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DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1924, Part C

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OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1926

No. 2091

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SUMMARY REPORT, 1924, PART C

EASTERN PART OF MATAWIN IRON RANGE, THUNDER BAY DISTRICT, ONTARIO

By T. L. Tanton

CONTENTS

INTRODUCTION

During the field season of 1924, the writer geologically mapped and examined an area which includes the eastern part of the Matawin iron range, Thunder Bay district. The northern edge of the map-area (Map 2069) is in part defined by the north boundary of Ware township, the southern limit passes along the southern boundary of Sackville township, and the east and west boundaries lie along longitudes 89° 30′ west and 90° west, respectively. The southeast corner of this rectangle is 20 miles west of Port Arthur.

The area is crossed by the main lines of the Canadian National and Canadian Pacific railways and by the branch line of the Canadian National railways between Port Arthur and Superior junction. Excellent roads which serve the agricultural settlements west of Port Arthur and Fort William extend through the eastern part of the area. The eastern part of the proposed highway between Port Arthur and Winnipeg is now in good repair from Port Arthur to the Dawson road near Finmark. With the exception of Dog river and Matawin river above the falls near Shebandowan River junction, the streams of the district are not regarded as canoe routes, especially now that lumbering operations and the control of water for power purposes increase the obstacles to canoe travel during certain periods. Roads provide easier alternative routes near the large streams.

The map-area embraces the better known part of the Matawin iron range, and the primary object of the examination was to map the distribution of the iron formations. A map of part of Thunder Bay district, issued in 1921 by the Ontario Department of Lands and Forests, was used as a geographical base map; and the Shebandowan sheet, issued by the Geological Survey, Canada, 1896, was used extensively in the geological work. The examination was made by numerous land traverses run by pace and compass methods.

The writer was ably assisted in the field by R. Thomson and G. G. Suffel. Information relating to the distribution of iron formation was kindly supplied by Messrs. J. J. O'Connor, J. E. Marks, and B. L. Morrison, of Port Arthur, and others.

BIBLIOGRAPHY

Geol. Surv., Canada, Rept. of Prog. 1866-69, pp. 330, 355, 358, and 362: R. Bell reports the occurrence of iron formations near the present station of Kaministikwia.

Geol. Surv., Canada, Rept. of Prog. 1872-73, pp. 95 and 111: R. Bell gives brief notes of general geological interest, not relating to iron ore.

Second Rept. Ont. Bureau of Mines, p. 66 (1892): M. Grady and D. Williams give brief, favourable reports on certain claims on the Matawin iron range; p. 78, H. L. Smith gives a valuable general statement of the result of his two years of work in the district. He found no workable body of iron ore, but considered that further prospecting was warranted; p. 86, A. Blue briefly discusses the topography of the Matawin iron range and its relation to possible mining operations.

Fourth Rept. Ont. Bureau of Mines, p. 123 (1894): A. Blue states that extensive deposits of excellent magnetic iron are known to exist on Matawin river and elsewhere west of Port Arthur.

Geol. Surv., Canada, vol. VIII, p. 49 A (1897): a brief report of field work by Wm. McInnes.

Fifth Rept. Ont. Bureau of Mines, p. 80 et seq. (1895): A. P. Coleman gives a description of the most promising deposits of the so-called iron ore then known on the Matawin range. He regards the iron formation as later in age than the Huronian (Keewatin) and indicates that it might be equivalent in age to the Animikie; p. 131, A. Blue gives a few details regarding development work on the Matawin iron range.

Geol. Surv., Canada, vol. X, p. 57 H, et seq. (1899): Wm. McInnes presents a comprehensive report on the geology of the Seine River and Lake Shebandowan map-sheets. The accompanying maps are on a scale of 4 miles to 1 inch.

Ninth Ann. Rept. Ont. Bureau of Mines, p. 87 (1900): Jas. A. Bow reports that a government diamond-drill is at work on the Matawin iron range; p. 154, A. P. Coleman compares the iron formation near Matawin river with the iron formations on the Vermilion and Mesabi ranges, respectively. He infers that if iron deposits occur in the valleys in the Matawin area they may be expected to be richer in iron than that part of the formation which occurs on hills.

Tenth Ann. Rept. Ont. Bureau of Mines, p. 35 (1901): T. W. Gibson states that the results of diamond-drilling on the Matawin iron range indicate that much of the ore is somewhat low in iron.

Eleventh Ann. Rept. Ont. Bureau of Mines, p. 25 (1902): T. W. Gibson states that the results of further diamond-drilling on the Matawin iron range show considerable ore, too low in iron to be of present value. On p. 60 information is given regarding the drill-holes; p. 128, A. P. Coleman gives descriptive notes on outcrops of iron formation in Conmee township and records other observations of geological interest.

Ont. Bureau of Mines, Ann. Rept., vol. XIV, p. 24 (1905): W. G. Miller includes the Matawin iron formation in a list of iron formations regarded as being of Keewatin age.

Hille, F.: " Some Iron Ore Deposits in the Districts of Thunder Bay, and Rainy River, Ontario "; Mines Branch, Dept. of Mines, Canada (1908). This report is well illustrated by sketch maps and gives particulars regarding the size and grade of the iron ore deposits in the Matawin iron range, together with the results of magnetic readings indicating the inferred extension of certain deposits. The possibility of producing ore by a process of beneficiation is discussed.

Lindeman, E., and Bolton, L. L.: " Iron Ore Occurrences in Canada "; Mines Branch, Dept. of Mines, Canada, vol. II, pp. 55-61 (1917). Maps 409, 410, and 416 which accompany this report show the results of magnetometric surveys on the Matawin iron range. The report includes a concise compilation of the available data regarding the known iron ore occurrences in this district. It would appear that no body of merchantable natural ore has been found in the district.

GENERAL CHARACTER OF THE DISTRICT

A range of rocky hills, averaging 3 miles in width, extends east and west across the map-area. The principal gap in the range is the valley of Kaministikwia river. North and south of this range a succession of plain-like or gently rolling areas is underlain by thick deposits of drift through which project low, rocky hummocks.

Rocks varying very considerably in hardness and in susceptibility to weathering occur on both the highlands and lowlands and it seems impossible to trace a relationship between the topographic features and the character of the solid rocks. Beyond the map-area, in the area underlain by Animikie rocks, there is a pronounced relation between the solid rock geology and the topographic forms.

GENERAL GEOLOGY

The solid rocks of the district are all Precambrian and are classified according to age as follows:

Table of Formations

Keweenawan	Diabase dykes
	Intrusive contact
Animikie	Sediments and lava
	Great unconformity
Batholithic intrusives	Granite and gneiss
	Intrusive contact
Post-Windigokan (?) intrusives	Peridotite, hornblende porphyrite, and quartz porphyry
	Intrusive contact
Windigokan (?)	Sediments
	Unconformity
Keewatin	Altered lavas and pyroclastics, iron formation, and various intrusives
Couchiching[1]	Banded mica schists and paragneisses.

[1]Originally spelled Coutchiching.

The classification of the strata presented above differs in certain respects from that adopted by the late W. McInnes in his report and on his map of the region. McInnes noted the presence of the sedimentary strata now classed as Windigokan (?), but, in conformity with the then prevailing usage, he considered these measures to be part of the Keewatin. He found these supposed Keewatin sediments to be in places closely associated with schists resembling the Couchiching of other areas and because of this close association concluded that the Couchiching-like rocks were merely more altered phases of the Keewatin sediments. The present writer, as a result of a more detailed study than McInnes could make during his geological and geographical reconnaissance of the region, finds that the Couchiching-like strata are a distinct group of sedimentary schists corresponding to the Couchiching of districts to the west, and presumably underlying the Keewatin, and that there exists a second sedimentary group, the Windigokan (?), which is younger than both the Keewatin and the Couchiching.

COUCHICHING

The pre-batholithic rocks occupy a broad belt extending east and west across the map-area. Omitting the Windigokan (?) series from present consideration, it may be said that the most striking lithological difference exhibited in the assemblage is between a group of banded mica schists which occupy an extensive area bordering the northern side of the belt and the lavas which underlie the remainder of the belt. The banded mica schists can be recognized in the field to be highly metamorphosed sedimentary rocks, and they have no counterpart within the Keewatin as described by Lawson in the neighbouring area to the west. The highly metamorphosed Keewatin rocks which occur along the southern margin of the belt and border a batholith, preserve traces of their relation to the characteristic Keewatin rocks and are quite different lithologically from the banded mica schist assemblage, thus indicating that the mica schists are not merely altered Keewatin rocks of the usual type. There is no evidence that the mica schist assemblage is younger than the Keewatin, and the conclusion that it is older is based on the following considerations:

Along the contact between the mica schists and the Keewatin there is no conglomerate or other recognizable evidence of an unconformity; from this one might infer that the change in the conditions of rock formation was the flow of lava over sediments rather than the deposition of sediments over lava, in which case some fragments of Keewatin rock would be expected to occur in the sediments.

The Windigokan (?) series is younger than both the Keewatin and the mica schist assemblage, and all three have been folded and eroded; but the Windigokan (?) series is more closely associated with the Keewatin than with the mica schists, thus suggesting that the mica schist group is the oldest of the three assemblages.

In Rainy Lake district Lawson has inferred that the Couchiching series is older than the Keewatin on the basis of their stratigraphic relations and their general distribution in relation to their major structure.

In the writer's opinion the group of rocks characterized by mica schists in Matawin River area may be properly correlated with the Couchiching[1] series of Lawson.

The Couchiching rocks occur in a zone averaging 2 miles in width and extending across the map-area in an east-west direction along the northern side of a broader belt of Keewatin strata. The predominant rocks in this zone are banded, fine-grained mica schists and stratified, pale grey rocks of fine texture. There are also siliceous, grey, schistose rocks which do not show stratification, but which are believed to be of either clastic or pyroclastic origin. Across considerable widths one commonly finds an alternation of light and dark grey banded mica schists, the bands varying in width from ¼ inch up to 2 feet. The banding is due to slight differences in texture and in the proportions of biotite in the layers. The schistosity usually appears to be coincident with the bedding. From the examination of the scattered outcrops it would appear that the structure in the rocks is remarkably uniform over large areas, the dip is in general vertical, and the average strike is south 80 degrees east. The bedding or colour banding is remarkably even and uniform, and it does not show folds and contortions such as characterize the equally finely banded tuffs associated with the Keewatin iron formation. The mica schists are frequently cut by small lenticular veins of white quartz; in some localities these are disposed parallel to the general foliation, but more commonly they cut across the structure in an irregular manner. In the vicinity of the granite batholith, areas of banded, fine-grained mica gneisses occur; these may be a somewhat more coarsely recrystallized phase of the mica schists. Narrow dykes of fine and coarse-grained granite occur abundantly as lit par lit injections through these rocks and also, locally, in the fine-grained mica schists. The granitic dykes are commonly composed of quartz and feldspar and are neither foliated nor sheared. The boundary between the Couchiching schist and the granitic batholith is of a gradational character; the granitic dykes become more abundant or larger towards the batholith and eventually they make up the greater part of the total volume, the schists appearing as block and lens-like inclusions in the massive granite.

A few outcrops were observed which showed rocks different from the prevailing types. On concession V, lot 20, Ware township, a band of black, medium-grained biotite schist contains disseminated, acicular crystals of black tourmaline. A small area of amphibolite was observed in concession II, lot 14, Forbes township. Small aggregations of pink feldspar and epidote are irregularly scattered through the fine-grained, dark green rock. The original character and age relations of this rock are not known. On mining location 163 T, Ware township, there is a lenticular area composed chiefly of diorite in which the feldspar is pink. In this rock near its margin are tongue-like projections and inclusions of mica schists which merge into the diorite. The rock is cut by pegmatite dykelets. The diorite is regarded as having resulted from the assimilation of Couchiching sediments by a granitic intrusive.

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[1]*See* footnote, p. 3.

KEEWATIN

The Keewatin rocks which extend across Matawin River area in a band some 14 miles wide form a wide part of a belt which has been mapped for many miles along a general east-west direction.

The predominant rocks in the Keewatin assemblage are lavas of intermediate composition, a variety of stratified and unstratified pyroclastics, banded iron formation, basalt, rhyolite, and hornblende, chlorite, and sericite schists. In certain localities carbonaceous shaly rocks rich in pyrite concretions occur associated with stratified tuffs, and with rocks made up largely of some carbonate, locally ferruginous dolomite. No attempt has been made to map separately the numerous members of the complex and though the relative ages of certain groups can be determined in various outcrops no general conclusions can be made as to the stratigraphic sequence. Evidence of intense folding is everywhere manifest by the stratified members and it may be inferred that the assemblage as a whole has been folded. Dykes ranging in composition from quartz porphyry to peridotite cut the Keewatin iron formation, but their age sequence was not determined. On the basis of degree of metamorphism it would appear probable that the massive lamprophyre dykes which occur abundantly in Conmee township and which have not been differentiated from the Keewatin are not older than the post-Windigokan (?) intrusives.

On the accompanying map (No. 2069) those rocks of peculiar lithological character which are commonly known as iron formation have been differentiated from the other Keewatin rocks.

Iron Formation

The iron formation is a layered rock usually found standing on edge and showing numerous large and small plications. In the well-exposed area between Kaministikwia and Mokomon the iron formation has been traced along its general strike in several approximately parallel belts, as indicated on the map. The belts are known to have widths of from 300 to 700 feet and lengths of at least a few miles where magnetometric surveys have shown the distribution of the concealed iron formation between the numerous outcrops. In the hilly area near Shabaqua an iron formation belt only 10 feet in thickness and traceable for over 100 feet was observed. As indicated on the map, iron formation is widely distributed through the Keewatin, but in most of the outcrops only a partial width is exposed, and the ends, or extensions along the strike, are in all cases concealed by drift. All the belts indicated on the map, with the exception of those northerly from Shabaqua, have partial widths of over 50 feet exposed and, where information has permitted, the width has been shown to scale. The belts, except in the well-exposed areas north of Mokomon and in the vicinity of Shabaqua, have been represented for short distances beyond the known outcrops in order to show the probable strike of the iron formation beneath the drift, as inferred by the writer from the strikes observed. The character and structure of the iron formation are such that the belts may reasonably be considered longer than is indicated, though allowance must be made for the possible existence of unsuspected faults or intrusive bodies.

All the belts of Keewatin iron formation are composed characteristically of alternate layers of finely crystalline silica and magnetite; but the colour, texture, and proportion of these constituents are not everywhere the same, and varying amounts of other materials occur. The individual layers in those parts of the rock which are not minutely plicated or brecciated are usually remarkably uniform in thickness for distances of several yards, but lenses of chert and minor irregularities in the layers are observable in many outcrops.

The typical varieties of the iron formation are indicated in the following descriptions:

On mining location R 340, Conmee township, the iron formation for a width of 50 feet is mainly composed of alternate layers of light and dark grey chert ranging in width from ¼ inch to 2 inches. At intervals of from 1 to 6 inches there are layers of fine-grained magnetite from one-eighth to one-half inch thick. Small amounts of pyrite are disseminated through the cherty layers.

On the northern half of lot B, concession V, Conmee township, the iron formation consists of interbanded grey chert and fine-grained magnetite —the thickness of the bands averaging one-half inch and one-eighth inch, respectively—and finely laminated pale grey and white rhyolitic tuff. The chert-magnetite and the tuff are interbedded in numerous layers varying from 6 inches to 6 feet in thickness and the tuff makes up approximately a quarter of the total volume of the rock. Pyrite is sparsely disseminated through all the layers and with a small amount of pyrrhotite occurs locally in the form of meshworks of fine stringers and linear segregations. Transitions can be traced from finely banded rock traversed by stringers of pyrite to solid masses of fine-grained sulphide with an intermediate stage showing disjointed and apparently corroded blocks of chert and tuff in a matrix of sulphides. The general character of the pyrite concentrations indicates that they have been formed by a process of replacement. From development work performed by the Nichols Chemical Company, it is reported that seven lenticular masses of rich pyrite have been located in the above-mentioned area. These masses are, individually, several hundred feet in length and scores of feet in width, the length being parallel to the trend of the best of iron formation. Irregularly projecting tongues of the rich pyrite replacement deposit extend from each of the lenticular masses, each of which in itself contains partly replaced, banded iron formation. Local concentrations of pyrite have been observed in some part of every outcrop found within the belt of iron formation mapped on lot B, concession V, Conmee township. Iron formation of similar character also occurs near the northeast corner of lot C, concession IV, Conmee township, and in a part of the outcrop a filigree of pyrite stringers ramifies through the banded material. Within the denser part of the pyrite meshwork subspherical concretions of pure pyrite up to one inch in diameter occur.

