hanna Company

1. Weighted analysis of Bessemer ore
2. Weighted analysis of Non-Bessemer ore
3. Weighted analysis of Manganiferous ore
4. Weighted analysis of combined ore
5. Average of six analyses of Ruth slate near five ore deposits.

In general, the bessemer ore has a lower loss on ignition, and phosphorus and alumina content, than either the manganiferous or non-bessemer ores. The relation between loss on ignition and phosphorus content is shown in Figure 7. The relation is the result, in part, of the fact that the blue ores, which are normally bessemer grade, have a lower loss on ignition than the brown ores.

Kaolin is formed on the alteration of the iron silicates. Much of the non-bessemer and manganiferous ores occur in the silicate-bearing iron-formation. Thus a higher alumina content for these ores would be expected. The fact that these ores are

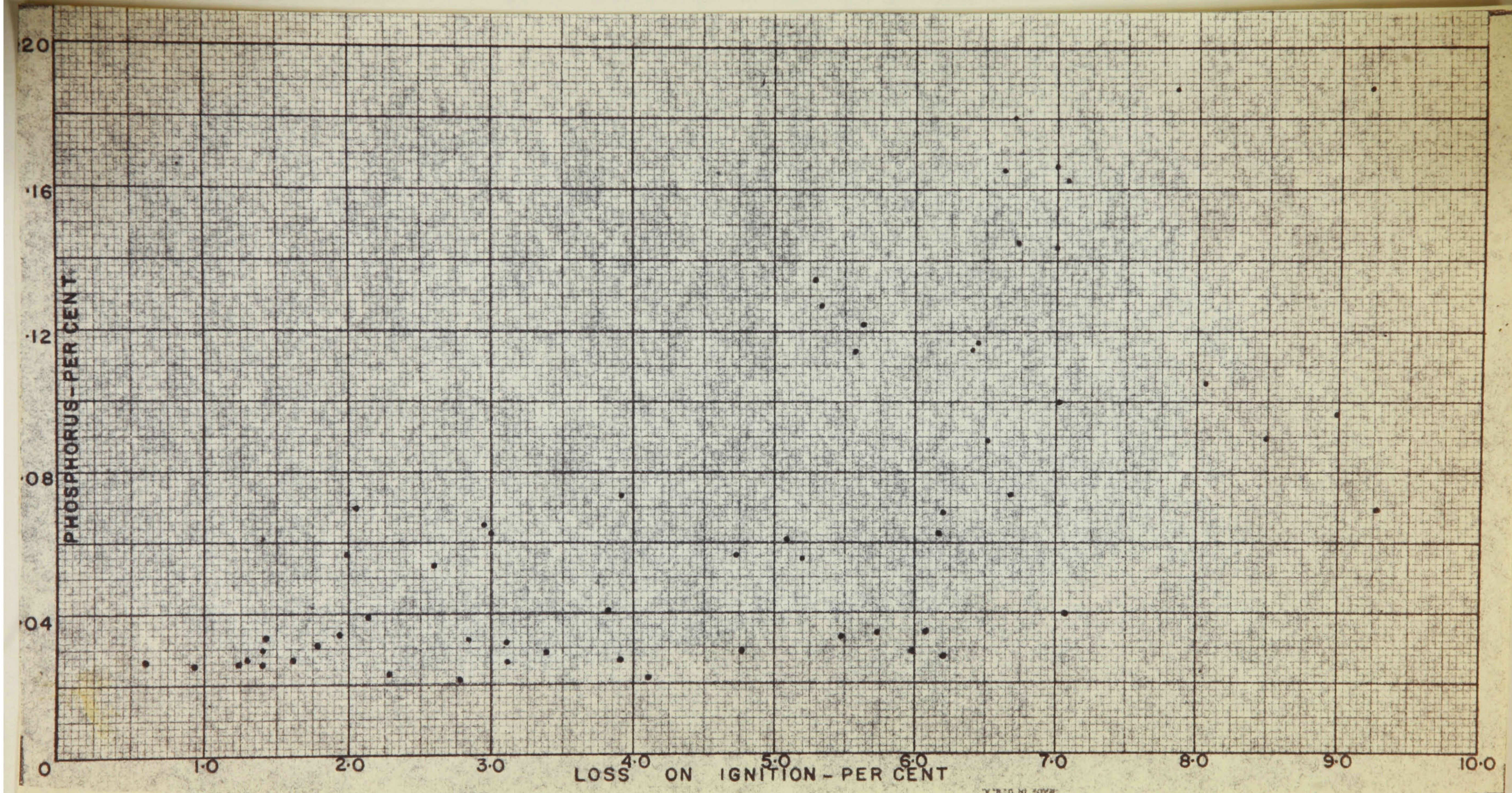


Figure 7. Diagram showing relation of phosphorus to loss on ignition in iron ores. Based on 59 analyses representative of all ore from 25 deposits.

non-bessemer indicates that the phosphorus content of the silicate-bearing members is higher than that of the jaspery or cherty metallic members. In addition, the rock associated with the Ruth slate is cherty carbonate or cherty silicate-carbonate iron-formation. The analysis of Ruth slate given is representative of the iron-rich facies, better termed iron-formation, found near many of the ore deposits. The percentage of alumina and phosphorus are relatively large.

The form in which the manganese occurs in the iron-formation is unknown, but it is assumed that it is present in the carbonates and silicates, and possibly as on oxide. Carbonates and silicates are abundant near the base of the iron-formation. Manganiferous ore not uncommonly forms the lower part of the ore deposits. However, this ore is not necessarily formed in situ as considerable migration of manganese is evident in the field and minor amounts commonly occur in the rocks underlying the iron-formation.

The lime and magnesia in the ore probably occur as carbonates. The sulphur may be present as a sulphide.

Comparison of the Chemical Composition of the Iron Ores and Iron-Formation

Insufficient analyses of the iron-formation have been made to determine with any accuracy the absolute changes in chemical composition during the development of the ore. However, a comparison of the anslyses of iron-formation and of the combined ore, given below, should indicate the relative changes, that is, whether there is an increase or decrease of each element, and give an approximation of the amount of each change.

X	(1)	(2)	(3)
Fe	58.6	45.0	30.5
Mn	1.25	1.07	0.27
P	0.062	0.073	0.027
SiO_2	8.25	28.04	52.22
CaO	0.10	0.10	0.44
MgO	0.05	0.06	1.06
Al_2O_3	0.89	1.15	0.23
S	0.013	0.022	0.014
Loss on ignition	4.54	3.99	1.96

X Based on dried analyses by The M.A. Hanna Company

1. Weighted analysis of all ore
2. Average of 38 analyses of enriched iron-formation near 15 deposits
3. Average analyses of two samples representative of the iron-formation in the map-area and that of the Heluva Lake area.

Thus, there is an increase in the percentage of iron, manganese, phosphorus, alumina and loss on ignition, whereas, the percentage of silica, lime, magnesia and sulphur decreases. In general, the relations indicate a progressive decrease in the easily soluble constituents, and an increase in those that are relatively insoluble. Silica is possibly an exception.

If it is assumed that the analysis of the iron-formation is representative of the protore, there was a greater increase in the phosphorus content than in the iron content during the development of the ore. This is unlikely. Van Hise and Leith (1911,p.194) noted a similar relation for the phosphorus in the Mesabi ores and explained it by assuming that introduction of phosphorus exceeded leaching. In both cases, it is more probable that the analyses do not represent accurately the protores.

Apatite has never been observed in the ores although its presence is generally assumed to explain the phosphorus content. However, it is just as reasonable to assume the occurrence of some unknown phosphorus-bearing mineral which resembles the iron minerals. Detection would thus be difficult.

Mineralogy of the Ore

The ore consists essentially of hydrous and anhydrous oxides of iron and manganese, and quartz. No carbonates or silicates were observed.

The iron minerals are magnetite, hematite and goethite. Most of the magnetite has altered to martite or goethite, or both.

The manganese minerals include pyrolusite, psilomelane and cryptomelane. Much of the manganese occurs as soft wad and was not identified. According to Fleisher and Richmond (1943, p.272), wad may be any one, or a mixture, of several distinct manganese-bearing minerals. However, it is generally a mixture of pyrolusite, psilomelane and cryptomelane.

The silica in the ore occurs as chert, and as secondary quartz veining the ore. The primary silica is generally distributed throughout the ore, but may be concentrated in beds, lenses, or more irregular forms.

Physical Character of the Ore

The physical character of the ore ranges from hard, dense and massive, to soft, porous and earthy. Hard, massive or vuggy beds and lenses occur in soft, porous material. In general, there is no relation between texture and hardness, and grade.

Tests indicate densities ranging from 2.5 to 5, and an average of slightly less than 3. This may be compared to 3 to 3.2 for the iron-formation.

THE ORE DEPOSITS

Present data about the iron ore deposits of Quebec-Labrador are from drilling and outcrops. Mining has not as yet been initiated. Less than one per cent of the surface area of the deposits is exposed, but thin overburden facilitates pitting.

Information related to the deposits is as follows:

1. The ore normally occurs in structural troughs. These may be synclines or formed by the intersection of folded strata and a fault (Figure 8).

2. Some ore deposits occur in homoclines, and appear to be unrelated to broad structures.

3. Exposures and drill hole intersections indicate a general conformity of the structure within the deposits and that of the containing rock. However, in detail, the ore commonly transects the strike of the bedding, and presumably, also the dip.

4. The localization of the ore within the broad structures appears to be related to the composition of the

original rock, and, to minor structures.

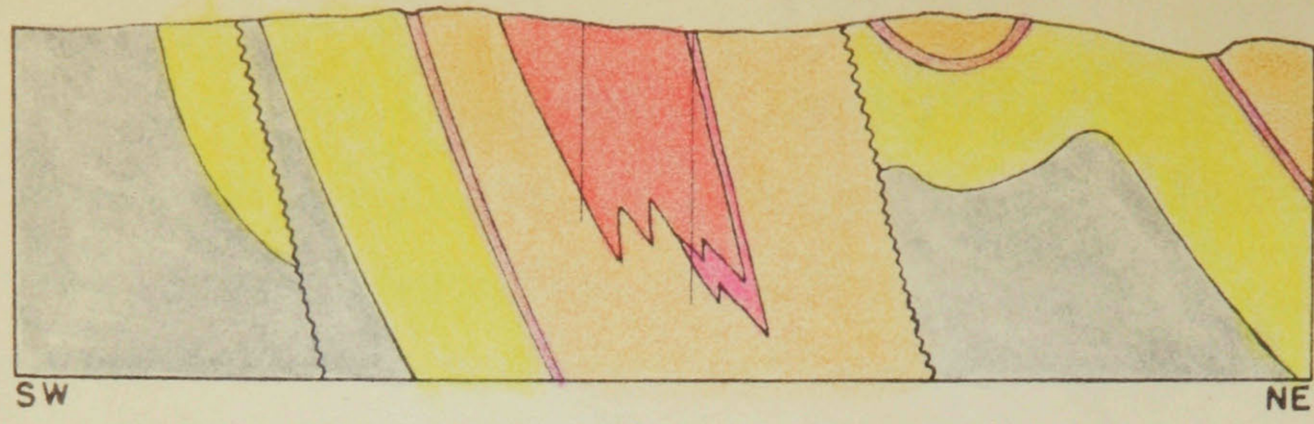
All the iron ore deposits lie within the iron-formation. Locally, however, adjacent rocks may be sufficiently enriched to be of ore grade. Thus, the limits of a deposit may extend slightly beyond the iron-formation into the Ruth slate, and rarely, the quartzite or chert breccia formations.

The distribution of the ore within the iron-formation indicates that certain members were more amenable to concentration than others. The actual composition of the protore is unknown but cherty silicate-carbonate rock appears to be more favorable than much of the jaspery and cherty metallic iron-formation. However, a local high percentage of iron oxides in the latter types would favor ore development in that less concentration would be required.

Minor structures aid in the localization of the ore, and in part offset adverse influences in the composition of the iron-formation. They include faults, joints and folds. The principal effect is the development of opening which permit the access of solutions. In addition to numerous longitudinal thrust-faults, there are longitudinal normal faults and cross-faults present in the area. The dips of the cross-faults are vertical or nearly so. They are predominantly strike-slip faults. The cross-faults and longitudinal thrust-faults appear to be genetically related and to have developed in conjunction with folding. The normal faults probably formed following release of the stresses.

Figure 8

Representative sections of typical ore bodies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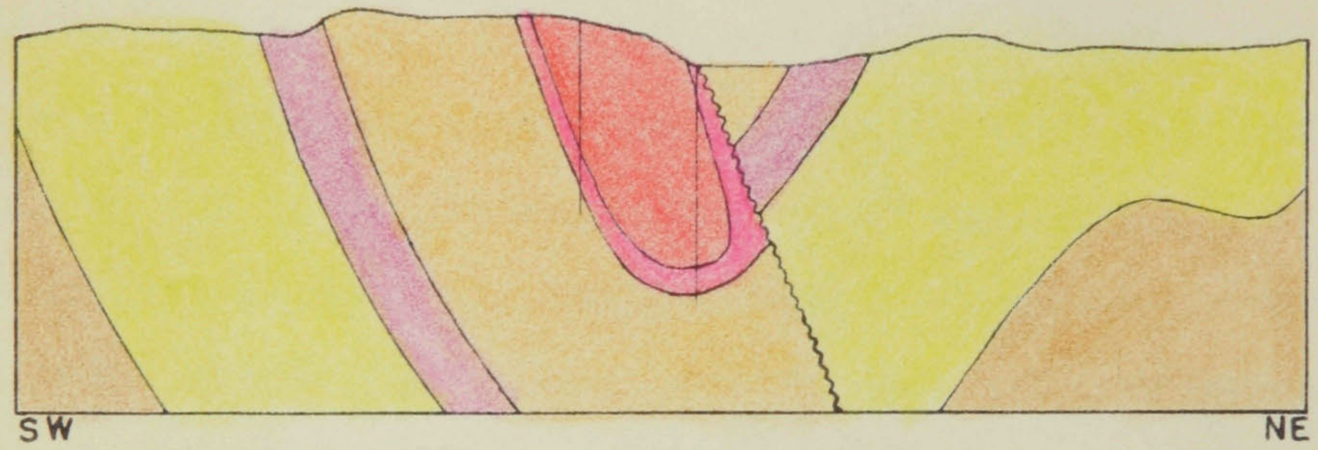
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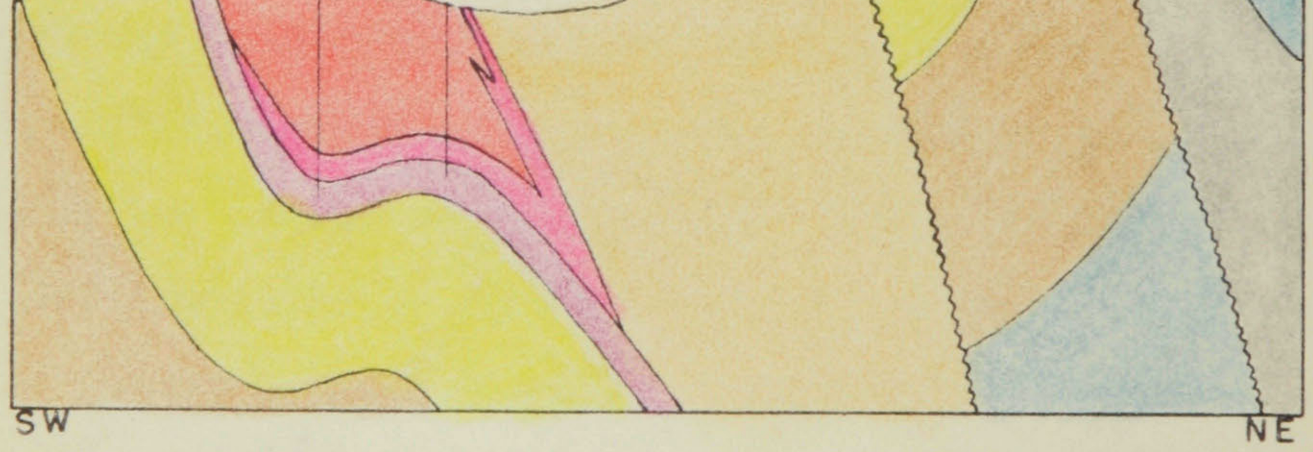
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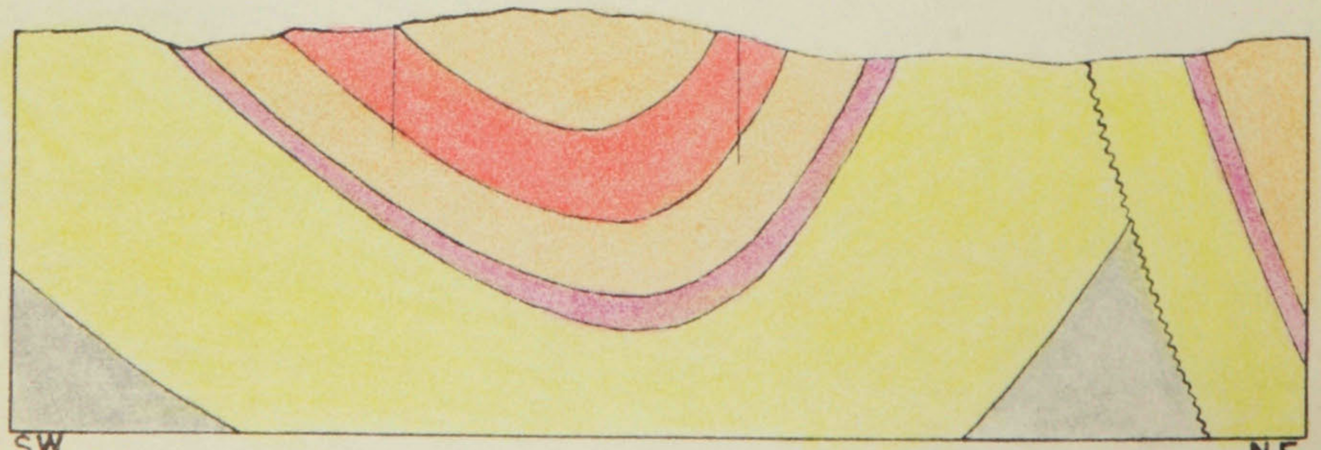
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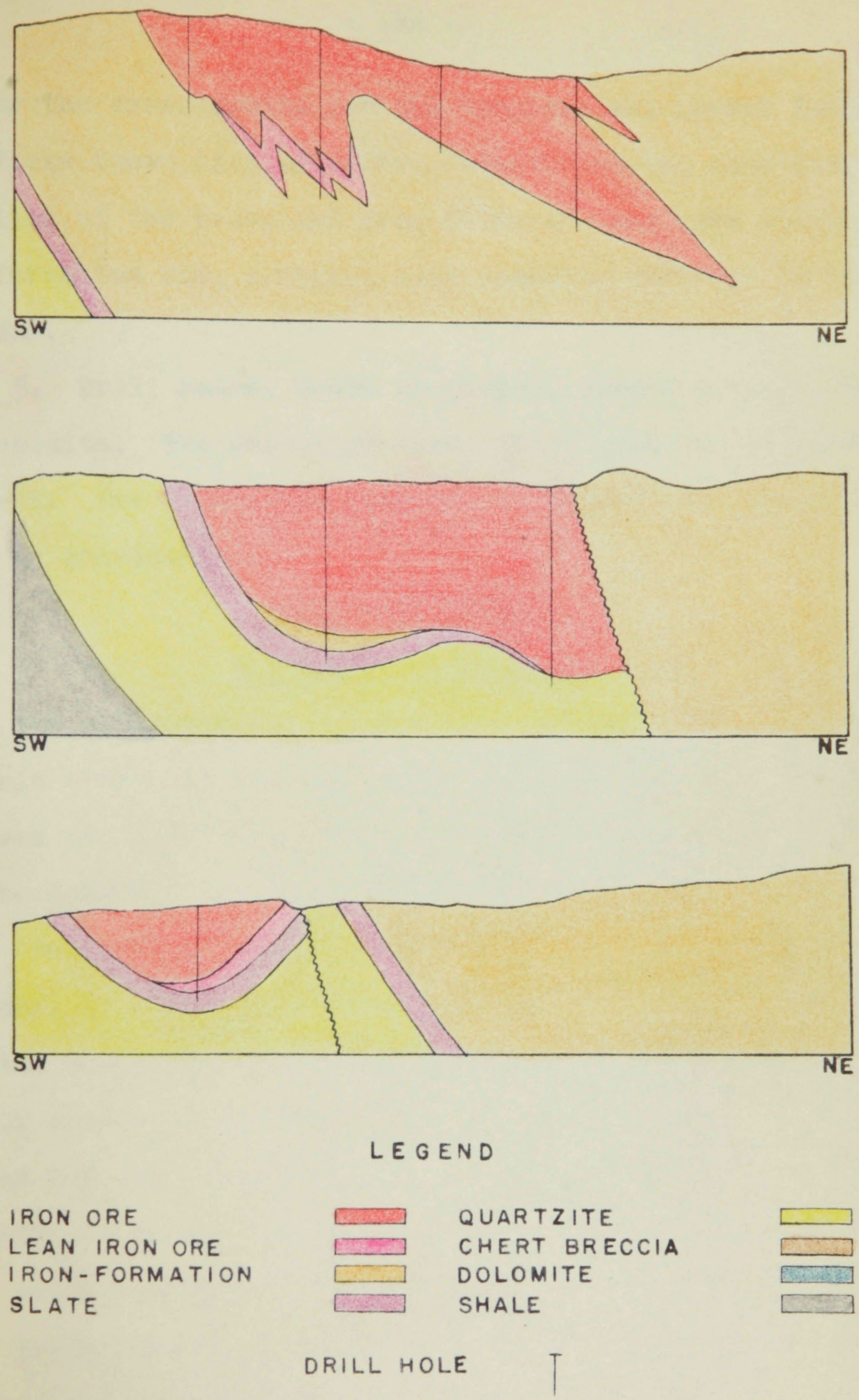


REPRESENTATIVE SECTIONS OF TYPICAL ORE BODIES

HORIZONTAL AND VERTICAL SCALE: 1" = 200'

> "It is proposed that the chief source of the hot waters was meteoric. The waters mingled with gaseous emanations that rose from large intrusives. Ordinarily nearly stagnant, these ground waters when heated became active solvents of silica."