Near the middle of the south boundary of mining location R 393, Conmee township, the iron formation is made up of two evenly banded, interstratified units each of a compound nature. One unit consists of layers of white, grey, black, or red chert, approximately one-half inch wide, alternating with layers of magnetite one-eighth inch wide. The other unit consists of interstratified grey and greenish-grey tuff, the textures ranging between that of shales and sandstones. These units occur in widths of from 1 to 4 inches and their relative proportions vary considerably in different parts of the iron formation.

The iron formation a short distance southeast of Cedar lake, Adrian township, consists of finely banded, siliceous and slaty, greenish-grey tuff and occasional thin layers of grey chert. Thin beds of magnetite less than one-eighth inch wide occur sporadically both in the slaty layers and the chert.

The most abundant phase of the iron formation occurs in all the wide belts between Stephen lake and Adrian township, mining location R 333, near Kaministikwia. It consists of evenly banded grey chert, black chert in which spots, seams, and irregular lenses of red chert occur, and thin layers of magnetite, with occasional layers of dark green slaty tuff. The layers are commonly less than one inch thick; their boundaries are usually sharply defined.

The richest observed phase is characterized by the presence of red jasper beds, and is present in all the wide belts from Stephen lake to mining location R 333. In some localities it makes up as much as a quarter of the total width of the belt. The rock consists of interbedded red jasper and fine-grained magnetite. Varying small amounts of hematite occur intermixed with the magnetite. The layers vary in width, the jasper averaging one inch, the magnetite one-quarter inch. Locally, the magnetite layers are closely spaced and make up approximately half the volume of the rock.

In the northwest part of mining location H 8, Conmee township, part of an iron formation belt consists of alternate layers of grey chert and grey cherty iron carbonate with discontinuous thin layers of magnetite. This phase of iron formation is rare in the district.

Throughout the iron formation the texture of the magnetite is fine grained. Under the microscope, thin sections of the magnetite layers appear as a sponge-like mass of finely granular magnetite with finely-crystalline silica filling the interstices and the whole presenting a banded appearance, due to variations in the amount of silica parallel to the general banding of the rock.

At certain localities the jasper in the iron formation shows a minute, rhythmic colour banding. The colours are commonly red and grey, and the width of the bands ranges from one-eighth inch to microscopic dimensions. The bands are disposed parallel to the boundaries of the individual layers, and in the small lenticular masses of jasper which occasionally occur within the otherwise normally layered iron formation the colour banding is parallel to the periphery, appearing in cross-sections as ellipses. In some cases the differently coloured bands are not continuous and the bands of one colour may be traced into a series of dashes or tiny globules.

Oolitic texture was not observed in any part of the Keewatin iron formation.

The individual layers of iron oxide, chert, and interstratified tuffs which make up the iron formation, almost everywhere preserve their identity and character, although it is evident that the iron formation has been intensely folded. The layers are nearly vertical and show drag-folds or, locally, plications of extraordinary complexity. Brecciated iron formation has been observed in numerous outcrops and consists of angular, disjointed layers of jasper in a matrix of the other constituents, such as magnetite and tuff.

Blocks of red jasper and other materials resembling fragments of iron formation were observed in lava near belts of iron formation. Half a mile southeast of Shabaqua there are several small outcrops of ellipsoidal andesite through which are sporadically scattered blocks of red jasper, streaked red and grey jasper, and material resembling lava. These blocks are of all sizes up to 2 feet in diameter and show angular and rounded outlines, and re-entrant angles. In an S-shaped block of banded red and white jasper the individual bands follow curves paralleling the outlines of the body. The inclusions in the lava are exposed to within 25 feet of a band of lean jasper-magnetite iron formation, the strike of which trends northwest and southeast parallel to the longer dimensions of the ellipsoids in the lava. The inclusions were found in the lava within a zone 75 feet wide which parallels the iron formation along its northeast side. The contacts of the belt of iron formation with the lavas that occur on both sides of it were not observed.

One mile north of Glenwater, on a thinly forested, rocky knoll, there is an exposure of ellipsoidal andesite 150 feet across. Within this rock there are numerous, subangular and rounded blocks of red jasper, and of white jasper streaked with red. These range in size up to 1½ feet in diameter and are abundantly distributed through linear zones which average 2 feet in width and 20 feet in length. The zones are irregularly spaced from 5 to 30 feet apart and trend approximately northwest and southeast in the same direction as the longer axes of the ellipsoids. On the northeastern side of the outcrop the ellipsoidal andesite gives place to andesite with no internal structure, and on the southwestern side of the knoll there is massive greenstone intrusive, which cuts sharply across the structure in the ellipsoidal andesite. Iron formation occurs in the vicinity of Glenwater, but no exposure of this or any other rock was found within a quarter mile of the knoll.

In the bed of Brûlé creek, midway between the east and west boundaries of lot B, concession V, Conmee township, there is an outcrop 50 feet long and 20 feet wide consisting of amygdaloidal, greenish grey lava, through which there are several, scattered, angular and rounded blocks, up to 8 inches in diameter, of grey jasper, red and grey streaked jasper, and a few blocks showing layers of jasper and fine-grained pyrite. There are also blocks of siliceous, fine-grained, greenish grey material permeated with fine-grained pyrite in the form of a meshwork of stringers. Flowage lines occur trending in a general northeasterly direction and these curve around the blocks. Narrow rims of rusty-weathering, dark green material occur around some of the rounded blocks. An outcrop of iron formation is exposed through a length of 100 feet immediately west of this exposure in the bed of the creek, and the contact between it and the flow agglomerate is exposed for a few feet trending north 50 degrees east; the contorted layers of jasper and magnetite trend north 20 degrees east at the contact and are cut across by the lava. At this locality and those described near Glenwater and Shabaqua the phenomena indicate that blocks of iron formation were disjointed and picked up by lava advancing over it.

One mile east of Stephen lake, and at the southwest corner of the north ½ of lot 4, concession IV, Conmee township, brecciated iron formation has a matrix of dark grey porphyrite. The exposures at these localities are small and it is not known whether the igneous rock is part of a lava flow or an intrusive.

Owing to a wide covering of drift the extent of the individual belts of iron formation is not known. It has not been possible to determine whether the iron formation occurs at few or many horizons. The broader structural features are unknown; and the minor structures are complex. In the circumstances it is hazardous to draw any inferences regarding the major structure of the iron formation. The iron formation, in places, has been altered in the vicinity of intrusive rocks. In lot 3, concession VII, Marks township, and the adjacent area in the southeastern part of Adrian township, near intrusive granite, the iron formation consists of interbanded, recrystallized chert, finely crystalline magnetite, and layers and films of tiny acicular crystals of green hornblende with, in certain layers, disseminated crystals of garnet. The hornblende crystals are oriented in a vertical direction and give a schistose structure to the rock. The phenomenon known as boudinage is well developed in an outcrop in Marks township; the chert layers, which stand on edge, have been separated along horizontal planes; the adjacent hornblende schist bulges in and partly fills the opening, the remaining space being occupied by quartz in the form of small lenticular veins.

Dykes of granite cut the banded iron formation in a small exposure near the margin of the granite batholith, 10 chains northeast of the southwest corner of lot C, concession II, Conmee township. The altered iron formation in this locality is similar in appearance to the above-mentioned occurrence in Marks township.

The pyrite which, in irregularly distributed bodies, permeates and cuts across the layered, cherty-magnetite iron formation in lot B, concession V, and lot C, concession IV, Conmee township, has been deposited by metasomatic replacement. This secondary pyrite is widely distributed through the iron formation belts in this general vicinity and, so far as known, is confined to them. Disseminated pyrrhotite occurs in the pyrite bodies and, since this is a mineral which forms only at high temperatures, it is inferred that the deposition of the sulphides took place at high temperatures, which, however, were not everywhere sufficiently high to cause the formation of pyrrhotite to the exclusion of pyrite. Part of the pyritized iron formation is not schistose and in it the pyrite is extremely fine grained and occurs as a multitude of tiny stringers traversing the rock in all directions and forming a meshwork. Locally, the pyritized iron formation is schistose, and the pyrite in it, though fine grained, is of coarser texture than that in the non-schistose rock; when viewed at right angles to the planes of schistosity the pyrite appears as a meshwork distinctly elongated parallel to the foliation. The differences in the manner of distribution and texture of the pyrite in the schistose and non-schistose parts of the rock are inferred to be due to the rearrangement and recrystallization of pyrite, already present in the rock, when regional compression caused the development of schistosity. Blocks of pyritized iron formation occur in lava 500 feet west of the rich pyrite deposit exposed in the bed of Brûlé creek. The occurrence of these pyritized blocks indicates either that the pyrite formed in isolated inclusions of iron formation as well as in the main belts, or that it formed before the block was detached and enveloped in lava. Dykes of different compositions intrude the iron formation and cut across the pyritized and unpyritized parts with no observed difference in contact phenomena. There is no indication that these intrusives played any part in the development of pyrite. These several inferences lead to the general conclusion that the pyritization of the iron formation was caused by lava which poured over it, and supplied the heat, sulphur-bearing solutions, and other reagents necessary for the alteration which occurred.

The general character of the iron formation indicates that it originated as a chemical precipitate. Whatever changes may have taken place since the precipitation of the material, it is evident that the banding was in existence prior to the time of folding and contortion of the strata. In the richer exposed parts of the iron formation, the banding is distinct, and the relatively high iron content is due to the closer spacing and somewhat greater thickness of the layers of iron oxide in these richer parts than in the leaner phases. These differences were determined at the time the layers formed. Locally, layers now composed of iron oxide are slightly wider at the crests of tight folds than on the limbs; the jasper layers do not show an equivalent thickening; enrichments of this nature have been observed over areas ranging from a few square inches to a few square feet. On mining location R 382 there is a localized development of secondary magnetite as a series of tiny stringers trending across the layers of the highly folded iron formation.

WINDIGOKAN (?) SERIES

The rocks of the Windigokan (?) series occur in several small areas, elongated in an east-west direction, in a zone within the northern part of the belt of Keewatin rocks. The series consists of a group of sediments, possibly as much as 1,600 feet thick. The lowest member appears to be a conglomerate, in the most westerly area succeeded upward by slaty beds above which is an iron formation.

The conglomerate, which occurs near the margins of the areas and which is regarded as the lowest member of the Windigokan (?) series, consists of closely packed, well-rounded pebbles up to 6 inches in diameter and consisting of granite, fine-grained igneous rocks, vein quartz, and chert. The matrix consists mainly of quartz grains and fine-grained schistose material. The relative abundance of the various kinds of pebbles varies considerably at different localities; granite pebbles predominate in the conglomerate in Ware and Goldie townships. The conglomerate grades into a thick overlying layer of arkose within which are thin, pebble-bearing layers and sporadically scattered subangular pebbles of red chert. The arkose is a thick-bedded grey rock; its thickness, together with that of the conglomerate, is approximately 1,000 feet, the conglomerate making up at least 300 feet of this.

Stratigraphically above the arkose there is an estimated thickness of 400 feet of finely stratified, grey, siliceous rocks, so fine-grained that no minerals can be identified in hand specimens, with the exception of micaceous minerals in schistose phases. Under the microscope the rock appears to consist chiefly of fine-grained chlorite, calcite, and quartz, with smaller amounts of biotite and plagioclase. These rocks appear to be either stratified tuffs or greywackes.

The next member in the succession is a thinly laminated rock, 30 feet thick, where exposed, and consisting of alternate layers of pale grey and pale greenish grey cherty and shaly material. The texture is so fine that the mineral constituents cannot be resolved under the microscope. The rock may be a mixture of fine, water-lain tuff and chemically precipitated silica.

Stratigraphically above the previously mentioned member is a slaty iron formation over 200 feet thick. The greater part is of thin beds of grey, slaty material with groups of beds of fine-grained silica mixed with a considerable amount of red hematite or magnetite or both minerals. In such groups the iron oxides tend to be concentrated along one side of the individual beds. Other groups of varve-like beds occur in which the hematite is so abundant that the greater part of each bed is red and yields a red streak. These groups of beds relatively rich in iron, range from a few inches to more than 20 feet in thickness and occur at different horizons; the number of horizons is not known. Belts of iron formation in which beds of this character make up widths of 20 feet, or are abundantly distributed as thin groups of beds through greater widths, have been traced through the claims west of Matawin river. All the locally rich parts of the iron formation shown west of Matawin river (Figure 1) are of this character, except the belt near the middle of mining location W 221 in which the iron oxide is chiefly magnetite.

There are also groups of beds essentially similar to the previously mentioned, but with these differences: the iron oxide is chiefly extremely fine-grained magnetite, the varve-like character of the thin individual beds is less pronounced, and in many places where the rock is sheared it consists of alternate layers of slate or chlorite schist and magnetite averaging one-tenth inch in width. The schistosity in the rock is parallel to the fine lamination. Many slight variations occur in the proportions and intimacy of mixture of the iron oxide and slaty material which make up these richer groups of beds in the iron formation. At certain localities within all phases of the iron-rich beds there are irregularly and sparsely distributed layers, less than one foot thick, of interbanded red jasper and hematite more or less abundantly mixed with magnetite, which resemble finely banded Keewatin iron formation. The slaty beds for a few inches on either side of these layers are highly siliceous.

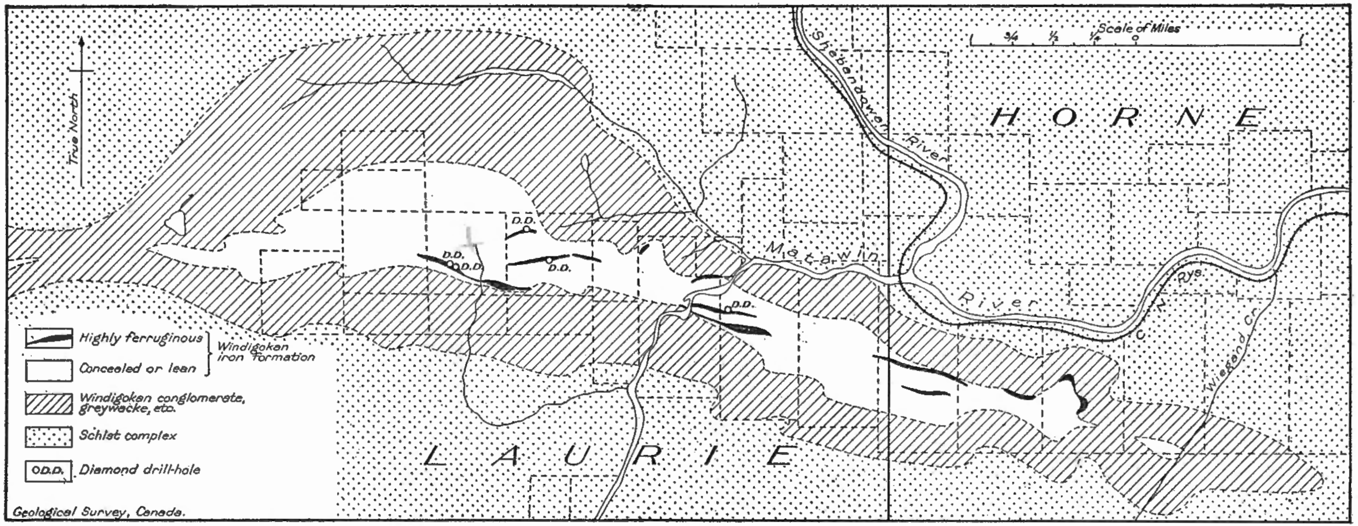

Figure 1. Plan of the more ferruginous parts of Windigokan iron formation as revealed in outcrops, workings, and by magnetic readings.

The richer part of the iron formation in which the iron oxide is chiefly magnetite occurs in all the belts east of Matawin river (Figure 1) and in the belt near the middle of mining location W 221, west of Matawin river. The details regarding the size of the numerous small outcrops, and trenches, and magnetic readings used in delimiting these belts is shown on sketch maps in the report by F. Hille[1].

The groups of beds in which the iron oxides are abundant grade, across the strike, into the lean slaty part of the formation, the thin individual layers becoming progressively more slaty.

Interstratified with the slaty members there are groups of beds of pink arkose, speckled with green chlorite, and green, chloritic, granular, stratified rocks which may be of pyroclastic origin. At certain localities these show frequent alternations with the shaly members in widths of a few feet; they are irregularly distributed through the formation, but their aggregate thickness is considerably less than that of the slaty members.

On mining location W 221 a few outcrops of rusty weathering, pale grey, ferruginous dolomite were observed within the area mapped as Windigokan (?) iron formation. The rock contains small scales of bright green mica. No evidence of stratification was observed and the contact with the adjacent bedded iron formation could not be observed because of drift covering.

The grade of the richest known parts of the iron formation is indicated by the following notes drawn from a previous publication.[2]

On mining location W. 215, the iron formation has been traced by dip-needle readings for nearly 1,800 feet. A stripping in the middle of the claim shows it to be 73 feet wide at that point. An average sample of the iron formation taken from this place gave the following analysis:

	Per cent
Iron	30·6
Silica	47·8
Sulphur	0·04
Phosphorus	0·11

Near the middle of mining location W 216 exceedingly fine-grained magnetite occurs in siliceous bluish grey slate. Two samples taken at different points across the exposure and representing widths of 57 and 35 feet, respectively, gave the following analyses:

—	No. 1	No. 2
	Per cent	Per cent
Iron	20·99	20·90
Silica	61·26	63·04

Several exposures of lean iron formation occur along an east-west trending belt which crosses W 216 and the adjacent part of W 217 west of it.

[1] Mines Branch, Dept. of Mines, Canada, Rept. No. 22, (1908).
[2] Lindeman, E., and Bolton, L. L.: Mines Branch, Dept. of Mines, Canada, pp. 57-59 (1917).

On mining location W 218 iron formation is exposed on hills near the western boundary. Two average samples taken 500 feet apart and representing widths of 47 and 17 feet, respectively, gave the following analyses:

—	No. 1	No. 2
	Per cent	Per cent
Iron	29·49	30·25
Silica	52·14	51·25

The westerly continuation of the above-mentioned belt of iron formation has been traced by magnetic readings 1,200 feet in the adjoining mining location, W 219. Several prominent exposures occur, and four samples taken at various points across the formation and representing widths of 47, 75, 52, and 33 feet, respectively, gave the following analyses:

—	No. 1	No. 2	No. 3	No. 4
	Per cent	Per cent	Per cent	Per cent
Iron	13·38	24·28	17·31	17·81
Silica	70·03	58·78	66·70	65·05

There is a gap of about half a mile between the previously mentioned belt and another which has been traced by outcrops and magnetic readings for 7,000 feet through mining locations W 220, W 221, and W 222 which adjoin successively on the west. Magnetic readings indicate a width of from 50 to 200 feet in W 220, over 1,000 feet near the boundary between W 221 and W 222, and from 100 to 400 feet in the westerly part of W 222. Two selected samples taken on W 221 and representing widths of 100 and 35 feet, respectively, and two samples from W 222 representing widths of 36 and 47 feet, gave the following analyses:

—	No. 1	No. 2	No. 3	No. 4
	Per cent	Per cent	Per cent	Per cent
Iron	25·07	29·35	30·89	27·86
Silica	54·20	48·76	46·34	49·44

The Windigokan (?) rocks have been metamorphosed in varying degrees. Many of the members have been rendered highly schistose and in these there has been a development of micaceous minerals. The thick arkose member, however, and parts of the iron formation, appear little altered, though as steeply inclined as the schistose parts. It is inferred that the magnetite in the iron formation is metamorphosed hematite, because magnetite is well developed only in the more highly schistose parts of the iron formation. Contact metamorphic phenomena have not been recognized, though small bodies of igneous rock regarded as intrusives have been found within the areas mapped as Windigokan (?).

The rocks of the Windigokan (?) series have been intensely folded. and the distribution of the formations in the principal area in which they are now found indicates that they there lie in a syncline, with an east-west trending axis. The beds are nearly vertical and the slaty members commonly show numerous drag-folds. It is difficult to recognize stratification in some of the members, but this structure is well preserved in the iron formation. In some parts of the latter the beds show a complexity of contortion much greater than would be expected from regional folding, and the layers of different composition appear to have been equally affected. It is possible that the beds were disturbed while still unconsolidated, and that regional folding took place subsequently. No large faults were detected.

The conglomerate and arkose members of the Windigokan (?) series are clastic rocks. It is inferred that their materials were derived by mechanical disintegration from rocks exposed over a land area of high relief and that they were deposited either in river valleys or near the shore of some large water body. It is not known whether the overlying greywackes are of clastic or pyroclastic origin. The relatively fine texture of the rock, and the entire absence of conglomerate, suggest changes in the geological conditions such as might be accounted for by a general depression of the area and a widespread submergence. The greater part of the iron formation was laid down in quiet water, as evidenced by the fine bedding in the clayey-textured materials and probably also by the even layering in the interbanded iron oxide and jasper which are considered to have originated as chemical precipitates. The dominant, grey, slaty material may represent mud derived from the erosion of older rock or it may be fine tuff, or tuff intermixed with mud. The localization of some of the iron oxides in groups of slaty beds with which iron-bearing chemical precipitates are occasionally associated may represent an intermixture of mechanically deposited and chemically precipitated sediments, or the iron oxides may also be finely divided clastics. The richer deposits of iron oxides are considered to be chemical precipitates.

The arkose and water-lain tuffs which occur in small amounts interstratified with the finer materials indicate that changes in the geological conditions took place intermittently. The tuffs indicate the existence of active volcanoes somewhere in the general region, and the occasional beds of tuff interstratified with the much finer material show that a combination of volcanic activity and a suitable transportation agent, such as strong currents, was occasionally operative.

As indicated by pebbles in the conglomerate, the Windigokan (?) series is younger than the Keewatin and certain granites. Though the Windigokan (?) rocks have not been found in contact with granite they are considered to be older than the granites because of their association with rocks known to be older, and because they have been folded, whereas the granites have not been schistified.

The sedimentary series as developed in Matawin River area is correlated with the Windigokan series in the vicinity of Windigokan lake, east of lake Nipigon. The correlation is based on lithological resemblances, similarity of relationships to other formations, and equivalence of structure and metamorphism. The strata may be equivalent to the Steeprock series which occurs in Rainy River district.

McInnes mapped these Windigokan (?) rocks as Keewatin; A. P. Coleman,[1] referring only to the iron-bearing formation, suggested a correlation with the Animikie; and A. G. Burrows called the Windigokan conglomerate east of lake Nipigon, Timiskamian (?).[2]

POST-WINDIGOKAN (?) PRE-BATHOLITIC INTRUSIVES

Various types of rocks intrude the Windigokan (?) series. Augitite, locally sheared, occurs as dykes on mining locations R 419 and W 215. A dyke of quartz porphyry with a granophyre phase, a pale grey massive rock, occurs on mining location W 221. Rusty weathering, pink felsite was seen on mining location W 214. Hornblende porphyrite occurs as a stock south of Strawberry creek. No features of economic significance are known to be associated with these rocks.

Numerous small dykes of black lamprophyre with biotite phenocrysts have been observed in the valley of Kaministikwia river. These have not been found in contact with Windigokan (?) rocks, but are believed to be of later age because they do not appear to have been sheared or otherwise affected by regional disturbance.

The most important of the post-Windigokan (?) intrusives, in point of size, is a stock of irregular shape composed of peridotite and related rocks. These have not been sheared, though they occur close to highly folded Windigokan (?) sediments. The stock occupies an area in the northeast part of Adrian township and adjoining townships. It measures 4 miles east and west by 2 miles in a north-south direction. The peridotite is massive, black or dark green, fine grained, and contains irregularly disseminated, fine grains of magnetite. The rock has been largely altered to serpentine. Tiny veinlets of pale green serpentine ramify as a network through the rock and on certain outcrops these present a pattern resembling mud-cracks. Pale green, cross-fibre asbestos occurs in certain of these veinlets. Locally, seams of white carbonate occur through the rock in an irregular manner; in certain exposures on Adair and Marble lakes the carbonate makes up the greater part of the rock, the black and green altered peridotite occurring as little polygonal blocks within it. The carbonate is crystalline and varies in texture through a wide range. Several specimens were tested and found to be calcite.

Associated with the peridotite and apparently forming part of the same mass are coarser-grained, similarly altered, basic rocks. The coarsest of these has a gabbroid texture. The dark constituents consist of chlorite and serpentine, the light grey constituent is altered plagioclase.

[1] Fifth Ann. Rept. Ont. Bureau of Mines, p. 83 (1895).
[2] Ont. Bureau of Mines, Ann. Rept., vol. XXVI, Map 26b (1917).

BATHOLITHIC INTRUSIVES

There are three areas of granite, one in Forbes and Ware townships, one in the southwest part of the map-area, and one in O'Connor and Conmee townships. The first mentioned is the southern part of a batholithic area extending north of the map-area, the two remaining bodies may be part of a single batholith, mainly lying south of the map-area. Tongues and small bosses of granite occur beyond the boundaries of the large batholiths within the Keewatin rocks. Pegmatite dykes occur abundantly in the Couchiching rocks neighbouring the northern batholith.

There are in these areas granites and gneisses of different colours and compositions. Remote from the contacts the predominant rock type is grey biotite granite; in their vicinity, differences of colour, composition, texture, and internal structure are more apparent, and some of these differences are due to the assimilation of xenoliths. Hornblende granite and gneiss of various shades of pink and grey occur adjacent to the intruded hornblende schists in the southern part of the area; paler grey, biotite granite and gneiss occur in the corresponding zone adjacent to the intruded mica schists in the northern part of the map-sheet.

The metamorphosing influence of the batholithic intrusions can usually be observed in the Keewatin-Couchiching rocks for a considerable distance from the contact. Highly developed foliation is not everywhere characteristic of the marginal part of the intruded rocks and in certain localities the greenstone has been altered to a massive amphibolite commonly cut by dykelets of granitic material. Where the rocks are schistose the dip and strike of the planes of foliation in the gneisses and adjoining schists are usually vertical and parallel to the contact. A short distance north of Kakabeka falls, however, the schists and gneisses dip in a northerly direction at angles as low as 45 degrees.

In the bed of Kaministikwia river near Kakabeka falls dykes of pink and grey porphyry trend north 50 degrees east through the granite gneiss complex including the pegmatite dykes.

No field evidence was found for assigning the granitic intrusives to more than one geological period. The granitic invasion took place prior to Animikie time and, as already stated, probably after the deposition of the Windigokan (?) rocks.

ANIMIKIE

Rocks of Animikie age occupy a few square miles in the southeastern corner of the map-area. Few outcrops are to be seen except in the river valley near Kakabeka falls. Near the Canadian National railway bridge there are several exposures of the thin bed of Animikie basal conglomerate lying horizontally on the gently undulating surface of steeply inclined schists and gneisses. The rocks immediately beneath the conglomerate show as little evidence of weathering as on nearby glaciated surfaces. The conglomerate consists of well-rounded pebbles of uniform size, of quartz, granite, and various greenstones. The matrix is a grit of the same materials with a submatrix of dark green, aphanitic material which weathers to limonite. Within the conglomerate are disjointed layers of pale grey chert ranging up to half an inch thick, which show a fine bedding locally contorted and resembling so-called algal structure. The conglomerate bed is approximately one foot thick. The conglomerate is overlain by a bed of crystalline, rusty-weathering carbonate averaging one foot in thickness; pyrite in spherical concretions and in closely spaced thin tubes and rods normal to the bedding is abundantly developed in certain parts of this member. Cherty taconite, a lean phase of iron formation, 10 feet thick, overlies the carbonate rock.

Shaly rocks 125 feet thick are exposed at Kakabeka falls, dipping about 2 degrees to the southeast. The upper members of this succession form almost continuous outcrops in the bed of Kaministikwia river for a quarter mile upstream from—that is, northwest of—the falls; and in the farthest outcrop there is a small anticlinal fold whose axis trends north 35 degrees east. A drift-covered stretch 500 feet long separates this outcrop from the nearest outcrop of basal conglomerate on granite, which lies northwest of it, and at a slightly higher elevation. The thick, shaly beds at Kakabeka falls, if projected northwesterly with a dip of 2 degrees to the southeast, would abut against granite. But on the undulating surface of the granite which rises gently in the area north, northwest, and west of the above-mentioned drift-covered stretch no shale occurs, though there are remnants of other Animikie strata. Consequently, it is inferred that a fault occurs within the drift-covered stretch, and that the rocks on the southeast side of it moved relatively downward. Assuming a continuity of the regional dip, an estimated throw of 35 feet would permit of the extension of the shaly members above the lower Animikie members northwest of the drift-covered stretch; there may, however, be a throw greater than 35 feet by approximately the figure representing the thickness of the Animikie strata between the lowest member exposed at Kakabeka falls and the basal member beneath it. The depth at which this basal conglomerate lies beneath the lowest exposed member is not known. In a partly exposed Animikie succession near Whitefish lake, 25 miles to the southwest, the group of beds which most nearly resemble those at Kakabeka falls lie more than 100 feet above the basal conglomerate, and at Shuniah mine, Port Arthur, 20 miles to the east, thick, shaly members lie 40 and 460 feet, respectively, above the base of the series.

At Kakabeka falls cliffs 125 feet high show a conformable succession of interbedded layers of various thicknesses of grey chert, cherty iron carbonate, thin-bedded grey and black shaly rocks, and grey and black, stratified fragmental beds having the texture of fine conglomerate. Across the bedding, the fragmental beds commonly grade into shaly beds interlayered with them.

The fragmental beds consist of angular and rounded fragments of dark grey material showing lava textures, in part replaced by calcite or some other carbonate, in a matrix of calcite. Some of the fragments show a microscopic amygdaloidal structure, others are microcrystalline and show tiny laths of altered feldspar, as commonly found in basalts. A considerable amount of carbonaceous material is disseminated through some of the fragments; it occurs as a rim around some and may be absent from other fragments in the same layer; it is not disseminated through the calcite matrix. The largest fragments observed are a little more than one-quarter inch in diameter, and in the layers containing these there are fragments ranging in size down to one-thirty-second of an inch. The fine-grained fragmental beds associated with, and grading into, the coarser material consist of more closely packed, smaller fragments of altered lava and a few angular and subangular, tiny grains of feldspar and quartz; calcite occurs within and around the fragments.

If the fragments of volcanic rocks, which make up the greater part of the fragmental beds, were originally formed by volcanic action, the rocks should be termed water-assorted tuffs; if, however, the fragments were derived from lava beds by erosion they would be normal clastic rocks and might be termed conglomerates or greywackes according to their texture. The process by which the fragments were formed is in doubt and in the following description of the section the term fragmental beds is retained.

Proceeding upward from the bottom of the cliff, the succession at Kakabeka falls is as follows:

(1) Iron formation, 3 feet, composed of irregularly interstratified thin layers of iron carbonate and grey chert. In places the grey chert is oolitic and contains disseminated pyrite and a little iron carbonate. The eroded surface of this layer is hummocky. It crosses the irregularly distributed materials in such a way as to show an intricate pattern of iron carbonate and chert. There are chert and pyrite concretions in this iron formation.

(2) 8 inches of fissile black shale.

(3) A layer, 1 foot thick, of iron carbonate thinly interstratified with black material containing pyrite, and thin lenses of chert showing parallel stratification. Pyrite concretions occur in both (2) and (3) as nodules up to 1 inch in diameter.

(4) 5 feet of fissile, black shale, through which pyrite nodules up to 2 inches in diameter are distributed.

(5) 1-foot layer of dense, cherty iron carbonate.

(6) 3½ feet of black, fissile shale with a few thin beds of limy greywacke. Limy concretions shaped like a curling stone up to 2 feet in diameter occur in this layer.

(7) 6-inch bed of intermixed shale and iron carbonate locally brecciated, the fragments lying in a matrix of crystalline carbonate and pyrite. Pyrite also forms replacements.

(8) 9 feet interstratified, fissile, black shale and fragmental beds. The layers of the latter are from 2 to 3 inches thick and are distributed at intervals of a foot or more through this member. There are also black, greywacke-like beds which show a gradation between the two.

(9) 3½ feet of cherty greywacke, thick bedded; the lower 3 inches contain a large amount of disseminated siderite. The upper surface of this lower bed undulates in a series of gentle curves with a distance between crests of 1 yard. The upper few inches of (9) consist of finely interlaminated carbonate and shale.

(10) 3 feet of finely interbedded, fissile, black shale and black, fragmental beds.

(11) 2½ feet massive, thick-bedded, fragmental beds. The lava particles have a maximum diameter of one-quarter inch.

(12) 9 inches of fissile, black shale.

(13) 2 feet massive, fragmental bed showing discontinuous thin layers of black chert, parallel to the bedding.

(14) 3¼ feet of interstratified, fissile, black shale and fragmental beds. The thickest fragmental bed is 6 inches and it contains fragments of basaltic lava between one-quarter and one-half inch in diameter. The fragmental beds here are locally very rich in carbonaceous matter.