There is little field evidence in the Lake Superior district to substantiate a hydrothermal leaching theory (Leith, 1931, pp. 274-288). Royce (1937, p.389) notes the absence of any igneous rock younger than the iron-formation, near the Mesabi deposits, whereas, that part underlain by the Embarrass granite is not productive.

General Remarks

Many of the mineral relations noted in the study of the iron-formation apply to the ore. Most of the magnetite has altered to martite or goethite, or both. As indicated previously (page 75), it is probable that the martite formed as the result of the action of hydrothermal solutions, whereas, the normal alteration product of magnetite under intense weathering, is goethite. Leaching and redeposition of iron and silica by these solutions may have caused minor concentrations of iron. Metallic hematite locally veins and replaces the iron-formation. Secondary quartz is generally present. In addition, patches of specular hematite and quartz crystals have been observed by the writer. It is considered, however, that these solutions were not instrumental in the development of the ore deposits.

Study of the iron ores in the field and in polished section indicates that concentration has resulted from

(1) removal of silica by leaching, and (2) introduction of iron by filling and replacement. Both processes are important.

Leaching is evident both in the ore and the adjacent rock. Much of the ore is soft and porous. Harder beds may be massive or vuggy. Near the ore, the iron-formation is commonly porous and friable. It disintigrates into minute grains of quartz or chert. Similar occurrences of quartzite and chert breccia have been observed.

There is no doubt of the migration of goethite. It lines vugs within the ore. Veinlets cut the ore, the iron-formation and the underlying quartzite. Fragments of ore are cemented together by goethite. Local pockets of ore represent enriched quartzite or chert breccia. Meteoric waters probably took the iron into solution and then reprecipitated it as a coagulum. Colloidal structures are not rare.

It seems reasonable to expect replacement of the silica by introduced iron. Grains of quartz, either individually or in groups, can be seen surrounded by limonite, suggesting unsupported nuclei. Limonite penetrates along cracks in the quartz grains. In addition, it is not uncommon to see granules of hematite (in part martite) surrounded by goethite or limonite.

In places, the brown ore shows perfect preservation of textures and bedding. There is no evidence of slumpage. Elsewhere, massive beds of blue ore alternate with brown ore. It suggests that the blue ore is more or less unchanged, whereas, goethite has been introduced into leaner beds, replacing the silica and, possibly in small part, filling pore space resulting from leaching.

The outlines of the known ore deposits lend no support to a hydrothermal leaching hypothesis.

The time of ore concentration is unknown. It may have been a continuous process since the period of orogeny. Flat-lying beds of quartzite occur on the tops of hills near Sims lake (latitude 53° 55' north, longitude 65° 50' west), just south of the Dyke Lake area. It is possibly of Cambrian or Keweenawan age, and suggests partial peneplanation following the folding and faults of the rocks of the Kaniapiskau system. It may be that most of the ore concentration occurred during this time.

There is no evidence, at least within the map-area and main ore zone, that there was any ore concentration following the deposition of the iron-formation but preceding the accumulation of the Menihek slate.

Conclusions

Concentration of the ore within the iron-formation is believed to be the direct result of weathering and the action of ground waters. The processes of concentration are removal of silica by leaching, and the introduction of iron by filling and replacement. Both processes are important.

The time of ore formation is unknown. Most of the concentration probably took place before the Paleozoic era.

SUMMARY

The Labrador Trough contains an assemblage of little-metamorphosed, Precambrian sedimentary and volcanic rocks, which is termed the Kaniapiskau system. It lies upon an older, eroded igneous and gneissic basal complex. The assemblage is cut by a few sills, dikes and stocks which are predominantly of basic composition.

The rocks within the Trough are folded and thrust-faulted. The fold axes and thrust-faults strike in a northwesterly direction; the thrust-faults and axial planes of the folds generally dip northeastward. There is evidence of at least one disconformity.

All the consolidated rocks within the map-area are of Precambrian age and form part of the Kaniapiskau system. From detailed mapping, the stratigraphy of the Kaniapiskau system in the south-central part of the Labrador Trough was determined. The thicknesses of the formations were measured. The rock-types are shale, slate, limestone, quartzite, chert and iron-formation. They are described in detail.

The iron-formation consists essentially of micro-crystalline quartz, hematite, magnetite, goethite, minnesotaite, carbonates, and rarely, stilpnomelane. It was divided into the following types;

1. Ferruginous slate
2. Cherty carbonate iron-formation
3. Ferruginous chert
4. Cherty metallic iron-formation
5. Jaspery iron-formation
6. Cherty minnesotaite-carbonate iron-formation
7. Amphibole-bearing iron-formation

Fibrous riebeckite has formed in connection with bedding slippage within the iron-formation exposed along the west arm of Hook lake. It is probable that sodium and quartz were introduced during deformation and that the riebeckite formed as a direct result of the combination of sodium, silica and iron under stress conditions.

The iron-bearing silicate, minnesotaite is abundant in part of the Sokoman iron-formation. Greenalite was not observed and stilpnomelane is uncommon. It was concluded that most of the minnesotaite developed directly from colloidal material, and, on crystallization or recrystallization, under the influence of diagenesis and low-grade metamorphism, developed its present fibrous form. The composition of the colloidal material probably varied slightly from place to place, but consisted essentially of hydrous ferrous silicate and silica. The transformation of carbonate and silica into minnesotaite after initial crystallization is not unlikely but there is no evidence that it occurred. The less common occurrence of stilpnomelane relative to minnesotaite is probably the result of a deficiency of alumina, and possibly also of lime and potash, in the iron-formation.

Partial or complete alteration of magnetite to martite is common in parts of the iron-formation. The martite forms rims around grains of magnetite and proceeds inward along either irregular lines or octahedral planes. In highly-altered iron-formation, goethite and martite are found in a similar relationship. It is probable that the martite formed as a result of hydrothermal solutions, and the goethite, as a result of weathering.

It was concluded that, with the exception of the martite, most of the hematite found in the jaspery and cherty metallic iron-formation formed from hydrated ferric oxide. Subsequent to precipitation, it was dehydrated to anhydrous ferric oxide, crystallized and possibly recrystallized, and probably altered in part, to magnetite.

The iron and silica in the Sokoman iron-formation are believed to have been derived from the weathering of the surrounding land masses. Minor amounts may have been contributed from a magmatic source. The iron and silica were transported principally as ferric oxide hydrosol and silica hydrosol, stabilized by organic matter. Although most of the iron was deposited as hydrous ferric oxide, in places, the precipitate consisted essentially of hydrous ferrous silicate and silica.

The iron ore normally occurs in structural troughs. These may be synclines or formed by the intersection of folded strata and a fault. Some ore deposits occur in homoclines. Localization of the ore within the broad structures appears to be related to the composition of the original rock (iron-formation), and, to minor structures.

The ore consists essentially of hydrous and anhydrous oxides of iron and manganese, and quartz. The iron minerals are magnetite, hematite and goethite; the manganese minerals include pyrolusite, psilomelane, and cryptomelane.

Concentration of the ore within the iron-formation is believed to be the direct result of weathering and the action of ground waters. The processes are removal of silica by leaching, and the introduction of iron by filling and replacement. Both processes are important. Most of the concentration probably took place before the Paleozoic era.

Plate 1A. Looking southeastward along Trough lake. Note parallel arrangement of lake and ridges.

Plate 1B. Looking southeastward from west of Snow lake towards ridge extending to Hook lake. Main ridge is formed by a syncline with subsidiary folding on the limbs.

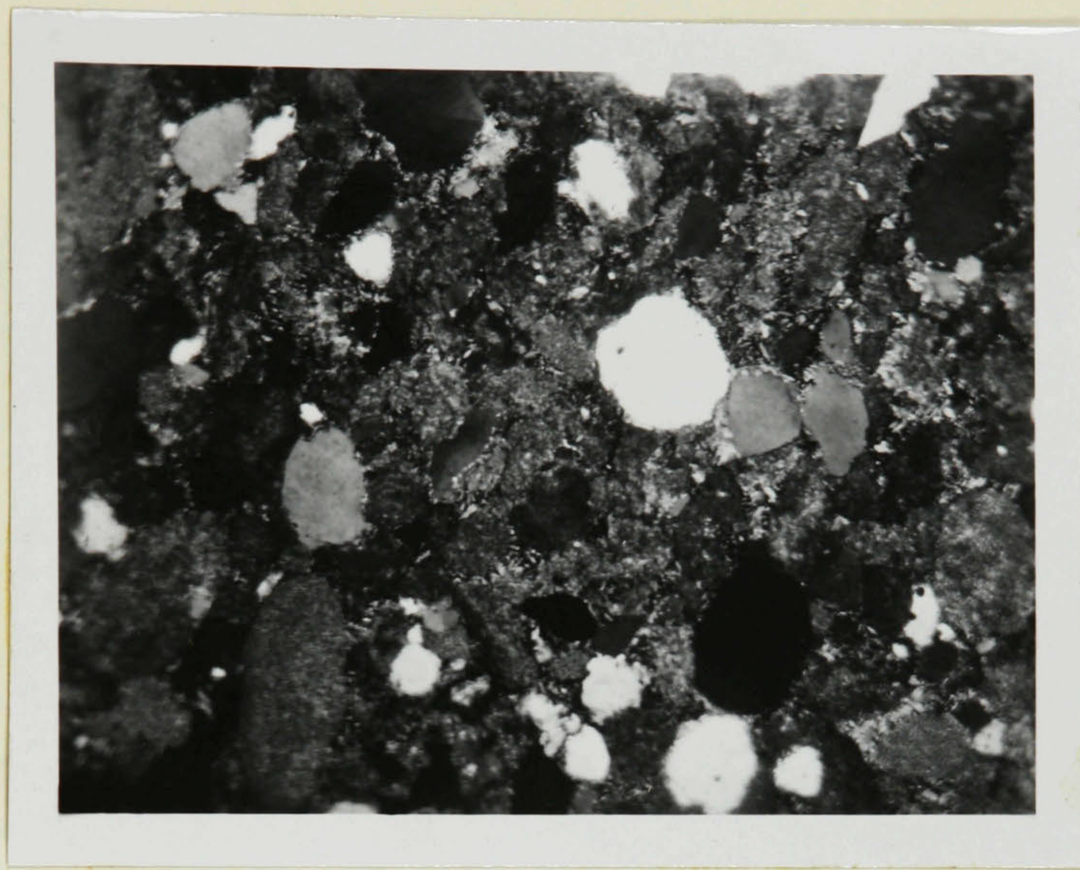


Plate 2A. Photomicrograph of matrix of clastic limestone exposed west of Snow lake. Matrix consists of grains of dolomitic limestone and quartz. Crossed nicols, 23X.