(15) 61 feet of fissile, black shale. At 25 feet above the base of this member there are a few thin layers of iron carbonate interlayered with the shale. There are also a few layers which contain abundant small nodules of grey chert up to one-quarter inch in diameter, which are occasionally rimmed with fine-grained pyrite. There is a half-inch vein of anthraxolite and calcite trending 40 degrees. There are certain shaly layers composed of black granules, in the high notch near the western side of the falls. At 35 feet above the base, bluish, translucent chert forms lenses and small spherical concretions less than one-quarter inch in diameter in the black shale. There is pyrite distributed both in the shale and the cherty concretions. In one thin layer, the closely spaced chert spherules are locally joined together. On top of this structure there is a development of smaller chert spherules. At 47 feet, a 4-inch layer of cherty iron carbonate is found, banded light and dark grey.

(16) 3 feet of finely stratified chert and cherty iron carbonate (this forms the brink of the falls). The upper surface of this layer shows a series of broad, gentle undulations, with axes trending south 85 degrees east. In general the layering is flat, but occasional small folds occur, also irregularities around chert concretions.

(17) 12 feet finely interstratified, fissile, grey shale and cherty iron carbonate.

(18) 2½ feet of cherty iron carbonate streaked and imperfectly interlaminated with grey, minutely speckled chert and carbonate.

(19) 6 feet of shale: at 2 inches and at 1½ feet above the bottom are 1½-inch layers of interlaminated black shale and grey carbonate [like top of (9)].

Flat-lying black shale occurs on the northern part of lot 12, concession II, and the northern part of lot 13, concession I, Oliver township. At the former locality the rock has been quarried for road metal.

In the southern part of lot 12, concession III, Oliver township, there is a low hummock, some 200 feet across, composed of massive, amygdaloidal basalt. Several small pieces of native copper were discovered in small amygdules of banded agate. The extension of this rock body cannot be traced on account of the heavy drift covering. The nearest outcrop is of flat-lying Animikie black shale which occurs 300 feet to the southwest at the same elevation. A fault possibly occurs between the two outcrops.

The lava is believed to be of Animikie age because the fragments of massive, altered basalt in the strata of Kakabeka falls indicate the existence of a rock of this character at that time and in this region. Amygdaloidal basalt occurs in the Animikie succession exposed northeast of Gravel lake, 28 miles southwesterly from this locality. Keweenawan lava, some of which is lithologically similar to the occurrence in Oliver township, is not known within less than 45 miles; it occurs to the east in Black bay.

KEWEENAWAN

Dykes of diabase, similar to those which occur in the Keweenawan rocks on lake Superior, were observed: 1½ miles southeast of Shabaqua and near the west boundary of mining location R 342, Conmee township.

ECONOMIC GEOLOGY

IRON ORE POSSIBILITIES

No merchantable bodies of iron ore have been found in the map-area either in the Keewatin or Windigokan (?) iron formations. Development work has been carried on intermittently during the past thirty-five years on the richer parts of the iron formations as exposed.

The Keewatin iron formation has been well exposed for widths of scores or hundreds of feet and lengths of hundreds or thousands of feet in the vicinity of Shabaqua and between Mokomon and Kaministikwia, and the belt-like distribution of great bodies can be inferred from these exposures and the magnetic variations found in the drift-covered areas between them. The iron formation is banded and has the appearance of steeply inclined and folded beds. From drillings in iron formation of similar appearance in Minnesota it is known that belts of steeply inclined iron formation extend to depths of over 1,000 feet, and it is to be inferred that in this district, also, the belts extend to considerable depth.

The Keewatin iron formation consists for the most part of magnetite-rich layers varying from a small fraction of an inch up to 2 inches wide, interbanded with equally thick or thicker layers of fine-grained silica and other materials of low iron content. The considerable variation in the iron content of large parts of the iron formation is due to the differences in thickness and closeness of spacing of the magnetite layers in certain groups of beds. Very little variation occurs in the iron content of any particular group of layers as traced along the strike. In Conmee township a number of average samples taken across outcrops representing a few hundred feet of contorted layers, show an iron content ranging from 16 to 35 per cent, with silica from 70 to 50 per cent.[1] No group of layers more than 10 feet thick shows an iron content of more than 35 per cent.

There is a local development of secondary iron oxide in iron formation on mining location R 382, but the iron content has not been materially increased, and it is not known whether secondary concentrations have or have not occurred elsewhere beneath the drift. In Vermilion district, Minnesota, concentrations of hematite ore occur on the limbs or in the troughs of the folded Soudan formation. The relatively lean, layered parts of this formation are similar in composition and geological relationships to the Keewatin iron formation of Matawin River area.

The possible commercial value of the richest known parts of the Keewatin iron formation depends on the feasibility of employing a method of beneficiation. For magnetic concentration it is desirable that there should be a large tonnage of material relatively rich in magnetite, with the magnetite clearly separated from the jasper in the individual layers, or sufficiently coarse in texture to permit of magnetic separation without extremely fine grinding. There are incidations that this combination of features exists along some part of all the wider belts. One such occurrence is on mining location R 333, Oliver township, on a hill adjacent to both the Canadian National railway and Canadian Pacific railway, and some interest has been attracted to this as a possible concentrating proposition.

The iron ore possibilities in the Windigokan (?) iron formation are, according to present knowledge, similar to those in the Keewatin, though on casual inspection in the field they appear greater. Hematite is more extensively developed in the wider part of the iron formation, as mapped, than in the narrower part of the belt. The largest known layers of slaty hematite occur on mining locations W 221 and W 222; no considerable

[1] "Iron Ore Occurrences in Canada"; Mines Branch, Dept. of Mines, Canada, vol. II, p. 61.

mass has been found to contain over 30 per cent iron, though the hematite is diffused through certain slaty beds, giving the appearance of thick layers of ore.

Referring to the Windigokan (?) iron formation on mining locations W 216 to W 222 inclusive, E. Lindeman[1] writes:

"It is evident that a large quantity of low-grade iron formation is available, all of which, however, requires fine crushing and concentration with subsequent briquetting or nodulizing before it can be made marketable. To carry on such an operation profitably at the present time (1914) does not seem feasible owing to the low iron content of the ore and the extreme fineness to which the grinding would have to be carried before a satisfactory separation could be obtained. The iron formation on the western claims W 221 and W 222 offers also another objectionable feature for magnetic separation on account of the iron-bearing mineral being present there chiefly in the form of hematite."

PYRITE

It is probable that pyrite occurs in large amount in certain belts of Keewatin iron formation, whose positions are shown on the accompanying map (No. 2069). The outcrops along these belts are, however, comparatively few and small, and in the larger exposures the pyrite appears to be very irregularly distributed. In the pyrite-bearing iron formation one commonly finds tiny seamlets and bunches of pyrite in the banded jasper and magnetite, and locally these become so abundant and closely spaced that they make up the greater part of the volume of the rock. Certain masses measurable in inches or occasionally in feet, are composed almost entirely of pyrite. The variations in the richness of the pyrite deposit and the extreme irregularity in the shape of the richer parts appear not only on a small scale but also on a large scale. In the larger exposures the concentrations of pyrite, made up of closely spaced tiny seamlets and bunches, enclose irregular-shaped masses of less pyritized iron formation; they also form tongues that extend out and merge into the less pyritized material. The opinion that pyrite is present in considerable quantity appears to be warranted by the fact that it is present in all of the exposures along certain belts of iron formation. Though the belts are poorly exposed their position has been traced by magnetic readings far beyond the outcrops.

A number of mining claims were taken up for iron pyrites on lots B, C, and D, concession V, Conmee township, and on lots 15 and 16, concession VII, Oliver township, prior to 1918. The following statement regarding the occurrences includes the information given in earlier reports of E. B. Fraleck[2] and A. H. A. Robinson,[3] and information supplied to the Geological Survey by Mr. B. L. Morrison of Port Arthur.

In the north half of lot B, concession V, Conmee township, on a mining claim owned by Mr. B. L. Morrison, Port Arthur, pyritized iron formation is exposed in the bed of Brûlé creek. Brecciated fragments of banded

[1] Mines Branch, Dept. of Mines, Canada, Sum. Rept. 1914.
[2] Ont. Bureau of Mines, Ann. Rept., vol. XVI, p. 172 (1907).
[3] Mines Branch, Dept. of Mines, Canada, Sum. Rept. 1918, pp. 2–24.

jasper and magnetite are to be seen enclosed and penetrated by seamlets of pyrite which make up somewhat more than half of the total volume of the rock in a zone about 30 feet wide and about 50 feet long, trending northeast and southwest. In 1901 a test pit was sunk by the Davis Sulphur Company of New York on the south bank of the creek, to a depth of 5 feet below the level of the creek, and about 80 tons are on the dump. An average sample of this material taken by Mr. Fraleck yielded 29·20 per cent of sulphur. Caved trenches which are to be seen within 500 feet southwest of the pit indicate that the extensive covering of bouldery gravel is here at least 6 feet deep.

Immediately south of the previously mentioned property in the same half of lot B, there are two mining claims leased by the General Chemical Company of New York. They embrace the forested upland which lies to the south of Brûlé Creek valley. A large amount of trenching, test pitting, and stripping was done on these two claims, but the caving in of earth had rendered them worthless for purposes of observation as early as 1918, when visited by Robinson. He reports: "In one stripping, pyrite with some included rock matter is exposed over a width of 70 feet. Another exposure, some distance to the northeast, consists of 25 feet of mixed gossan, leached rock capping, and pyrite. Magnetite and pyrrhotite occur locally mixed with the pyrite. Lean siliceous magnetite, very similar to some of the magnetite found in the iron formation, is also found as angular and subangular fragments enclosed in pyrite, usually toward the edge of the deposits."

Four diamond-drill holes were sunk by the General Chemical Company in 1917. Seven lenticular masses of brecciated, banded iron formation have been defined, in which pyrite has replaced a considerable part of the rock. The largest of these masses has a maximum width of 75 feet and is 800 feet long; it trends northeast and pitches toward the northwest at a high angle. The smaller masses trend in the same direction, but they are not in alignment with one another. It is reported by Mr. B. L. Morrison that development work on these claims has proved the existence, above a depth of 600 feet, of 200,000 tons of pyrite with an average sulphur content between 37 and 40 per cent.

On the north halves of lots 15 and 16, concession VII, Oliver township, on lot C, concession IV, Conmee township, and on the south half of Dawson Road lot No. 19, concession A, irregular deposits of pyrite are to be seen in small outcrops of Keewatin iron formation.

Adjoining Morrison's and the General Chemical Company's claims on the north, east, and south, there are a number of other claims on which pyrite deposits have been reported to occur. They have a multiplicity of owners. The late W. A. Matheson, barrister, of Fort William, was more or less directly interested in all of them.

Mining location R 702 takes in the southern part of lot C, concession VI, Conmee township. In 1913 or 1914, a diamond-drill hole was put down near the southwest corner of the location to test at depth the iron formation that outcrops a little to the west. Pyrite is said to have been found in this hole, but authoritative information is lacking.

On the southern part of the north half of lot C, concession V, a number of trenches have been dug through drift near the west boundary of the lot. Pyrite is said to have been found in some of them, but the trenches having fallen in, the statement could not be confirmed.

What is sometimes known as the Morton Lease constitutes the northwest quarter of the south half of lot C, concession V. Near the northwest corner of the claim there are two old prospecting shafts and, between them, a stripping 30 or 40 feet in diameter. The general trend of the workings is north and south. The south shaft is just at the edge of the stripping and is now filled with debris. The other shaft is about 50 feet north of the stripping, and higher up the hill; it is about 20 feet deep. A section across the stripping shows 2 feet of pyrrhotite; 6 feet of mixed pyrite and pyrrhotite; 15 feet of mixed pyrrhotite and rock; and 12 feet of pyrite with some intermixed silica. On the uphill side of the stripping the sulphides are overlain by about 8 feet of mixed granular quartz, leached rock capping, and impure limonite. At the bottom of the north shaft there is about 8 feet of pyrites mixed with some quartz. The upper part of the shaft is in a gossan of leached rock and limonite. The material on the dumps contains both pyrites and pyrrhotite.

On the northeast quarter of the south half of lot B, concession V, lumps of iron pyrite enclosing fragments of fine-grained magnetite were picked up alongside some caved-in trenches. In a stripping nearby, a seam of pyrite, 2 to 3 feet thick, occurs in a 12-foot band of rusty quartzose rock that lies between porphyritic greenstone and banded iron formation.

Near the middle of the south half of lot C, concession V, some shallow pits have been sunk in a zone of rusty gossan-bearing rock. The pits are now partly filled with loose earth and gossan, and no unweathered formation can be seen in them. Mingled with the rock matter on the dump, however, there is a considerable amount of fine-grained, mixed pyrite and magnetite. Crumpled, cherty, banded iron formation lies east of the rusty, pyritous rock; between the two is a curious breccia, made up of shattered iron formation cemented by magnetite and quartz.

On lot D, concession V, a triangular, fractional lot bounded on the northeast by Kaministikwia river, large boulders of clean pyrite "float" have been found in the bed of the creek that flows into the river from the southwest. Attempts to trace them to their source have been, so far, unsuccessful.

MINERALS ASSOCIATED WITH PERIDOTITE

No deposits of economic value have been reported from the area underlain by peridotite around the northeast corner of Adrian township. Pale green, silky, cross-fibre asbestos was observed by the writer in narrow seamlets on cliffs at the north end of Gold lake in Conmee township and half a mile southwest of Gold lake. Further prospecting might reveal larger occurrences of this mineral. Concentrations of chromite have been found in peridotite in other districts.

In those localities where a crystalline carbonate ramifies through the black and green peridotite an ornamental building stone of pleasing appearance could be obtained. The topography is such as readily to permit of quarrying.

The carbonate in the peridotite where tested was calcite; further exploration might be made in the hope of finding magnesite deposits. The occurrence of talc is to be expected in altered peridotite.

GOLD

No gold occurrences of economic value have been reported in the mapped area, though many mining claims have been staked for gold. At several localities the general geological relationships indicate the possibility of occurrences of this mineral, particularly where quartz veins occur in Keewatin schists near the margins of granitic intrusives. The areas adjacent to small intrusive bodies are generally considered to be more promising than the zone adjacent to large batholiths.

Numerous claims were staked for gold in Adrian township near Twist lake in 1924. Several pyrite-bearing quartz veins are exposed on these claims, but gold was not found by the writer in any of them.

A small boulder of vein quartz, rich in gold, is reported to have been found in the drift on lot 3, concession VII, O'Connor township. A specimen of gold-bearing quartz vein material in the possession of Mr. T. Fawcett is believed by him to have come from an excavation which was dug more than thirty years ago on his property in the south half of lot 13, concession IV, Oliver township.

MOLYBDENITE

Molybdenite has been found in four pegmatitic quartz veins distributed through a distance of a mile along the contact of the tongue of granitic rock which, in lots A and B, concessions II and III, Conmee township, extends north from the batholith.

The largest of these veins is on the north side of the road in the southern part of lot B, concession III, on property owned by Messrs. S. Young and Wm. Welsh of Fort William. The vein consists of fine-grained, translucent, white quartz in which occurs amorphous molybdenite in thin streaks and platy segregations lying parallel to the walls and irregularly spaced through the vein. Small amounts of disseminated chalcopyrite and pyrite are present. The country rock is a pyritiferous chlorite syenite. A part of the vein material occurs as small lenses whose contacts with the adjacent silicified rock are not sharply defined; there is also a zone about 10 feet wide in which there is an intimate intermixture of vein material and abundant, indefinitely bounded horses of country rock. The major part of this siliceous deposit is a vein 20 feet wide, with few inclusions, which trends approximately north 50 degrees east and dips 80 degrees toward the southeast. The complete width of the deposit, including the small, lenticular veins adjacent to the main vein, has not been determined and on account of drift covering its length has not been proved beyond 30 feet. A shaft measuring 4 by 8 feet has been sunk to a depth of 47 feet, entirely in vein material. A small vein of post-

Keweenawan age cuts the molybdenite-bearing vein; it consists of coarsely crystalline white quartz, amethyst, and calcite with small amounts of disseminated galena and chalcopyrite.

A sample weighing 270 pounds, said to represent the run-of-mine from this deposit, was tested at the Mines Branch, Ottawa, in 1918.[1] The material contained 1·29 per cent of molybdenite, and by crushing to 80 mesh it was found possible to recover 80 per cent of the molybdenite values by flotation.

COPPER

The copper occurrences found by the writer in amygdaloidal basalt on lot 12, concession III, Oliver township, are too small and scattered to be of commercial value. It is possible that larger concentrations may be found by prospecting.