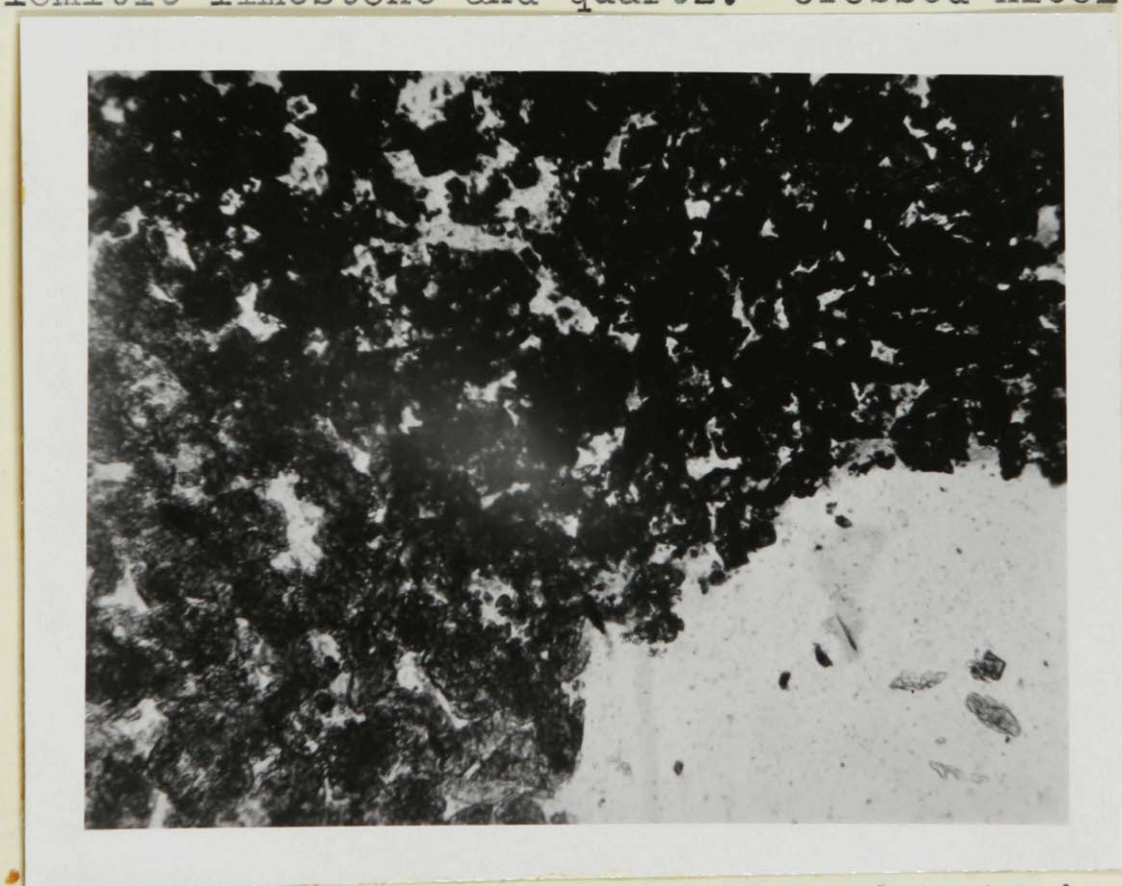


Plate 2B. Photomicrograph of cherty carbonate iron-formation from Hook lake. The rock consists of carbonate (dusty grey) and microcrystalline quartz (colorless). On alteration, the carbonate changes to limonite (lower left). Lenses of chert are not uncommon (upper left). Without analyzer, 100X.

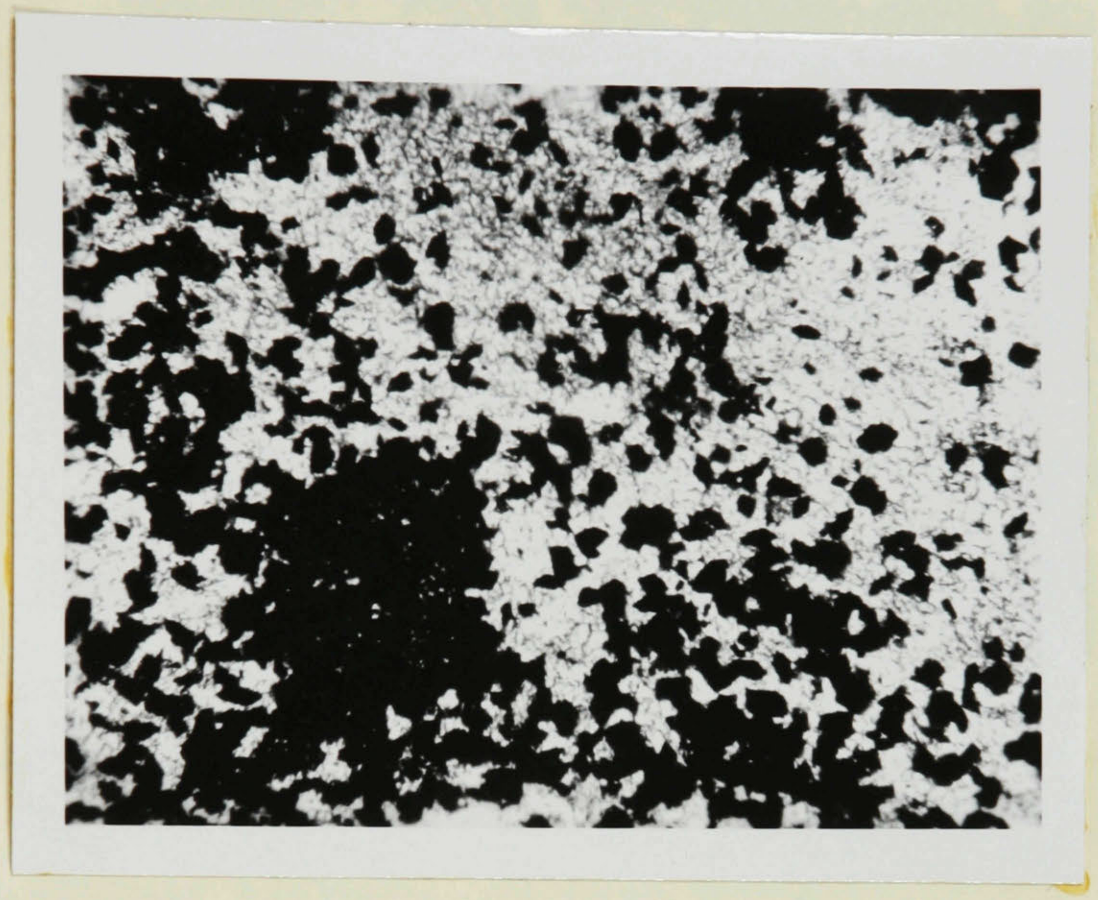


Plate 3A. Photomicrograph of ferruginous chert showing limonite pseudomorphic after rhombohedral carbonate crystals, and partially outlining crystals of quartz. Without analyzer, 150X.

Plate 3B. Photomicrograph of ferruginous chert consisting of fibrous limonite, microcrystalline quartz, and goethite pseudomorphic after magnetite. Without analyzer, 90X.

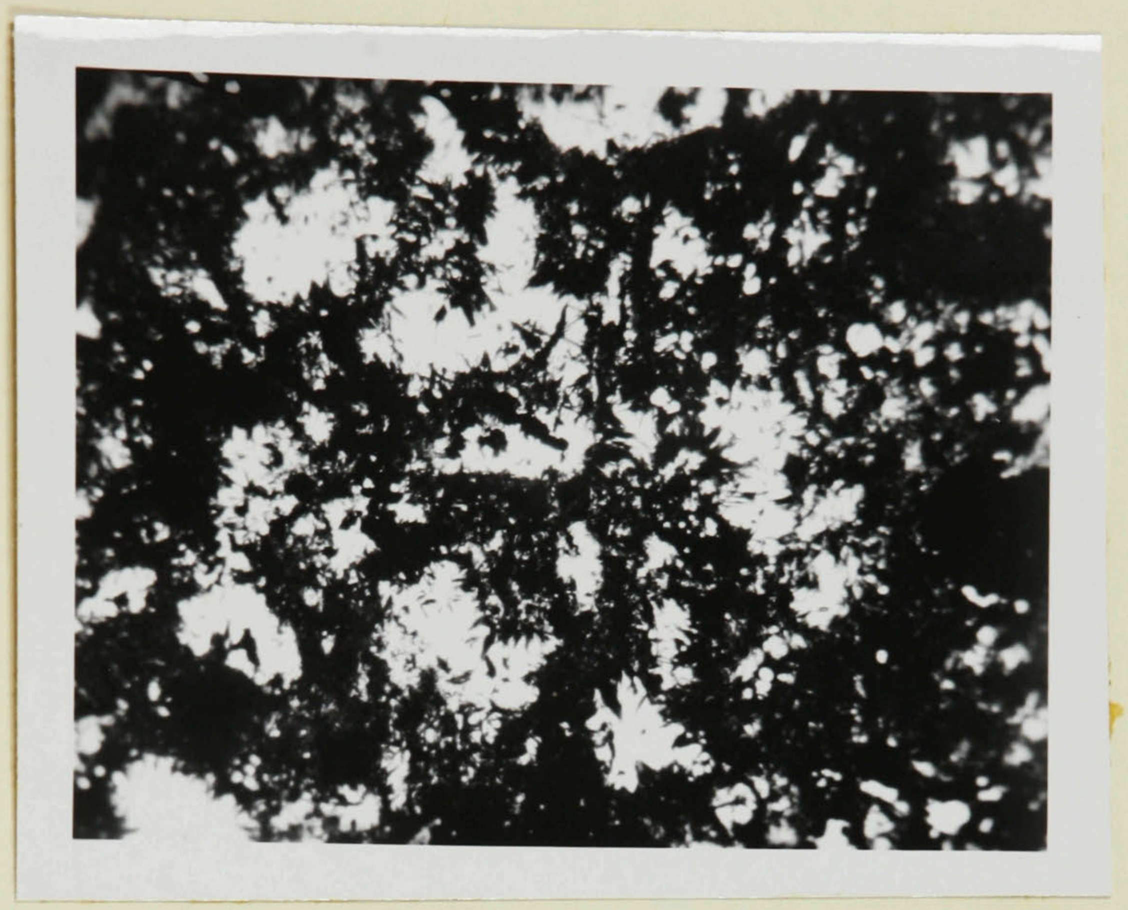


Plate 4A. Altered cherty minnesotaite iron-formation. Most of the minnesotaite has altered to fibrous limonite. The opaque mineral is magnetite. Note the preservation of a granule texture. Without analyzer, 22X.

Plate 4B. Cherty metallic iron-formation. The opaque minerals are magnetite (euhedral grains) and hematite. Minor fibrous limonite is present. Without analyzer, 110X.

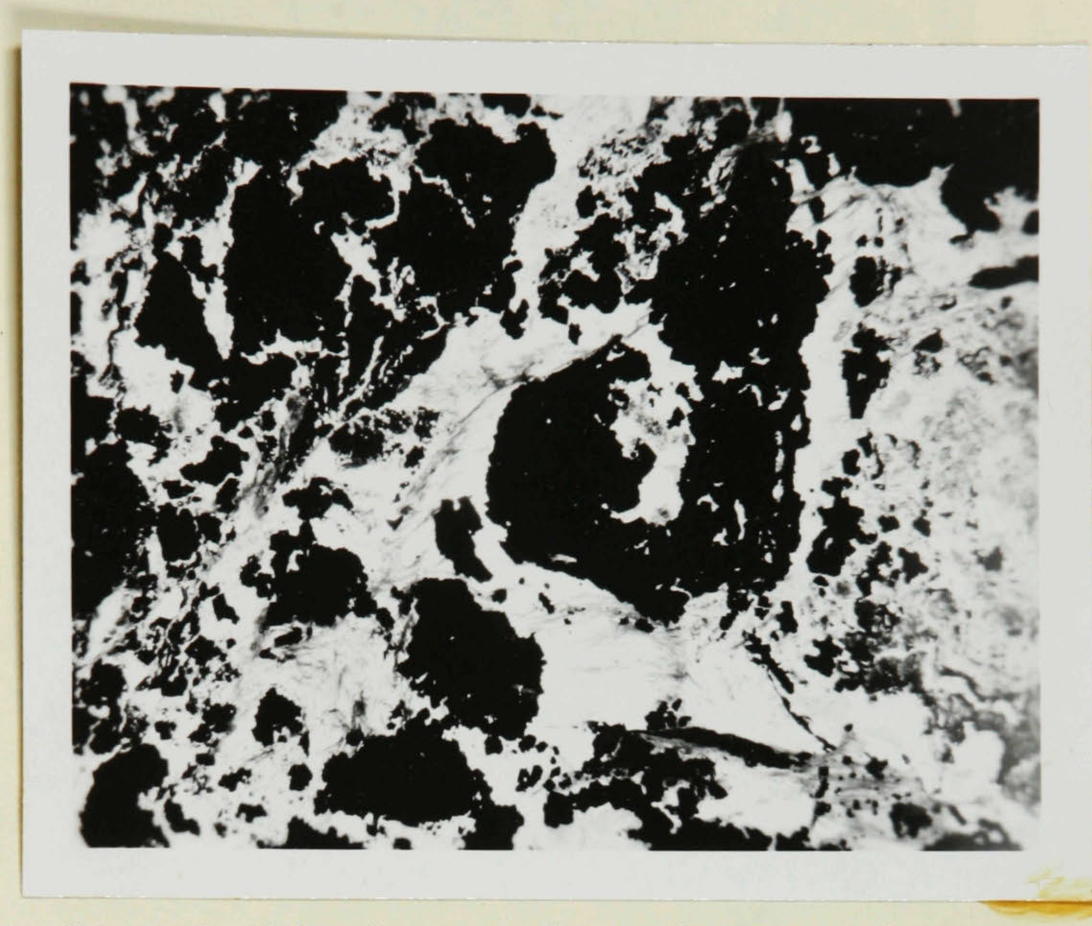


Plate 5A. Amphibole-bearing, jaspery iron-formation consisting of magnetite and hematite, chert, fibrous riebeckite, and minnesotaite. The chert and minnesotaite are colorless; the riebeckite, light grey. Without analyzer, 28X.

Plate 5B. Amphibole-bearing, cherty metallic iron-formation. The opaque minerals are magnetite and hematite; the fibrous mineral is riebeckite. Without analyzer, 100X.

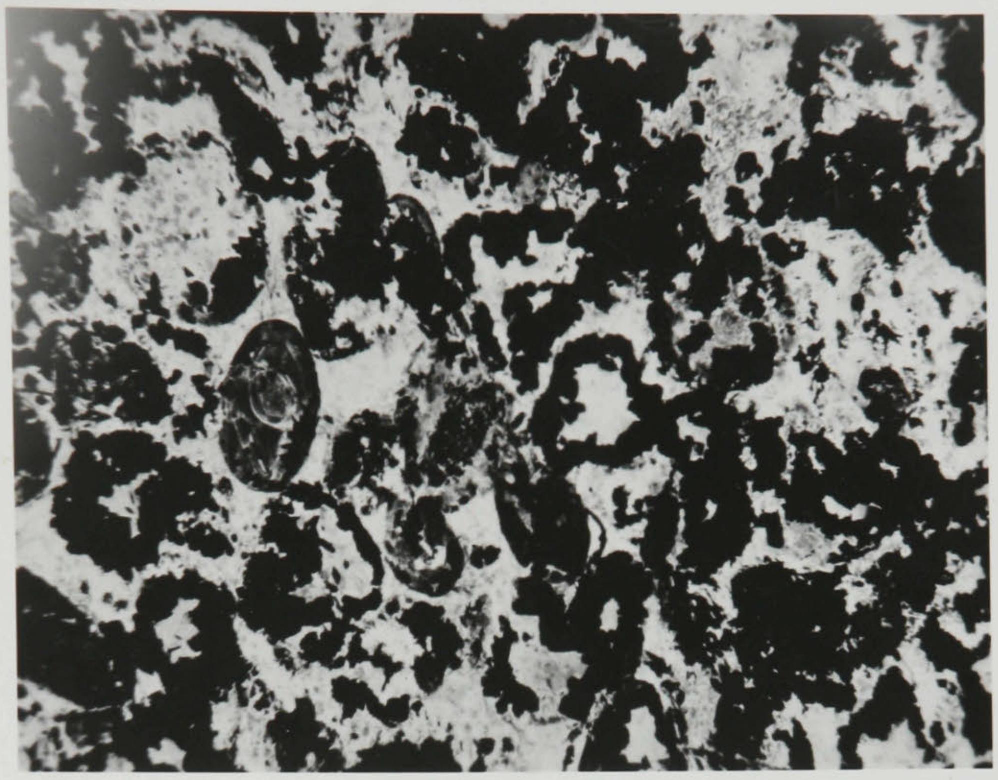


Plate 6A. Jaspery iron-formation consisting of magnetite, hematite and chert. The jasper is light grey. Note the internal structure outlined in the jasper-centered granule at left. Without analyzer, 28X.

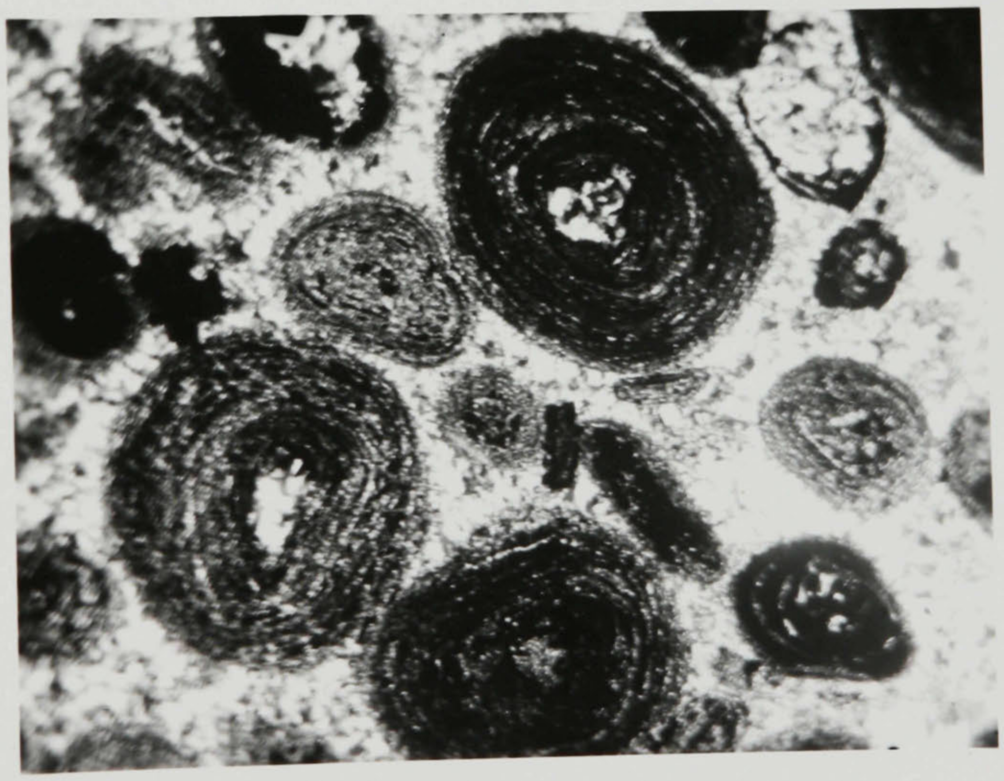


Plate 6B. Oolitic structures found in jaspery iron-formation. Such structures are normally absent but are contained by two small exposures which represent the near-top of the iron-formation. The opaque minerals are hematite (dusty grains) and magnetite (larger grains). The large masses consist of magnetite, and hematite which is in part, at least, martite. Without analyzer, 22X.