SILVER

Numerous small veins resembling those which contain silver ore in the vicinity of Port Arthur have been observed. They consist of crystalline white quartz, amethyst, and calcite, with irregularly disseminated galena, sphalerite, chalcopyrite, pyrite, and occasionally silver and argentite. Concentrations of valuable minerals other than silver have not been found in commercial quantities in this general district, in veins of this type.

Mineralized veins, in which it is possible that silver may be found upon further examination, occur as follows: 700 feet north of the east end of Stephen lake; on mining location D 4, Oliver township; and at a point described by Mr. J. Merrifield of Kakabeka Falls as being in the bed of a creek 2 miles north-northeast of the outlet of Twist lake.

The vein on D 4 outcrops on the south bank of Kaministikwia river with a width of 4 feet, and trends south 12 degrees west. The vein cuts hornblende schists which have a foliation strike of north 80 degrees east and also pegmatite dykes; together with horses of these materials there are inclusions of small blocks of Animikie conglomerate and iron formation. The vein has been stripped for over 200 feet southerly from the shore, exposing small concentrations of galena and chalcopyrite. Beyond this point the main vein is concealed and a stockwork of smaller mineralized veins which here branch out from the main vein can be traced south 30 degrees west in discontinuous outcrops for 100 feet.

An inferred fault trends in a northeasterly direction through the drift-covered area between a quarter and a half mile north of Kakabeka falls. A small amount of argentite was observed by the writer in an irregular veinlet richly mineralized with galena in the bed of Kaministikwia river about 100 feet north of the position in which the inferred fault might occur. There is a possibility that silver ore occurs in this general locality.

CLAY

The possible economic value of the red clay which is extensively developed in the lowlands between Finmark and Mokomon has been described by the late Mr. J. Keele.[2]

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[1] Mines Branch, Dept. of Mines, Canada, Sum. Rept. 1918, p. 111.

[2] Geol. Surv., Canada, Mem. 142, p. 128.

GUNFLINT IRON-BEARING FORMATION, ONTARIO

By J. E. Gill

CONTENTS

Illustrations

INTRODUCTION

GENERAL STATEMENT

Mesabi district, Minnesota, has risen, since the discovery of ore, in 1890, to first place among the iron-producing districts of the world. It has been recognized for years that the iron-bearing beds which appear in almost continuous outcrop from Gunflint district in northeastern Minnesota to Loon lake, Ontario, though not continuous with the Biwabik formation—in which the Mesabi ore-bodies occur—are exactly equivalent to it in age, and closely resemble it in composition. In spite of this fact, no large hematite ore-bodies of the Mesabi type have been discovered in Ontario, and the production of iron ore from the Gunflint formation has been nil. The reason for this is not known. The outcrops have been gone over fairly thoroughly by prospectors, engineers, and geologists, but there are extensive areas blanketed by drift with regard to which no direct information is available. Three possibilities exist: ore-bodies may be present in these covered areas; they may have been present at one time and later removed by erosion; or conditions may have differed from those obtaining in Mesabi district during the period of concentration in such a way as to have prevented the development of ore-bodies of this type in Ontario.

No exhaustive study of the iron formation in Ontario had been made, and hence there was not sufficient basis for a comparison between the two districts. In undertaking such a study, the present writer did not expect to make any direct discoveries of secondarily concentrated hematite ores, but did hope that it would be possible to form a fair estimate of the possibilities of the occurrence of ore-bodies and to outline favourable localities. Incidentally it was thought possible that certain beds might be found with an original iron content sufficiently high to make them commercially available and that others might be readily concentrated to a marketable grade by magnetic concentration, a possibility which has recently received a great deal of attention owing to the activities of the Mesaba Iron Company, at Babbitt, Minnesota.

AREA COVERED AND MEANS OF ACCESS

The outcrop of the Gunflint iron formation extends southwestward from Loon Lake district at the head of Thunder bay, across the International Boundary at Gunflint lake, and about 8 miles beyond into Minnesota, making the total length approximately 110 miles. In the present report, attention is confined to that part of the formation lying between Gunflint lake and Silver Mountain station on the Port Arthur, Duluth, and Western railway, a length of about 50 miles. The railway is a branch line of the Canadian National system, leaving the main line at Port Arthur and following along the iron formation outcrop between the points mentioned. Originally it extended to what is commonly known as the Paulson mine, in Minnesota, but the rails have been removed beyond North Lake station and the service discontinued west of Mackies. Trains leave Port Arthur

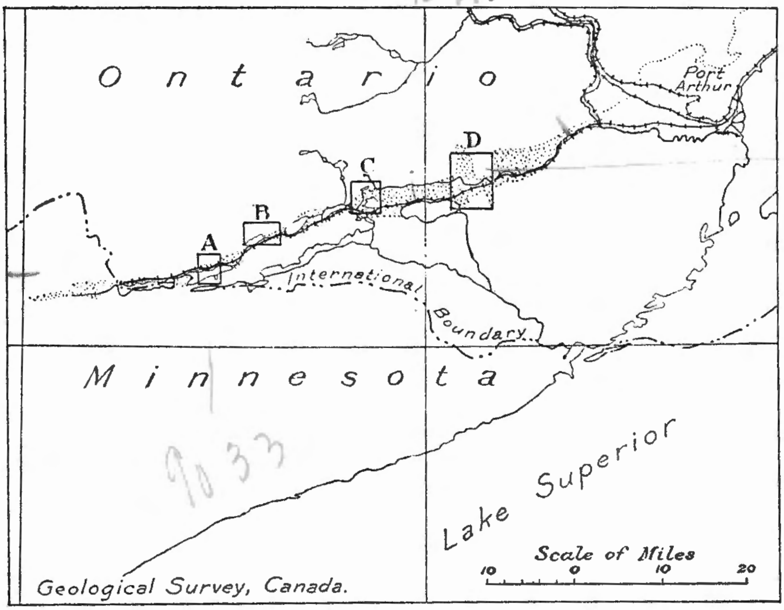

Figure 2. Index map showing position of southwestern part of the Gunflint iron formation and of the areas specially investigated. A, North Lake area; B, Bishop Lake area; C, Little Gull Lake area; D, Silver Mountain area.

daily except Thursday and Sunday. Beyond Mackies arrangements can usually be made for transportation by speeder to North Lake station. For the remainder of the district to the boundary, canoes provide the most convenient means of transportation. On the American side, a road from Grand Marais was being extended in 1924 to Gunflint lake. Access may also be had by canoe from Winton, Minnesota, about a three-day journey.

Over a large part of this area the outcrops are very scattered. No attempt was made to prepare an areal map, but the best exposed parts were selected and mapped in detail. In this way a number of partial sections of the iron formation were worked out, three of which are fairly complete. The areas between those mapped (*See* Figure 2) were traversed rapidly, with the exception of that north of Iron Range lake and that between Little Gull and Whitefish lakes. These yielded very little information, however.

ACKNOWLEDGMENTS

While in the field during the summer of 1924, the writer received helpful information and assistance from many people. Special mention is due the officials of M. A. Hanna and Company and of the Oliver Mining Company, whose willingness to assist made it possible to cover the chief points of interest in Mesabi district in the brief time available. The writer is particularly indebted to M. C. Lake, geologist for M. A. Hanna and Company, and J. F. Wolff, geologist for the Oliver Mining Company, for geological information and other assistance. To T. L. Tanton thanks are due for helpful suggestions in connexion with the field work.

Messrs. A. Bishop, T. Brown, J. McGugan, and M. L. McEwen supplied useful information regarding the local geology and mining operations.

R. W. Howe and H. S. Hicks acted very efficiently as assistants in the field.

The laboratory work necessary for the preparation of this report was carried on in the laboratories of Princeton University, where every facility was provided. Special thanks are due to Dr. C. H. Smyth, jun., whose criticism and interest in the work were invaluable to the writer, and to Dr. A. F. Buddington for help with the microscopic work and suggestions during the preparation of the report. W. A. Kelly and C. S. Evans also contributed useful suggestions.

PREVIOUS WORK

The earliest recorded observation on the iron formation in this district is that made by John J. Bigsby, who, in a report published in 1824, mentioned the presence on the north shore of Gunflint lake of jasper described as "red, with rusty brown spots". J. G. Norwood, during the course of a rapid trip along the International Boundary in 1852, made a few observations on the geology of the region in the vicinity of Gunflint (Flint) and North (Mountain) lakes. Robert Bell on a similar trip along the boundary in 1872, noted the similarity between certain brecciated beds on the north shore of Gunflint lake and those "of the same formation" exposed at the head of Thunder bay. Both N. H. and Alexander Winchell include descriptive details in their reports on exploration along the International Boundary; that by A. Winchell published in 1887 is particularly interesting and complete in detail for such an early report. In the same year, E. D. Ingall mapped the surface geology and topography of the country in the vicinity of Silver mountain and wrote the most detailed report on any part of the district published up to the time when the present work was undertaken.

In 1898, U. S. Grant described in some detail the geology of the region around and to the west of Gunflint lake, embracing the part of the Gunflint formation which lies in Minnesota. J. Morgan Clements in 1903 and T. M. Broderick in 1920 contributed further information regarding the same area. Broderick was the first to attempt correlation in detail between the Gunflint and Biwabik formations. He found that the chief horizon-markers used by geologists in Mesabi district are also present in Gunflint area and that the fourfold division used in Mesabi district is equally applicable to the Gunflint formation. The equivalence of these two formations had been previously established by Grant and Van Hise and Leith on more general grounds.

G. M. Dawson, W. McInnes, and J. D. Trueman with the Geological Survey, Canada, and W. N. Smith, L. P. Silver, and N. L. Bowen with the Ontario Bureau of Mines, have dealt with various problems in the district, but no detailed investigation of the iron formation was undertaken by any of these writers. N. L. Bowen extended the mapping commenced by Ingall in Silver Mountain area. More recently T. L. Tanton made a brief examination of the McGugan-Dowler property, near Gravel lake.

No serious attempts at mining iron ore have been made in the region examined by the writer, but in Gunflint district the presence of beds unusually rich in magnetite, attracted considerable attention as early as 1892. Several unsuccessful enterprises have centred about those in sections 28 and 29, townships 65-4, Minnesota. The Port Arthur, Duluth, and Western railway was completed to that place in 1892, but no ore was shipped. Small secondary concentrations of hematite are known to occur in Loon Lake district, but so far no mining has been carried on.

In Silver Mountain area, silver mining was carried on successfully for a number of years. The reports by Ingall and Bowen, mentioned above, deal primarily with the silver deposits of the region.

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GENERAL CHARACTER OF THE DISTRICT

The basal contact of the iron formation is the dividing line between two distinct topographic provinces. To the north the region is underlain by massive crystalline rocks; to the south, the other province is underlain by sedimentary rocks and intrusive sills. The difference in the topographic manifestation of these two types of bedrock is very striking.

The general aspect of the region underlain by rocks predominantly massive and crystalline is typical of a large part of the vast expanse of country surrounding Hudson bay and commonly known as the Canadian Shield, or Northern Protaxis. It is characterized by low, rounded hills, uniformly low relief, and imperfect drainage, resulting in the formation of a great many lakes. The remarkable uniformity of the sky-line has been emphasized by many writers and it is generally agreed that it has resulted from partial dissection of a land-mass reduced by erosion almost to base-level and subsequently uplifted with respect to the sea.

A prominent ridge of granitic rocks running parallel to the strike of the sediments and flanked by them on the south side, is the equivalent of the Giant's range in Minnesota. The drift is everywhere thin and in many places is almost absent. Areas with even a thin mantle of drift formerly supported a fairly heavy growth of timber, but in recent years this has been removed almost completely by fire. In the swampy areas a few green trees remain, usually accompanied by a host of standing dead ones and windfalls. Most of the remainder is at least partly covered by a growth of young poplars. Alders are common in the swampy depressions.

In the area to the southeast, underlain by sedimentary rocks, control of topography by the underlying rock structures and the varying hardness of beds is the characteristic feature. Diabase sills, which appear at intervals following the bedding planes of the sediments, and the more siliceous beds of the iron formation stand out in relief. The sediments, and consequently the sills, dip uniformly toward the southeast at an angle of about 5 degrees, so that the ultimate result of this differential erosion is a step-like series of parallel ridges with cliffs and long talus slopes facing northwest and gentle dip slopes toward the southeast. The valleys between successive ridges are occupied by a succession of lakes with short, connecting streams, a modification of normal drainage directly attributable to Pleistocene glaciation.

Various views regarding the origin of these hills have been summarized by Martin[1]. The chief bone of contention has been whether faulting has played a significant part in their formation. At several places in the area covered by this report there is undoubted evidence of faulting parallel to longitudinal valleys. Along the south shore of Arrow lake, for instance, strike faults with small throws were observed and suggest the possibility of the presence of a major fault along the valley occupied by the lake. At other places it is equally certain that faulting has played no part in the formation of these ridges, as has been pointed out by Grant[2]. This is obviously true of such hills as those in which the iron formation is exposed to the north of North lake, where the geological relations are not obscured by lakes and there is absolutely no evidence of faulting parallel to the trend of the hills. It seems, therefore, that though faulting has undoubtedly aided in the formation of some of the monoclinal ridges, differential erosion alone is capable of producing them and is an adequate explanation in the absence of good evidence for faulting.

In a few places erosion has cut through a sill, leaving one or more outlying parts. These now appear capping buttes which stand out prominently above the surrounding country because of the great rapidity with which the softer sediments underlying them are eroded once the protective covering is removed.

Pleistocene deposits are more abundant in this part of the district than in that underlain by granitic rocks and consequently it is more heavily wooded, but here, too, wide stretches of forest have been destroyed by fire. The principal varieties of trees represented are spruce, balsam, tamarack, red, white, and jack-pine, birch, and poplar. Spruces are by far the most numerous in the older forests. Areas recently burned over are usually covered by a thick second growth of young poplars and birches. Small cedars are locally quite numerous. White pine are rare, most of them having been removed from the areas near the railway. A number were observed around the western end of Arrow lake and around Rose lake. A thick growth of alders is the usual thing in the moist depressions.

There is evidence that at least twice in the history of the region erosion has reduced it to a state of low relief. At a number of places along the range, the old floor upon which the iron formation was deposited is exposed over considerable areas with but little modification by erosion, as is shown by the presence of remnants of the basal conglomerate or larger outliers of the iron formation. In such areas the maximum relief observed was about 50 feet, which seems to warrant the conclusion that, preceding the deposition of the Animikie sediments, a region probably mountainous had been deeply eroded and reduced almost to base-level. With the exception of a few remnants, the older formations intruded by the batholithic rocks were completely removed, exposing the massive plutonics.

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[1]Martin, L.: Mon. U.S. Geol. Surv., vol. 52, pp. 98-99 (1911).
[2]Grant, U.S.: Final Rept., Geol. and Nat. Hist. Surv. of Minn., vol. 4, p. 485 (1899).

The general accord between the level of the granite plateau to the north and the parallel, sill-capped ridges to the south suggests post-Keweenawan peneplanation. That erosion has been profound since the close of the Keweenawan period is shown by the coarseness of grain of some of the sills which, therefore, certainly cooled under a thick cover of sediments since removed. Again, if the sediments were produced northwestward, and their present dip maintained, they would extend far above the present surface on passing the crest of the range of granitic hills. Outliers of the iron formation appear at several points near the summit of this prominence and show no evidence of rapid thinning, so that it seems certain that the old shore-line lay at a considerable distance northwest. The only adequate explanation for the physiographic relations seems to be that following the intrusion of the sills and tilting of the sediments, erosion cut deeply into the land-mass, reducing it to a condition of low relief. In the summits of the present hills this peneplain has been preserved with only slight modification through the succeeding cycles of normal erosion and glaciation.

The general level of the granitic upland areas near the outcrop of the iron formation is 1,700 to 1,800 feet above sea-level. The granite ridge, flanked on the southeast by the iron formation, in most places rises to altitudes of from 1,900 to 2,000 feet. The local relief in the areas examined was nowhere more than 300 feet and probably averages between 100 and 200 feet.

In the sedimentary areas the relief ranges between 300 and 500 feet and is usually about 400 feet along the valley which follows the iron formation outcrop. The maximum elevations are attained at the divide between Iron Range and Bishop lakes. At this point, the summits to the south reach 2,100 feet, and the lowest point on the watershed stands at about 1,800 feet. To the east and west of this point there is a gradual downward slope to 1,282 feet at Silver Mountain station and about 1,540 feet at Gunflint lake.