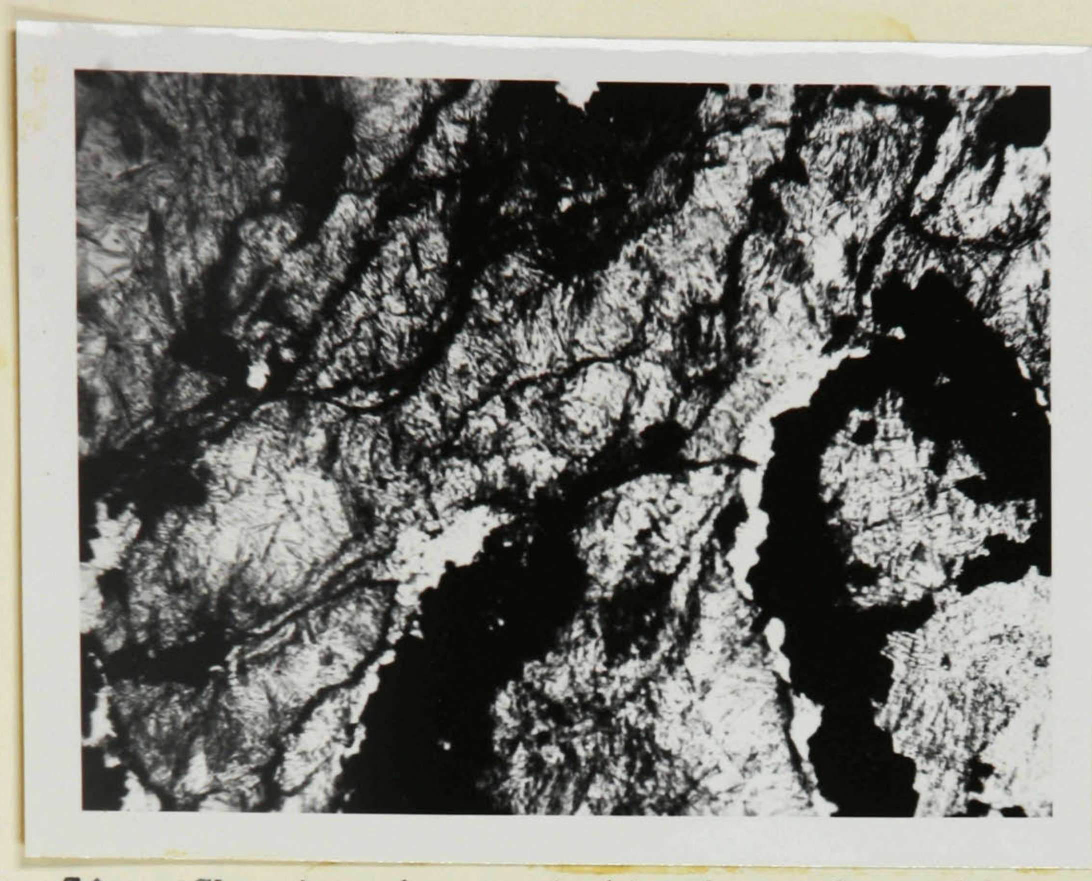


Plate 7A. Cherty minnesotaite iron-formation. The rock consists of microcrystalline quartz (colorless), fibrous minnesotaite and magnetite (black). The minnesotaite is altered and has a greenish yellow color. Limonite from the alteration forms veinlets (dark grey). The magnetite outlines and fills granules. Without analyzer, 80X.

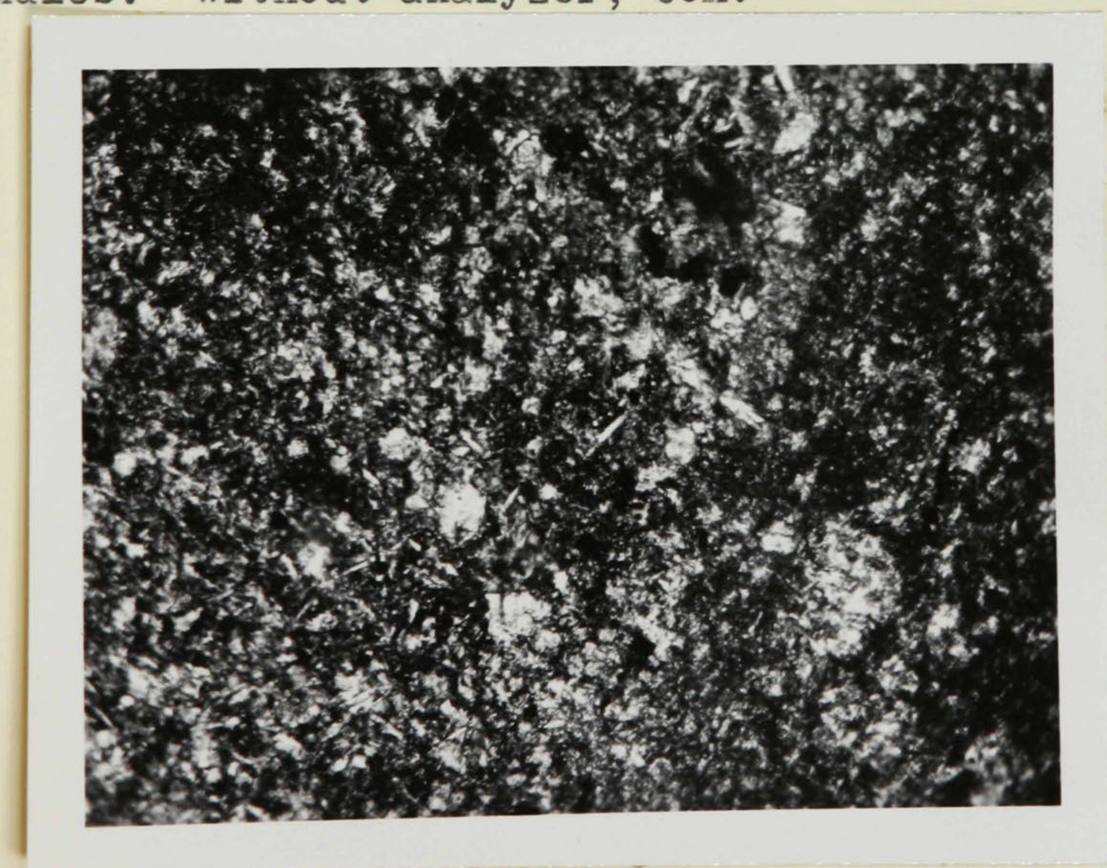


Plate 7B. Cherty minnesotaite-carbonate iron-formation. The principal constituents are dusty grey carbonates and microcrystalline quartz. Fibres of minnesotaite form about 20 per cent of the slide. The opaque mineral is magnetite. Without analyzer, 60X.

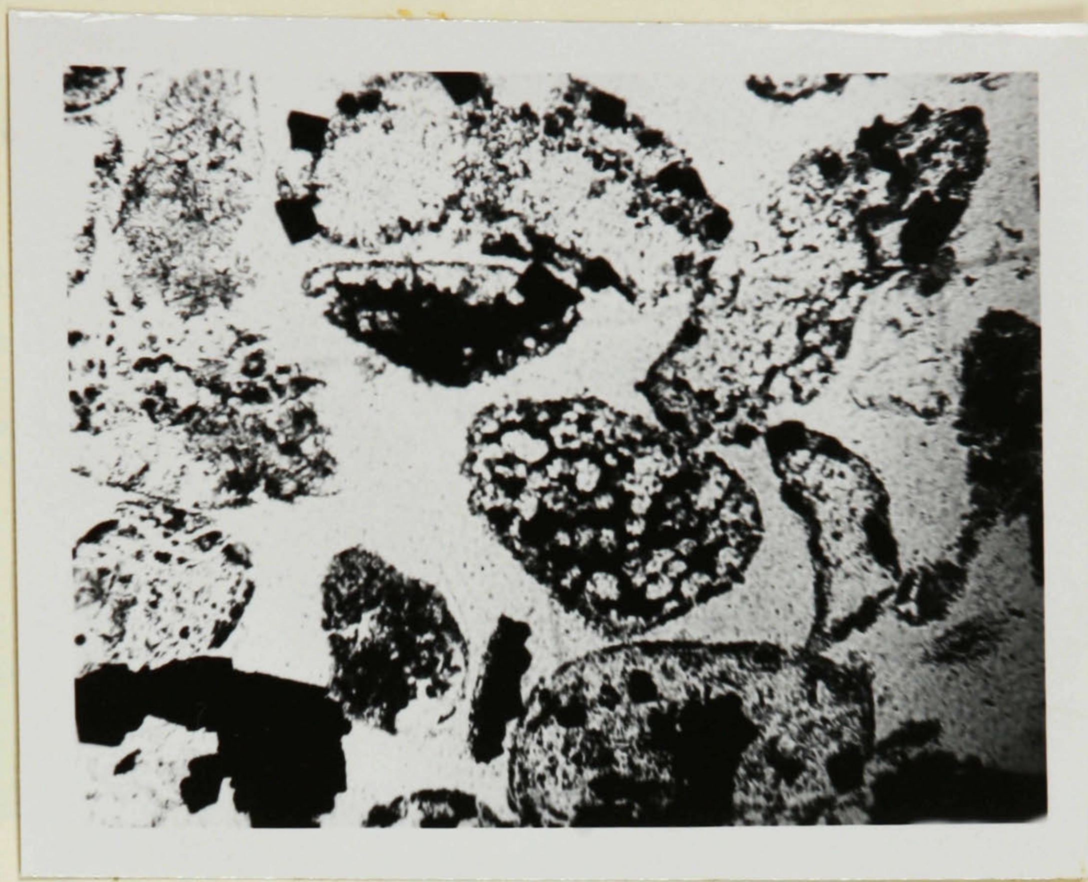


Plate 8A. Cherty minnesotaite-carbonate iron-formation. The circular structures in the granules are formed by chert and confused aggregates of minute fibres of minnesotaite. The grains of magnetite (black) commonly transect the outline of the granules. Without analyzer, 85X.