Drainage of the area is effected by two great river systems. The height of land separating the rivers draining into the Great Lakes and those draining into Hudson bay, passes between Iron Range and Bishop lakes, follows along the ridge to the south of the iron formation outcrop, passes between North and South lakes, and thence into the United States.

The present drainage patterns show almost perfect adjustment to the underlying rock structures, though the stream gradients have been greatly altered by the deposition of drift and abrasion of the rock floors by the Pleistocene ice-sheets. In the areas of massive crystalline rocks the events of Pleistocene time have given rise to a multitude of lakes, most of which occupy basins scoured in the solid rock. Damming by drift has been only local and temporary, and lakes formed in this way are comparatively few. In the sedimentary rocks, the main effect has been to produce a modification of the contours of the stream valleys by irregular scour and by drift deposition in such a way as to produce a series of elongated lakes connected by short, sluggish streams in what was formerly a well-graded valley. East of Whitefish lake a different condition has resulted from the formation of lake deposits during the retreat of the ice-sheet at the close of Pleistocene time. These deposits formed in a lake dammed back by the retreating ice front against the higher land to the west. As the lake waters subsided, Whitefish river flowed outward across the gently dipping clays, sands, and gravels and incised a new channel through them. At present the river is again flowing over bedrock at a number of points. At such places it is out of adjustment with the older topography and falls or rapids are common.

Large, transverse valleys are rare and in all cases observed their original development was probably controlled by the presence of faults. Good examples are: that now occupied by Sack bay; the gaps to the south and northwest of the west end of Sand lake; and the valley through which Sand river flows to Round lake and thence to Arrow lake. All of these have been considerably modified by glaciation.

Numerous, small streams flow down the gentle southward slopes to the rivers and lakes occupying the main longitudinal valleys. These ordinarily flow over the basic igneous rocks of the sills, are in many cases clogged by drift, and in general have done very little cutting since the Pleistocene.

In the area under discussion, the writer was able to distinguish records of only one episode of glacial advance and retreat, the evidence of earlier ones having been completely obliterated or rendered obscure by the final advance. Glacial striation and grooving were observed in all parts of the district. In the western part the directions of these were consistently within 10 degrees of south. In Silver Mountain area, however, the average of the writer's observations is south 70 degrees west and this average checks approximately with observations made by E. D. Ingall[1] and N. L. Bowen.[2] The conspicuous difference in the direction of movement of the ice in the eastern and western parts of the district is in agreement with generalizations made from information obtained in other parts of Lake Superior region.[3] The western part was covered by the Rainy Lake lobe of the sheet spreading from the Keewatin centre, and over the eastern part, the Superior lobe of the sheet from the Labrador centre was dominant. The two lobes must have coalesced somewhere in the vicinity of Whitefish lake, where a considerable range in the direction of the striations is observable, though those approaching south 70 degrees west dominate. One set of striations on the top of Silver mountain trends south 10 degrees west; Bowen records a few with directions from south 38 to 44 degrees west. Ingall's observations range from south 60 degrees west to north 70 degrees west.

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[2]Bowen, N. L.: Ont. Bureau of Mines, Ann. Rept., vol. XX, p. 127 (1911).
[3]Mon. U.S. Geol. Surv., vol. 52, pp. 427–428 (1911).

GENERAL GEOLOGICAL RELATIONS OF THE IRON FORMATION

STRATIGRAPHY

The rocks encountered in the areas examined in detail are classified as follows:

Table of Formations

Quaternary	Recent	Alluvium
	Pleistocene	Clays, sands, and gravels
Precambrian	*Great unconformity*	
	Keweenawan	Diabase sills and dykes
	Intrusive contact	
	Animikie	Rove slate Gunflint formation and lava
	Great unconformity	
		Batholithic rocks, mostly granite
	Intrusive contact	
		Hornblendite

PRE-ANIMIKIE ROCKS

Pre-Batholithic Rocks

No extensive areas of these rocks are present within the region dealt with. They appear as scattered fragments or larger remnants never more than a few hundred yards across, included within the intrusive granitic rocks. Massive hornblendite is by far the most common rock appearing in this relationship. Ordinarily it is unfoliated or only slightly foliated and from medium to coarse grained. A number of remnants of considerable size appear along the crest of the upland north of North lake, and small, angular fragments are very abundant as far east as Bishop lake. Farther east they are less conspicuous and in fact inclusions of any kind are rare or entirely absent. The only other rock type observed as inclusions within the granite is a finely banded granitic gneiss. A small remnant of this rock occurs just east of Shekaka creek in North Lake area, where it can be clearly seen to be older than the main mass of granitic gneiss. The latter is much coarser grained and many dykes and stringers of it cut across the finer-grained rock. It is possible that this inclusion represents an early stage of intrusion in the same general period of igneous activity to which the granite belongs. It may even have been a chilled marginal phase of the main granite magma which, after solidification, was fractured and intruded by the still fluid part.

Batholithic Rocks

With the exception of the inclusions described above, the basement upon which the Animikie rocks rest is composed entirely of granitic rocks remarkably uniform in composition and showing locally a more or less pronounced gneissic banding. The average rock type is a medium-grained hornblende-biotite granite. Variations occur, but they are seldom very pronounced or persistent. By increase in the proportion of plagioclase and decrease in the amount of quartz, the rock locally approaches monzonite or even diorite in composition. Either biotite or hornblende may preponderate locally amongst the ferromagnesian minerals and the biotite-rich varieties usually show the most conspicuous banding.

ANIMIKIE SERIES

Gunflint Formation

The Gunflint formation rests directly on the basement of granitic rocks. It varies in thickness from about 300 to 700 feet, and consists dominantly of cherty rocks carrying a variable amount of iron as silicates, oxides, or carbonates. At the base, there is a thin conglomerate made up of materials derived from the underlying rocks. The formation is described in detail on later pages.

Lava

A small basaltic lava flow appears within the iron formation in the eastern part of Little Gull Lake area.

Rove Slate

The slates are very uniform in appearance. Outcrops are fairly continuous throughout and in general the attitude of the slates agrees with that of the iron formation beneath, though in the western part there is an apparent unconformity between them and the brecciated and folded upper beds of the iron formation. They are not true slates, but in many places have a slaty cleavage parallel to the bedding. They are pale grey, greenish grey, or black. The darker varieties are nearly always carbonaceous. They are finely fissile in places, but beds from one-quarter to one-half inch thick are more common. Locally, thicker beds resembling argillites appear. They are always very fine in grain and thin sections reveal very little regarding their composition. Some of them were found to contain small amounts of chert and disseminated iron oxides. A greenish, chloritic substance is present in some cases. One slide is almost entirely black and opaque. A few thin beds of limestone are present locally.

The intrusion of the sills has had but little effect on these rocks. In one case a number of microscopic crystals of chiastolite have been developed, and in another a small amount of a fibrous amphibole was observed. Calcareous beds show recrystallization and the development of metamorphic minerals, such as garnets. Megascopically the changes are seldom noticeable.

KEWEENAWAN SERIES

Only igneous rocks of this age appear within the district. They are in the form of dykes and sills, cutting, or lying conformable with the older rocks. Sills up to 300 feet thick appear within the iron formation and the overlying Rove slate. The smaller ones, from 10 to 50 feet thick, are very numerous and usually quite local in extent. The thicker ones in many cases extend over large areas and have played a prominent part in the development of the topography. In western parts of the district there are as many as four of these sills within the iron formation and the alteration of the sediments caused by them is in places very pronounced. In the eastern part of the district, there is rarely more than one and locally they may be entirely absent below the Rove slate.

Outcrops of these rocks are grey or greenish grey and they ordinarily have a columnar or blocky structure due to jointing. This, with their common occurrence capping the hills, makes them readily recognizable at long distances. In composition they are remarkably uniform. The important constituents are plagioclase, augite, magnetite, ilmenitic magnetite, and ilmenite. The rocks exhibit the usual gradation from fine to medium or coarse grain going from the walls toward the centre. The fine-grained marginal phases usually consist of a swarm of microscopic crystals of the above minerals in a groundmass showing aggregate polarization. The central parts of the sills are holocrystalline and either even grained or porphyritic. Large phenocrysts of waxy plagioclase are quite common and locally segregations of plagioclase crystals have formed, giving a rock approaching anorthosite in composition. These segregations are seldom more than a few feet across. In places the oxides, particularly magnetite, are very abundant and may form as much as 5 per cent of the rock. Most of the rocks are typical gabbros or gabbro porphyrites. They have been commonly referred to as diabase sills and the prevalence of the ophitic texture justifies the use of this as a general designation.

Dykes are rarely observed within the sediments, but several were found cutting the granite north of the iron formation outcrop. They resemble the sills closely in composition and appearance and are probably of the same age. Within the sediments, offshoots from sills were observed to cut across the bedding at a few places and at others the main mass of a sill was seen to have broken across the bedding in passing to a higher or lower level. In general, however, such irregularities are scarce.

PLEISTOCENE SERIES

Sedimentary deposits connected with Pleistocene glaciation are present in all parts of the area. The summits and upper slopes of the hills are usually partly covered by a thin veneer of unsorted drift or till, which is very irregularly distributed. The lower slopes and valley bottoms are, in most cases, completely covered by till, fluvioglacial and lake deposits, with some recent alluvium. Here, too, the distribution is very irregular. In the broad, longitudinal valleys, areas of dominant deposition alternate with others in which intense scouring by the ice-sheet with its load of debris excavated basins of considerable depth. The latter are now occupied by lakes.

West of the height of land, stratified deposits are inconspicuous. A sandy beach at the east end of Gunflint lake and a similar one with fairly well-sorted, though coarser material, along the south shore of North lake, near the entrance to Sack bay, are the only representatives of such deposits observed by the writer. East of the height of land, and west of Whitefish lake, small areas of stratified sands and gravels are quite numerous. They apparently formed in transient lakes and stream beds following the final retreat of the ice. Several small ponds still exist in depressions on the surface of the drift in the Whitefish River valley. In the vicinity of Whitefish lake and eastward, stratified, well-sorted clays, sands, and gravels are quite prominent. These deposits near Whitefish lake reach an elevation of about 1,350 feet and their broad, flat surface, modified only slightly by modern erosion, gradually decreases in elevation toward the east. At Hillside station it stands at 1,180 feet and Whitefish river has cut a deep channel through the deposits, exposing sections 60 feet or more thick at one or two places. These sediments obviously have formed in a lake, which probably existed during the early stages of the retreat of the Lake Superior lobe of the Labrador ice-sheet. The upper beds are arenaceous clays of pale grey colour, containing, here and there, a few pebbles. The lower beds, exposed along the river, are more sandy and locally include beds of gravel, marking the locations of former stream channels.

STRUCTURAL RELATIONS OF THE IRON FORMATION

Except where locally disturbed by faulting or igneous intrusions, the iron formation has a uniform dip to the southeast, which never exceeds 10 degrees and averages about 5 degrees. It lies on an eroded granitic land surface of low relief and is succeeded conformably by the Rove slates, except where local disturbance of the upper beds has produced an apparent unconformity. Faulting and irregularities in the floor have caused local variations in the strike of the beds, but in general they strike approximately north 60 degrees east.

Local folding and brecciation have occurred in the uppermost beds of the formation from Gunflint district eastward to a point beyond Little Gull lake. Farther east, in Silver Mountain area, the strata are undisturbed and are conformably overlain by the Rove slates. In Mink mountain, south of Little Gull lake, 30 feet of undisturbed slate appears between the diabase sill which caps the hill and the disturbed upper beds of the iron formation. The intensity of the disturbance decreases downward and finally dies out at about 150 feet below the slates. The upper strata, which formerly consisted of interlaminated, cherty and calcareous beds, show a great many local flexures, giving dips up to 45 degrees or slightly more, but no closed or overturned folds. The most striking feature is the great number of angular chert fragments, evidently parts of what were formerly continuous cherty beds. The calcareous beds have flowed about these fragments and locally show minor contortions and crenulations which may resemble drag-folds. The lower beds show only minor flexures or, in the case of massive cherty beds, have been fractured and buckled slightly.

Clements[1] has suggested that in Gunflint district these disturbances are due to the intrusion of the sill above. This explanation seems to be disproved by the fact that 30 feet of undisturbed slate underlies the sill and rests with apparent local unconformity on the folded beds beneath. The actual contact was not observed, but the slates appear at one point with the normal dip of 5 degrees, and at the same elevation and about 150 feet distant, the upper beds of the iron formation have a dip of 43 degrees. It is hardly conceivable that this 30 feet of slate would have remained undisturbed if the folding of the underlying beds were due to drag by a mass of magma being intruded above them.

Broderick[2] thinks the disturbance is due to drag-folding of incompetent beds during the gentle folding which has affected the iron formation in Gunflint district. This explanation certainly does not apply to the Mink Mountain occurrence, for nothing more than a very gentle warping of the formation as a whole has taken place.

The only other explanation which seems possible is that violent volcanic disturbances occurred nearby toward the end of the iron formation period and before the deposition of the Rove slates. The cherty beds were sufficiently hard and brittle to yield by fracturing, whereas the calcareous beds, probably only partly consolidated, yielded by flowing about the fragments so produced. Contact metamorphism has since altered the calcareous beds to amphibolites.

Except for the local disturbances mentioned above, the only pronounced rearrangement of the beds of the iron formation has been caused by faulting. Normal gravity faults are found in all parts of the area. Usually the movements have been small. The maximum throw observed, 300 feet, occurred along the north-south fault followed by Shekaka creek (North Lake area). In general the faults may be grouped into two systems trending approximately north-south and east-west, respectively. The dips in all cases are nearly vertical.

It is generally assumed that the mineral veins of the region were formed in late Keweenawan time, during the later stages of the general period of igneous activity of which the Logan sills are but one manifestation. Since nearly all the fault fissures are sealed by quartz-calcite or quartz-calcite-barite-fluorite veins in some cases carrying appreciable amounts of metallic minerals, and since many of them have dislocated the sills, it follows that most of the faulting occurred in late Keweenawan time

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[1]Clements, J. Morgan: Mon. U.S. Geol. Surv., vol. XLV, p. 377 (1903).

[2]Broderick, T. M.: Econ. Geol., vol. 15, pp. 437–438 (1920).

between the period of sill intrusion and that of vein formation. Only one minor fault could be definitely dated as later than Keweenawan. This occurs at the northwest end of the downfaulted block of iron formation preserved in the northwestern part of Bishop Lake area, where a smooth, ice-scoured granite surface can be seen to be offset about 10 feet by it.

DETAILED DESCRIPTION OF THE GUNFLINT IRON FORMATION

DEFINITIONS OF DESCRIPTIVE TERMS

Some of the terms used in the following descriptions have been used in different senses by different writers and it is, therefore, necessary to define the meanings attached to them here.

Granule is used to refer to the small particles, spherical, spheroidal, or more irregular in form and averaging a little less than 1 mm. in diameter, which are clearly discernible in most of the rocks of the iron formation. As used it does not imply any definite internal structure.

Taconite has been used in various senses by geologists who have described the iron formation[1] of Mesabi district. In the present report it is used to refer to rocks with a granule texture and is used with qualifying descriptive terms which always refer to the composition of the granules. Thus " greenalite taconite " is a rock composed of granules in which greenalite is the most important constituent other than chalcedony, which is present in practically all cases. Unless otherwise specified, the groundmass is microgranular or spherulitic chalcedony.

Oolite and pisolite are used to refer to a few of the beds which are made up of granules with a concentric structure. The groundmass is identical with that of normal taconite. The individual granules are called spherites.[2]

Chert as used here includes all forms of microgranular, spherulitic, or amorphous silica. It is also used more rarely to refer to more coarsely crystallized masses of interlocking quartz crystals, but in such cases the coarser texture is always specified in the descriptions.

Slate. True slate is not present in the areas examined. In Mesabi district the term is used to refer to any dense, fine-grained, thin-bedded rock and it will be so used in this report.

MINERALS FOUND IN THE GUNFLINT FORMATION

Chalcedony. This mineral is by far the most abundant in the iron formation. It usually forms all but a small proportion of the groundmass, and a variable proportion of the granules in taconite, and it is in many

[1] *See*—
Winchell, H. V.: "The Mesabi Range"; Geol. and Nat. Hist. Surv. of Minn., Ann. Rept., vol. XX (1893).
Leith, C. K.: Mon. U.S. Geol. Surv., vol. XLIII, p. 101 (1903).
Grout, F. F., and Broderick, T. M.: Minn. Geol. Surv., Bull. 17, p. 14 (1919).
Gruner, J. W.: Minn. Geol. Surv., Bull. 19, p. 10 (1924).