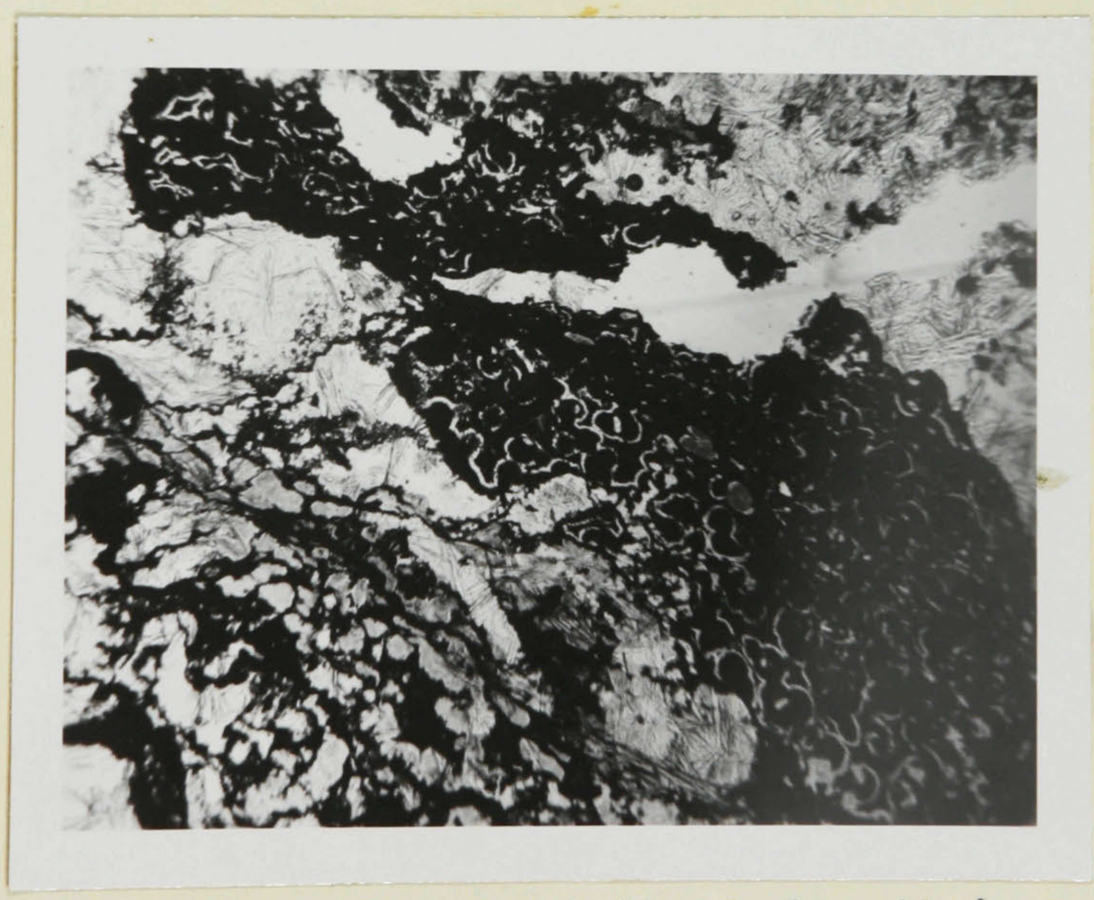


Plate 8B. Cherty minnesotaite-carbonate iron-formation. The opaque mineral is graphite. The colorless area at the lower left is the result of a break in the slide but elsewhere represents chert. Without analyzer, 75X.

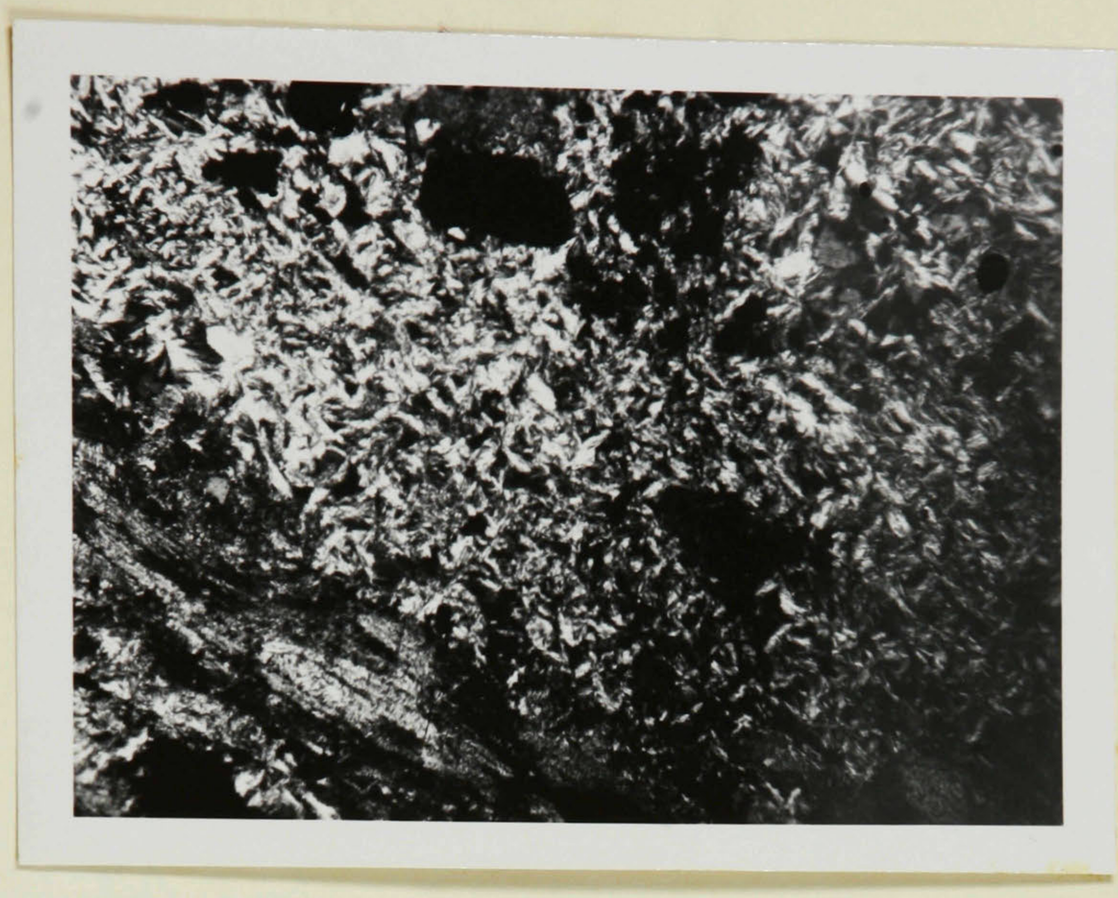


Plate 9A. Cherty minnesotaite-carbonate iron-formation. Most of the carbonate (dark grey) is concentrated in one bed (upper right). Other constituents are fibrous minnesotaite, chert and magnetite (black). Crossed nicols, 70X.

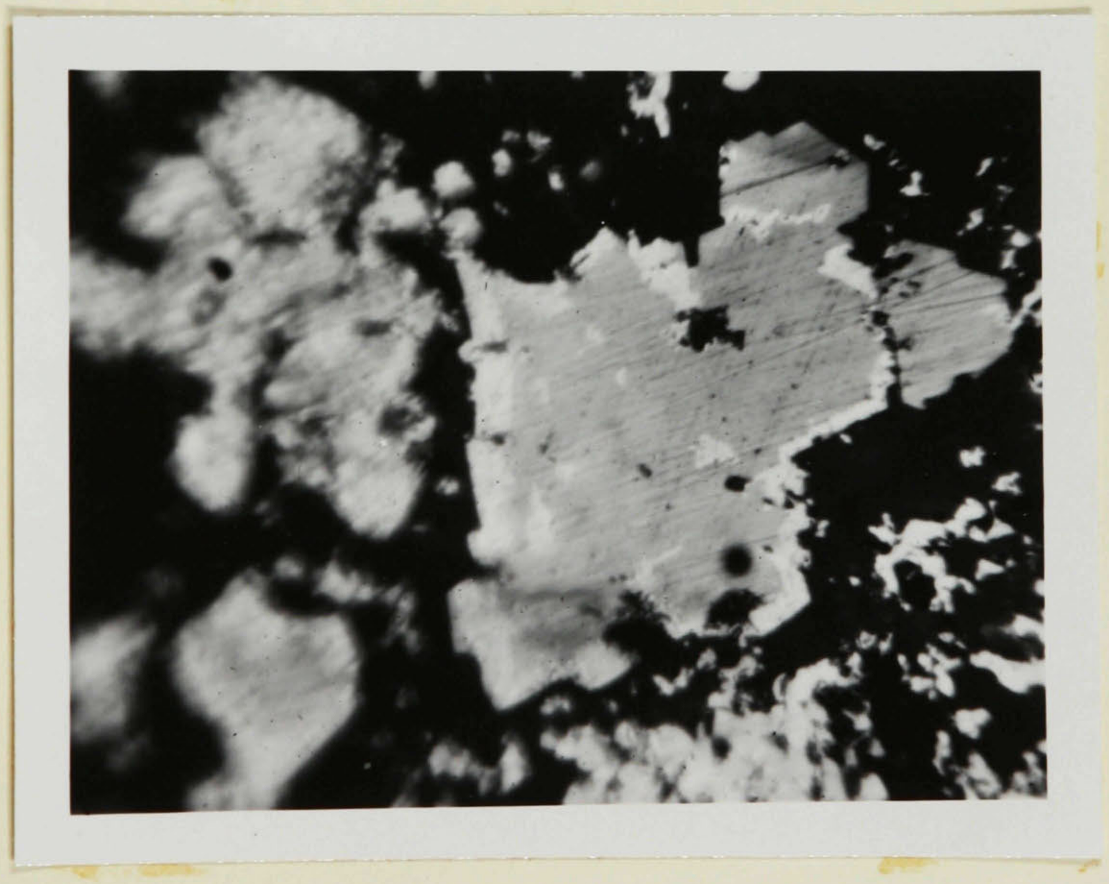


Plate 9B. Photomicrograph of martite (white) replacing magnetite (grey). The grains on the right (out of focus) show a similar relation. 430X.