[2] cf. Bucher, W. H.: Jour. of Geol., vol. 26, p. 593 (1918).

cases quite prominent as a constituent of the more " slaty " beds. Certain beds, and lenses within beds, are almost pure chalcedony. In addition it is commonly observed filling veinlets. By recrystallization it changes to coarser-grained aggregates of quartz crystals. This change has taken place in many of the beds. The red variety, coloured by extremely fine, dispersed particles of hematite, is called jasper.

Vein Quartz. Vein quartz forms most of the pebbles of the basal conglomerate and is common as a gangue mineral in the veins which cut the iron formation.

Greenalite. Greenalite is the name given by Leith to the pale green, amorphous, ferrous silicate, in many cases containing small amounts of magnesia, which is commonly observed forming part of the granules of greenalite taconite and imparting the green colour to that rock. It is regarded by many geologists as the original mineral from which most of the iron oxides and some of the chert of the formation have been derived.

Magnetite. Magnetite is the most abundant iron oxide, though hematite is almost equally abundant in the areas examined. The two oxides commonly occur intergrown with one another and the hematite would in many cases escape detection if appearance in hand specimens or the ordinary test of magnetism were relied upon to distinguish them. Thin beds of nearly pure magnetite occur locally. In taconite it is found in variable amounts forming part of the granules, but rarely appears in the groundmass except in metamorphic phases of the beds. It occurs in many cases as pseudomorphs after hematite.

Hematite. Hematite appears in the granules of hematite taconite, as microscopic particles distributed through chalcedony or more rarely forming almost the entire granule. In such instances it is regarded as an original constituent of the beds. The abundance of magnetite pseudomorphs after hematite makes it clear that a considerable proportion of the iron in magnetite was formerly present as hematite.

Hydrated Iron Oxides. Yellow and red, pulverulent hydrated iron oxides are common as products of weathering. *Goethite* in many cases appears as a secondary mineral filling veinlets.

Carbonates. Primary carbonates, abundant in certain beds, include $CaCO_3$, $MgCO_3$, and $FeCO_3$. Of these, calcium carbonate and ferrous carbonate are much the most abundant and in most cases the minerals consist of these two molecules in isomorphous mixture in variable proportions, with occasionally a small amount of magnesium carbonate. Pure siderite and almost pure calcite were observed as primary constituents of some beds, but they are comparatively rare. Practically all the carbonates will give a test of iron. In colour they vary from white, through grey and reddish brown to brown. Secondary calcite is quite common, occurring in veins and stringers at many places. It was also observed replacing parts of the granules and groundmass of certain beds.

Amphiboles. Amphiboles are very abundant as products of metamorphism. They commonly occur as microscopic needles, many of which lie in granules and were probably formed from greenalite, though in many cases carbonates, chert, and iron oxides contributed to their formation. Colours vary from yellow and pale green to dark green or brown and probably indicate a considerable range of composition. The most common variety is pleochroic in thin sections, varying from pale yellowish green to bluish green in colour, and in many cases forms radiated groups of fibrous crystals. The general appearance and optical properties agree most closely with those of iron-rich actinolite. Some of the darker varieties are probably grünerite.

Pyroxenes. Augite was observed in a few sections as a metamorphic mineral associated with amphiboles.

Epidote. Epidote in well-formed crystals several millimetres in length was observed as an alteration product associated with amphiboles in two slides.

Chlorite. Chlorite is present in the matrix of the basal conglomerate and as an alteration product of the ferromagnesian minerals in the crystalline rock pebbles. It is also present as an alteration product in some of the slaty and tuffaceous rocks.

Mica. A few flakes may in some cases be observed in the "slaty" beds. They are probably pyroclastic in origin in most cases.

Feldspars. Orthoclase appears as a constituent of the basal conglomerate and in some of the pyroclastic material of the tuffaceous beds. Plagioclase forms part of the pebbles of crystalline rocks in the basal conglomerate.

Pyrite. Pyrite in small amounts is widely distributed, especially in greenalite taconite and some "slaty" beds. In some cases it has clearly replaced iron oxides and in others, greenalite.

Manganese Oxides. Black oxides of manganese were observed at only two places and in these instances they were present in only very small amounts.

Carbonaceous Matter. Carbonaceous matter was detected in some of the slaty rocks by heating them to redness. It is also quite abundant in some of the dark-coloured beds of the Rove slate which overlie the iron formation.

Anthraxolite. Anthraxolite was observed in one of the cherty carbonate beds toward the top of the Upper Slaty division (5) and in the algal layer at one point.

GENERALIZED SECTION

Division 5 (Upper Slaty)	Feet
Ferruginous limestone and dolomite with interbedded magnetitic and amphibolitic cherty taconite	30–120
Massive thick beds of greenalite and cherty taconite with magnetitic and carbonate-rich partings	10–150
Thin siderite-greenalite and magnetite-rich beds with fissile, ferruginous, in some cases tuffaceous, partings; lenticular beds of nearly pure chert, and a few of greenalite taconite. All show more or less alteration to amphibolitic and magnetitic types near sill contacts	50– 80
Tuffaceous taconite	1½– 2
Hematite-magnetite taconite, with ferruginous, slaty, in part tuffaceous, interbeds	20– 60
Conglomeratic hematite and cherty taconite	4– 5

Division 4 (Upper Cherty)	
Chert with algal structures	5– 10
Cherty taconite, in part oolitic, associated with algal chert and intraformational conglomerate	5– 10
Massive cherty taconite, locally magnetitic, with jasper seams and locally intraformational conglomerate	2– 20
Division 3 (Upper Cherty and part of Lower Slaty)	
Magnetitic greenalite and cherty taconite	30– 50
Magnetitic chert with magnetite nodules and interbeds of greenalite taconite; grading horizontally into greenalite taconite with carbonate nodules and cherty-carbonate beds	70–120
Greenalite taconite with small carbonate nodules locally; siderite-greenalite slate; cherty taconite at the bottom	50– 75
Division 2 (Intermediate Slate)	
Ferruginous slate including some fragmental, probably pyroclastic material, and locally carbonaceous matter	8– 15
Division 1 (Lower Cherty)	
Cherty and (or) greenalite taconite with variable amounts of carbonates	5– 15
Chert with algal structures and small amounts of cherty taconite, in part oolitic	5– 10
Basal conglomerate	0– 2

DIVISION 1 (LOWER CHERTY)

North Lake Area[1]

No complete section of this division is exposed in North Lake area where, except for one exposure at the extreme west end of North lake, only the lowermost members outcrop. The best exposures are mere remnants, at most a few square feet in area, which appear on the granitic surface at the head of Bridge bay. A few fragments of red chert showing faint, wavy banding were found along the foot of the hill just east of Bridge bay. These are probably from the upper beds of the division, but no outcrops were observed. This lack of exposure is due to the presence of talus from the cliffs above and some glacial drift covering the lower slopes. The " Intermediate Slate " (Division 2) which overlies the beds of this division is exposed at a number of places and hence the thickness can be determined approximately. It certainly does not exceed 17 feet and is probably about 15 feet.

Remnants of the basal conglomerate up to 2 feet thick were observed. The thickest of these occupy what were evidently depressions in the floor of the Animikie sea. Pebbles vary in diameter from a fraction of an inch to 8 inches. By far the greatest number are milky quartz, in some cases with associated orthoclase. The others—with the exception of a few of chert, the origin of which is doubtful—are partly rounded fragments of the rocks composing the surface upon which the conglomerate was deposited. The rock types represented are granite, syenite, diorite, hornblendite, andesite, and chert. The pebbles are set in a matrix of finer rock fragments and quartz particles with much chloritic material, probably developed from the ferromagnesian minerals of the underlying rocks, and a few mica flakes. This obviously sedimentary accumulation grades downward, through material with the same general appearance as the chloritic cement of the conglomerate with only a few quartz particles distributed through it, to unaltered granite, in such a way that it is in many cases impossible to be sure just where the sediment ends and the granite commences.

[1] *See* Figure 3.

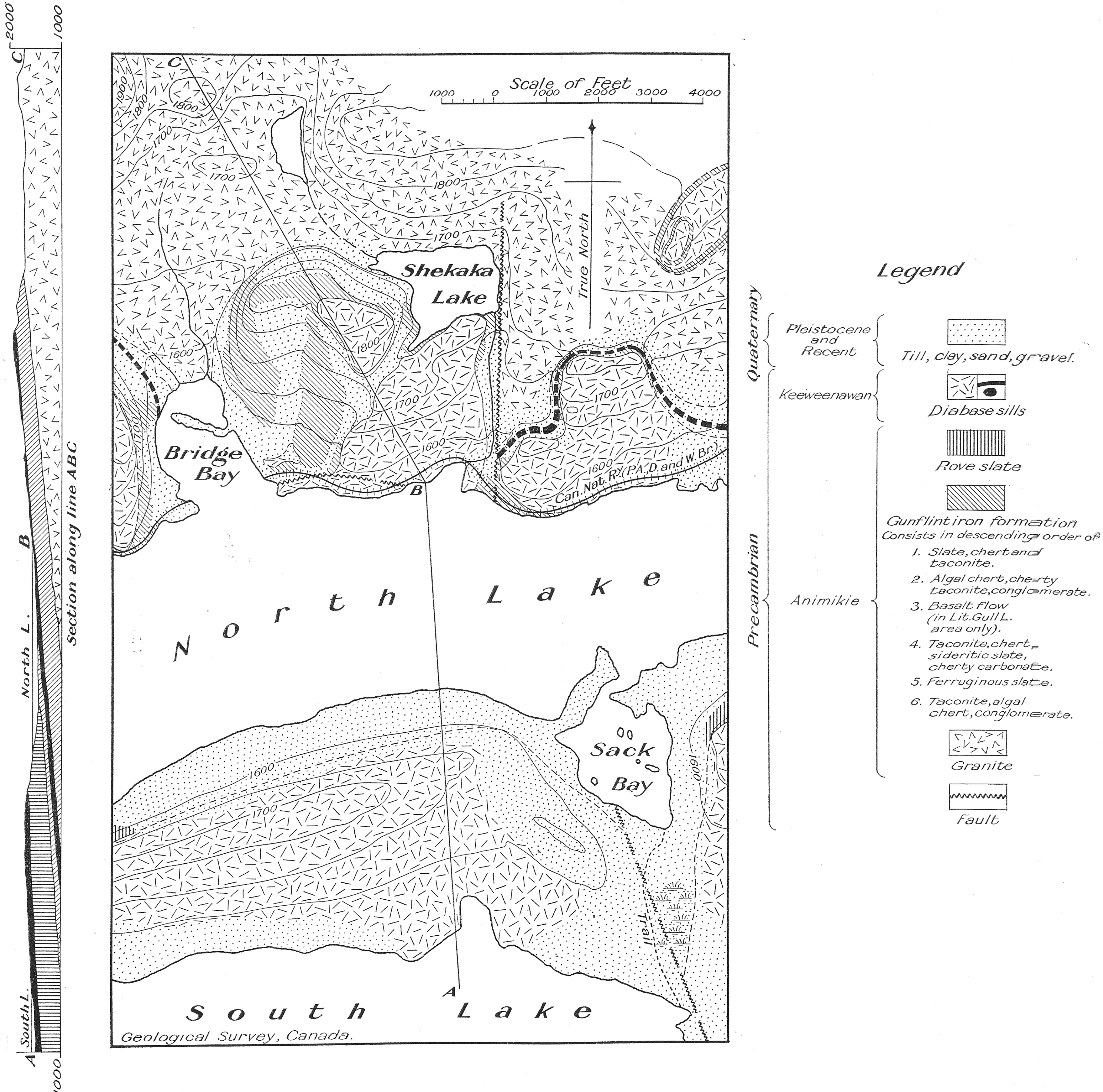

Figure 3. North Lake area, Thunder Bay district, Ontario.

The pebbles show typical water-worn forms, but rounding is usually very imperfect. There has been little or no sorting, for individual outcrops show all gradations from large pebbles to the very finest particles, without any marked stratification. From the poorly-sorted nature of the material, the lack of rounding of the pebbles, and the fact that they have all been derived from the rocks immediately below the conglomerate, it is clear that no great transportation intervened between erosion and deposition. Again, from the great preponderance of the resistant quartz pebbles, the abundance of finer materials of granite decomposition in the cement, and the observed gradation from the conglomerate matrix to altered granite, it is concluded that this sediment has resulted from reworking of a residual soil on the pre-Animikie land surface, by the advancing Animikie sea.

Associated with the basal conglomerate are many patches of chert, grey, blue-grey, grey-white, or yellow. From observations in the other areas examined, it is clear that these patches are remnants of a formerly continuous bed overlying the conglomerate. No finer clastic sediment intervenes. Locally the conglomerate is entirely absent and the chert is in contact with the altered granite. In one case chert was observed to enclose the upper layer of pebbles of the conglomerate.

On fresh fracture, the chert appears as a blue, extremely fine-grained, flinty, structureless mass. Weathered surfaces, however, show a distinct but very fine, wavy banding, with no clearly defined system. Occasionally the lining appears as closed curves in horizontal section. These structures resemble the algal structures found in great abundance at the top of the Upper Cherty division (Division 4). Granules may in many cases be observed. A thin section of the granule-bearing chert shows it to consist almost wholly of chalcedonic silica of variable texture. Granules are defined in transmitted light by a pale green pigment and consist of uniform, granular, or partly granular and partly spherulitic, chalcedony. The groundmass consists of a coarser-grained mosaic of quartz crystals up to 1 mm. diameter. A small amount of siderite is present, almost entirely confined to the groundmass. A few rhombs were observed to penetrate the outer margins of granules. It is difficult to account for the distribution of this carbonate by replacement, for the silica of the granules, being finer in grain than that of the groundmass, should have been more readily replaced. It is, therefore, concluded that the siderite is an original constituent and that it assumed the present crystalline form before the silica of either the granules or groundmass had attained the crystallinity which they now exhibit. The presence of this carbonate is often indicated on weathered surfaces by solution pits, some of which show rhombic outlines.

Bishop Lake Area[1]

In Bishop Lake area the rocks of this division are also very poorly exposed. One good exposure of the cherty member was found just south of the old 52 mile-post on the railway. A number of isolated remnants of the basal conglomerate appear along the western margin of the down-faulted blocks in the northwestern part of the map-area, and also along the northern margin of the iron formation northeast of Bishop lake.

[1]*See* Figure 4.

The total thickness of the beds is at least 15 feet and is tentatively placed at 20 feet. They fall naturally into the following groups:

	Feet
Chert with algal structures	5
Magnetitic greenalite taconite	10
Basal conglomerate and algal chert	5

The basal conglomerate of the Bishop Lake area presents no essential differences from the North Lake occurrences, except that the pebbles nowhere exceed 2 inches diameter and the maximum thickness of the exposed remnants of the conglomerate itself is less than 12 inches. The same gradational change from conglomerate matrix to altered granite was observed. The fresh rock is a typical biotite granite. The feldspar shows small amounts of sericite and chlorite as alteration products, but otherwise the rock is unchanged. The weathered material shows an identical texture, but alteration of the feldspars has proceeded so far that the grains are unrecognizable except by their shapes and their relations to the unaltered minerals. The principal product of alteration is a greenish chloritic mineral. Biotite and muscovite are only slightly altered, and the quartz grains perfectly fresh. Where the conglomerate has been entirely removed and the weathered granite appears at the surface, as is usually the case for a few feet around these patches of conglomerate, modern weathering has caused oxidation of the iron-rich minerals and the rock assumes a striking brick-red colour. It seems probable that some chloritic material rich in iron was formed in this porous weathered granite by reaction with iron salts during the deposition of the lower beds of the iron formation. Similar reactions have undoubtedly occurred in some of the tuffaceous beds of Division 5.

As at North lake, small remnants of bluish grey chert with fine lining forming irregular structures is associated with the basal conglomerate.

Above the conglomerate and chert there is about 10 feet of altered greenalite taconite. The internal textures of typical greenalite granules are still distinguishable, though partly obscured by alteration of the greenalite to magnetite and chert. The magnetite commonly forms concentrations about the borders of the granules. The lower beds contain a larger proportion of magnetite. This appears as irregular patches in the outcrop, some of which are more or less equidimensional, others are elongated and very irregular in detail, and a few are best described as streaks. One 4-inch bed is almost wholly magnetite. The greenalite taconite is succeeded by about 5 feet of algal chert, which shows the fine red and white lining with variable contorted structures, some of which are repeated, as described from the type section of the upper horizon of algal chert at North lake. Here, however, and this is generally true of the lower horizon, the smaller structures predominate. The largest structures are entirely absent. A few druses, up to 4 inches across, lined with quartz crystals and iron oxides, were observed. The origin of these cavities is in doubt. All the above rocks are cut by veinlets of quartz and jasper with, rarely, goethite and magnetite.