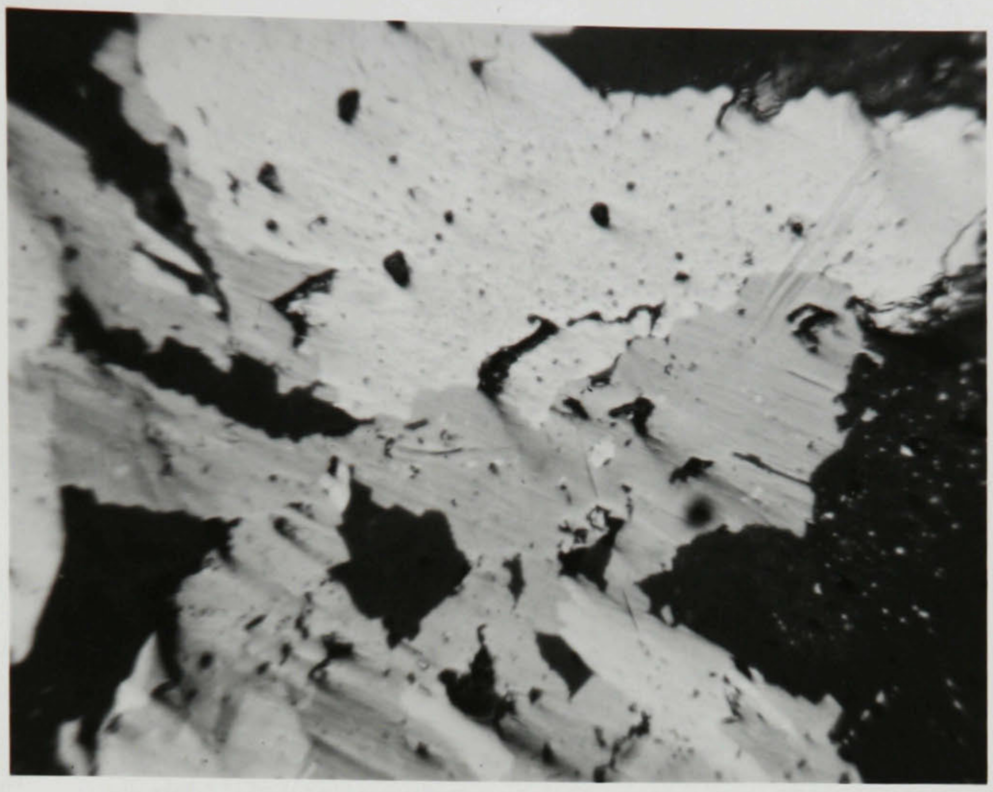


Plate 10A. Photomicrograph of magnetite (grey) and hematite (white). Part of the hematite may be martite. 430X.

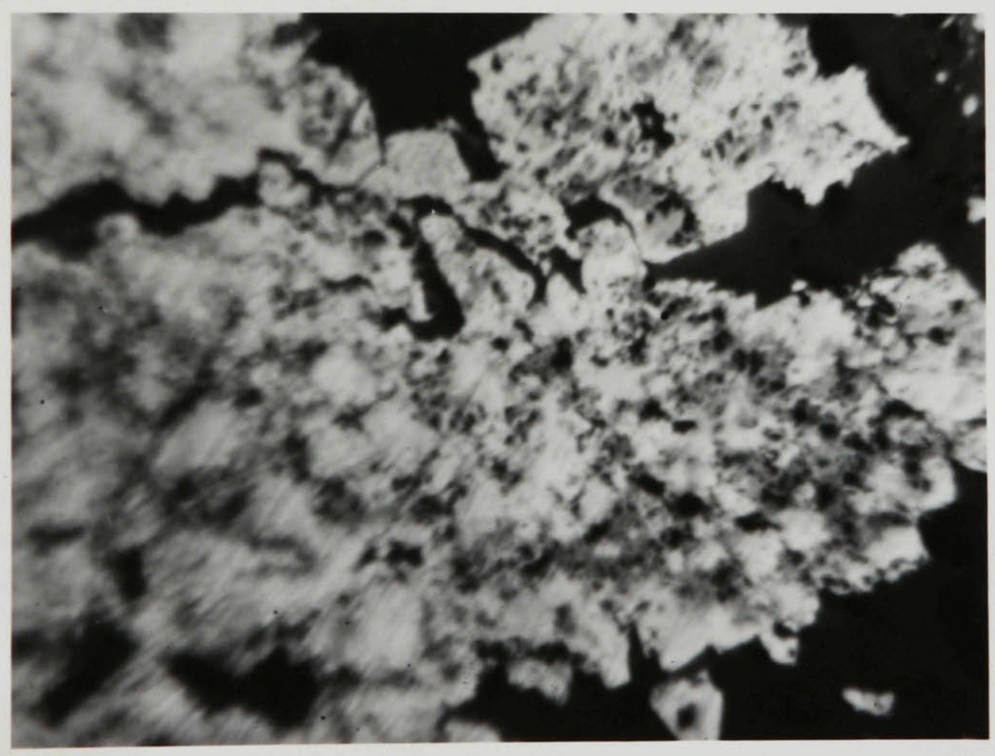


Plate 10B. Photomicrograph of martite (white) containing patches of goethite (grey). The goethite is much softer than the martite and the surface becomes pitted on polishing. 430X.

LEGEND

HURONIAN-TYPE

PRECAMBRIAN

- SLATE
- IRON FORMATION
- CHERT AND QUARTZITE
- SHALE
- UNCONFORMITY
- LIMESTONE
- SLATE

ROCK OUTCROP (SCATTERED, APPROXIMATE)

GEOLOGICAL BOUNDARY (DEFINED, ASSUMED)

BEDDING (HORIZONTAL, INCLINED, VERTICAL)

FOLIATION (HORIZONTAL, INCLINED, VERTICAL)

FAULT (ASSUMED)

ANTICLINAL AXIS (APPROXIMATE)

SYNCLINAL AXIS (APPROXIMATE)

TOP DETERMINATION BY GRAIN GRADATION

SHORELINE (DEFINED, APPROXIMATE)

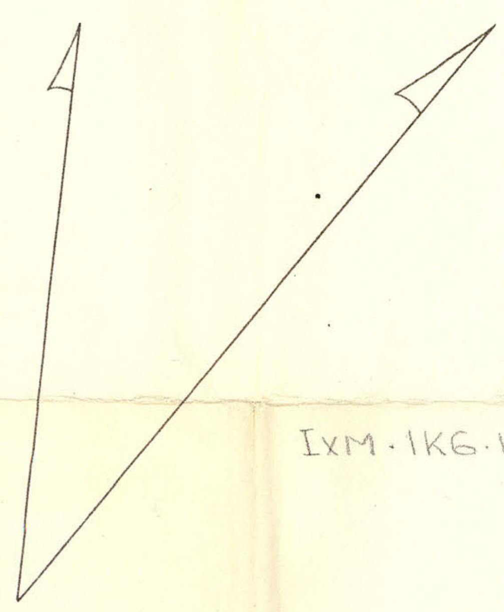
STREAM

TRIANGULATION STATION (LAT. 55°10' LONG. 67°05')

MARSH

CONTOURS (INTERVAL 100 FEET)

SPOT ELEVATION



IXM·1KG·1950

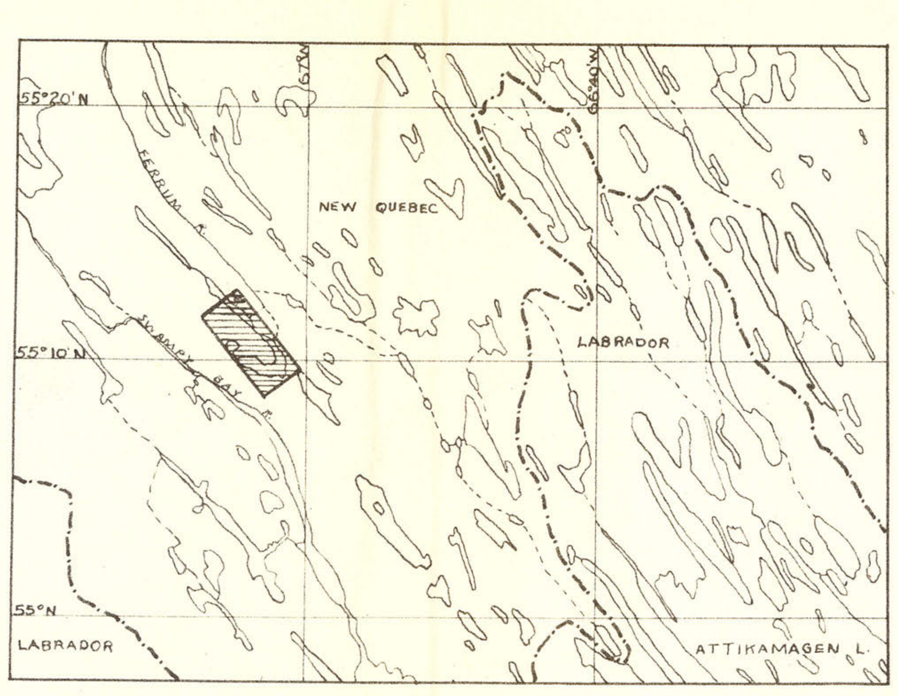
APPROXIMATE MAGNETIC DECLINATION, 33° WEST

SNOW-HOOK LAKES, NEW QUEBEC

SCALE: 1" = 1000'

ASSUMED DATUM SNOW LAKE 1725 FEET

FEET 1000 0 1000 2000 3000



INDEX MAP SCALE: 1 INCH TO 8 MILES


BRUIN LAKE
1725'
WEASEL LAKE
SYNCLINE
LAKE
1885'
1961'
TROUGH
LAKE
1812'
JOHNSTON LAKE
LEGEND
HURONIAN-TYPE
PRECAMBRIAN
SLATE
IRON FORMATION
CHERT AND QUARTZITE
SHALE
UNCONFORMITY
LIMESTONE
SLATE
ROCK OUTCROP (SCATTERED, APPROXIMATE)
GEOLOGICAL BOUNDARY (DEFINED, ASSUMED)
BEDDING (HORIZONTAL, INCLINED, VERTICAL)
FOLIATION (HORIZONTAL, INCLINED, VERTICAL)
FAULT (ASSUMED)
ANTICLINAL AXIS (APPROXIMATE, OVERTURNED)
SYNCLINAL AXIS (APPROXIMATE)
TOP DETERMINATION BY GRAIN GRADATION
SHORELINE (DEFINED, APPROXIMATE)
STREAM
TRIANGULATION STATION (LAT. 55° 08' LONG. 66° 59')
MARSH
CONTOURS (INTERVAL 100 FEET)
SPOT ELEVATION
APPROXIMATE MAGNETIC DECLINATION, 33° WEST
IXM·1K6·1950
BRUIN-SYNCLINE-TROUGH
LAKES, NEW QUEBEC
SCALE: 1" = 1000'
ASSUMED DATUM BRUIN LAKE 1725 FEET
FEET
1000 0 1000 2000 3000
55°20'N
67°W
66°40'W
NEW QUEBEC
FERRUM R.
SWAMPY BAY R.
55°10'N
LABRADOR
55°N
LABRADOR
ATTIKAMAGEN L.
INDEX MAP SCALE: 1 INCH TO 8 MILES