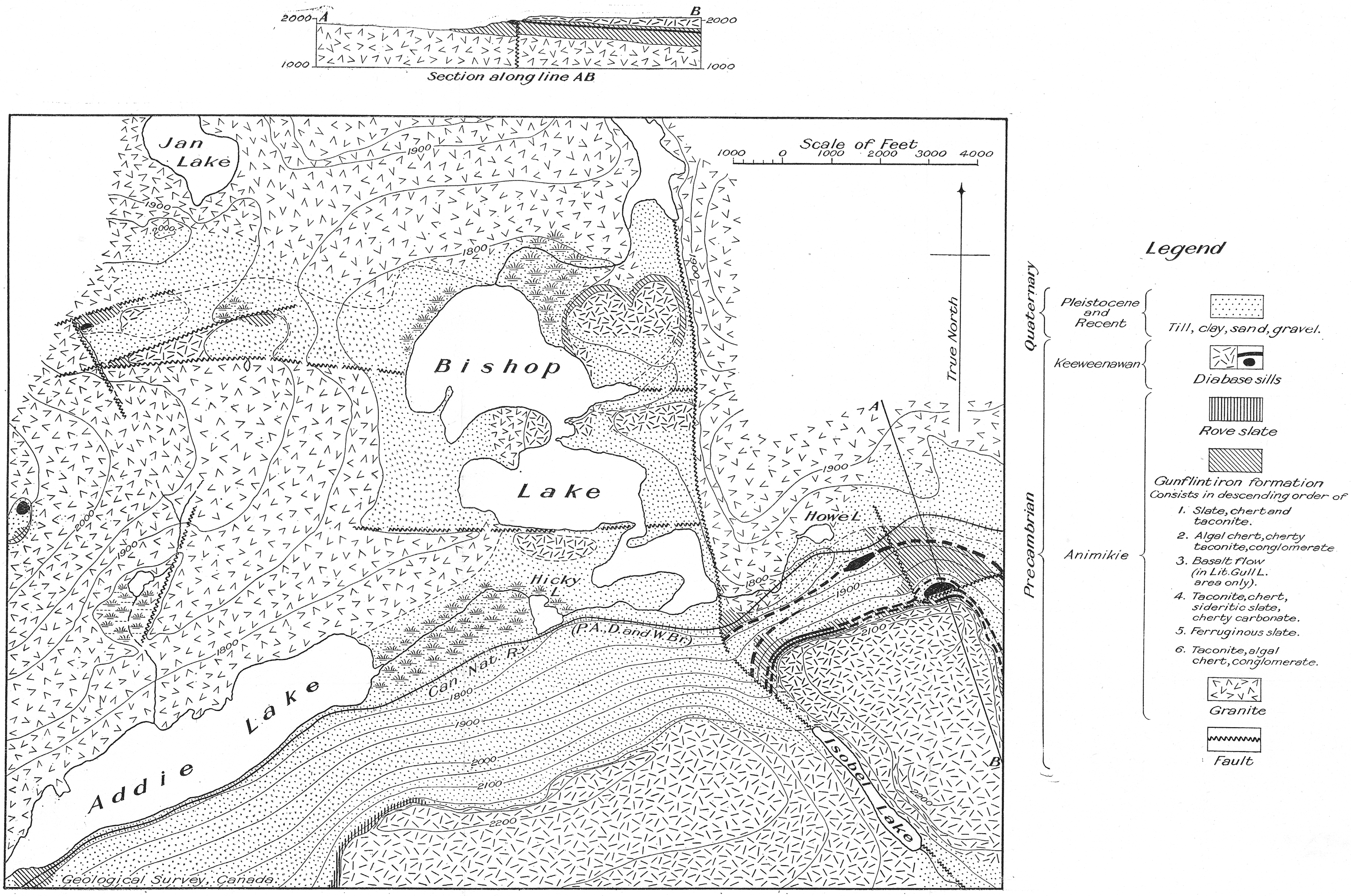

Figure 4. Bishop Lake area, Thunder Bay district, Ontario.

Little Gull Lake Area[1]

In Little Gull Lake area the algal cherts in this division are very well exposed. Outcrops appear at intervals along the basal contact of the iron formation, and yield the best information regarding the lithology of the division obtainable in the length of outcrop examined. The total thickness is at least 20 feet.

Remnants of the basal conglomerate were observed at many places along the basal contact or short distances north of it. Nowhere was the conglomerate found to be more than a few inches thick and in many places the algal chert, which overlies it, was observed in contact with the altered surface of the basement rocks. The chert is practically identical with the chert showing the fine contorted banding in North Lake area. The colours vary from reddish to grey and there is a marked preponderance of small, arched structures. Locally, larger structures resembling wavy growths start from a point and spread upward. Grey oolite in masses usually only a few inches across is occasionally associated with the chert and in such instances the outcrops are practically identical with those of the upper layer of algal chert (Division 4).

Microscopic examination of the banded chert shows rhythmic banding of hematite and greenalite in the chalcedony. Locally, continuous bands have not developed and the greenalite appears as shreds or as irregular patches some of which have a more or less perfectly developed spherical form. The geenalite is in many cases associated with magnetite which is probably secondary after it. Well-formed granules are most abundant in the trough-like depressions between the arched structures, where they may be so abundant as to completely destroy the normal continuous banding and to give the arched parts of the structure the appearance of isolated growths. Usually, however, the banding passes across the troughs at intervals. Normal greenalite-chert granules are present, with others of almost pure chert. Most of them have added layers of greenalite and chert showing concentric banding. These may surround one or several granules.

The algal chert is succeeded by cherty greenalite taconite grading upward to almost pure bluish grey chert with a conchoidal fracture and an obscure granule texture. Locally magnetite-rich seams are present. Veining and replacement by calcite has occurred in a few places and in others grains of pyrite were observed disseminated through the rock.

A local variation of the lowest beds of the division is a rock in which magnetite is present up to 50 per cent by volume, or about 65 per cent by weight. This variety occurs at the western side of the area mapped, lying on the granitic rocks and dipping under a large swamp. All the younger beds have been removed by erosion for a considerable distance to the east. A few square yards are shown by many exposures to consist of beds in which magnetite is a prominent constituent. The proportion of this mineral varies a great deal, however, even in this small area. In an open-cut 5 feet by 5 feet by 4 feet the beds are heavily

[1] *See* Figure 5.

charged with magnetite, decreasing in amount downwards. Polished sections show the magnetite to be intergrown with chert in a very irregular manner. A small amount appears as microscopic veinlets associated with amphibole and is, therefore, secondary. Some recrystallization has also occurred in the chert, for the grain is considerably coarser than that of the normal chert of these beds. The development of the amphibole, magnetite, and the coarse grain of the chert is undoubtedly connected with the intrusion of a small dyke which passes through the centre of the magnetite-rich area. This dyke, which is 1·5 feet wide and accompanied by smaller parallel dykelets, cuts the granite about 75 paces from the open-cut mentioned above, and strikes directly towards the magnetite-rich area, though it was not observed cutting the magnetitic beds because of the drift cover. Thin sections of the dyke rock show that it is identical in composition with the Keweenawan sills and this, with the local abundance of high temperature minerals, justified the assumption that it is of Keweenawan age and has caused the changes observed. Non-titaniferous magnetite as octahedrons and skeletal crystals is quite abundant within this dyke. There may have been some contribution of iron from this source, but the textures of the beds seem to indicate that they have developed by simple recrystallization from beds originally rich in iron. Within short distances on both sides of the iron-rich exposures the beds pass into the normal algal cherts. The transition could not be observed because of drift. The basal conglomerate is absent in this area, and replacement of some of the minerals of the granite by magnetite has occurred where the iron-rich rocks are in contact with it.

Silver Mountain Area[1]

In Silver Mountain area a few exposures of the beds of Division 1 appear along the western side of the strip of iron formation preserved by down-faulting and extending northward parallel to North river. The only other outcrop observed is in the bed of Whitefish river, just east of Hillside station. The total thickness of the division in this area is not known. It is, however, at least 10 feet and probably nearer 20 feet. The maximum observed thickness of the basal conglomerate is 3 inches.

At Hillside station the conglomerate is succeeded by red, green, or grey chert with fine wavy lining, forming the algal structures typical of this horizon. The small, arched structures with granules concentrated in the intervening troughs are most common. The red chert which locally may be bleached to grey, passes upward into green chert showing larger structures, which finally give place to a fine-grained phase of greenalite taconite with siderite nodules up to one-eighth inch diameter and either chert or carbonates as cement. In this case, the carbonate has obviously replaced part or all of the chert of the groundmass and some of the chert of the granules. Coarse granular aggregates of silica have escaped where all the finer chalcedony has been replaced. Carbonates were observed in a few cases to have developed between the grains of the coarser aggregates. Locally a magnetitic phase appears a few inches above the algal chert.

[1] For map of this area, *See* Ont. Bureau of Mines, Ann. Rept., vol. XX (1911).

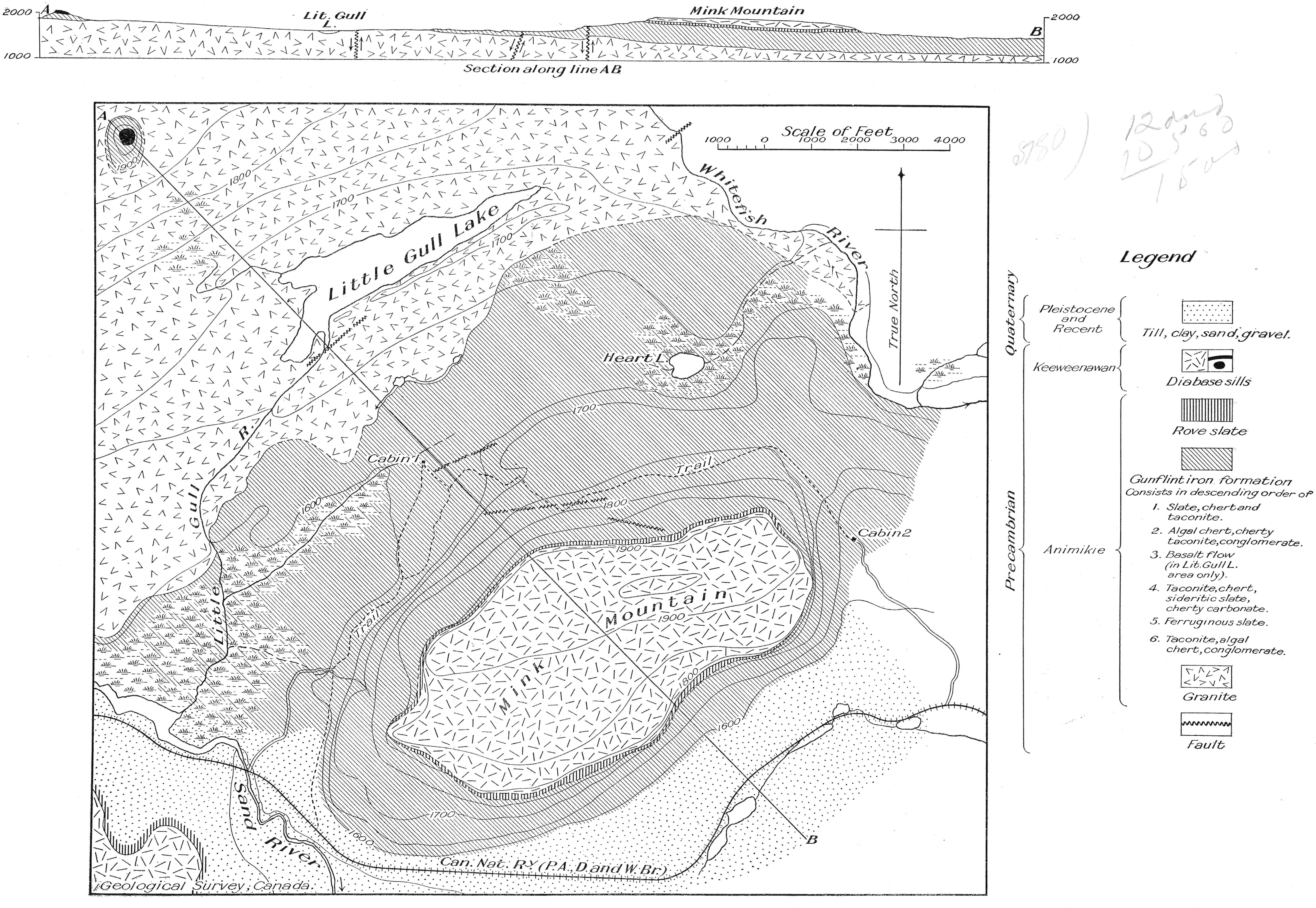

Figure 5. Little Gull Lake area, Thunder Bay district, Ontario.

This, where observed, was nearly solid magnetite for about 5 inches and heavily charged with magnetite over a thickness of 2 feet. One of the most remarkable features of this occurrence is the extreme irregularity of the upper surface of the algal chert. The average thickness of the bed is about 4 feet, but it rises in a series of mounds often 10 or more feet in diameter, several feet above the general level. Since there seems to be but little doubt that organisms have played an important part in the formation of the structures in the chert, this configuration of the surface is not surprising. The explanation of the development of these forms and the structures within the chert, on a purely mechanical hypothesis, would be extremely difficult in view of the lack of disturbance in the other beds of the formation.

DIVISION 2 (INTERMEDIATE SLATE)

North Lake Area

Several good exposures of the Intermediate slates (Division 2) appear in North Lake area on the northwest slopes of the hill just east of Bridge bay and of the hill east of Shekaka Creek valley. None of these shows the entire thickness, which is at least 8 feet. This division, though thin, is one of the most uniform and persistent in the iron formation, and is, therefore, of great value for purposes of correlation.

In outcrop the rocks appear as finely laminated, in places paper-thin, rusty, or almost black slates whose cleavage is parallel to the bedding and is due to variations in the composition of the original sediments—aided, perhaps, by pressure due to loading by the succeeding sediments. Examination of hand specimens reveals very little regarding the composition of these beds except the presence of hematite, which on polished surfaces is seen to be arranged in tiny rosettes with very irregular borders. They merge into neighbours or occur as distinct individuals in a groundmass which contains some quartz or chert. A large part of the groundmass was undeterminable, but is thought to consist largely of altered volcanic ash, with perhaps some fine material of detrital origin. An occasional grain of pyrite was observed, usually surrounded by a rim of oxide.

Bishop Lake Area

Along the main line of section in the Bishop Lake area the beds of this division are not exposed. The nearest exposure appears in a railway cut just east of the 53 mile-post. Northeast of Bishop lake there are continuous exposures for about one-quarter mile. The maximum thickness observed was 8 feet, with sills above and below.

In the railway cut only the upper 2 feet appears in outcrop. The beds are fissile, extremely fine-grained, and consist mainly of limonite intermixed with finely divided silica and probably some clayey substances. A small amount of black manganese oxides was observed, associated with marcasite nodules. The latter are usually slightly elongated parallel to the bedding and attain lengths of three-quarters inch or more. The dip of the beds is exceptionally steep (17 degrees) probably due to drag along the main north-south fault. The other exposures include dense, fine-grained, almost black beds up to 3 inches thick, giving a pale green powder when scratched; more fissile black beds with goethite developed as a secondary mineral along bedding planes and minute fractures; and others of similar texture, but including many small, irregular patches of pale yellow chert. All of these beds gave tests for carbonaceous matter. A thin section of the denser, less fissile material proved too fine grained for complete resolution under the microscope. A great deal of chloritic material is distinguishable, also some chert in irregular patches and veinlets, a few small quartz crystals, and opaque, black or almost black particles, probably partly iron oxides and partly carbonaceous matter.

Little Gull Lake Area

The best exposures of these beds in Little Gull Lake area appear in prospecting openings on the McGugan-Dowler property about one-quarter of a mile north of cabin No. 1. In one of these a complete section of the intermediate slates is 8 feet thick. Another opening about 250 paces to the southwest, exposes 12 feet with neither the top nor the bottom uncovered. This thickening is due partly to numerous intercalated beds of chert and partly to minor folding or crumpling of the slaty beds. The chert beds in the 12-foot exposure have an aggregate thickness of 33 inches.

The slaty beds are very fine grained, thin bedded, and black, weathering yellowish brown as a result of the oxidation and hydration of the iron content. Pyrite is common and forms nodules of irregular shape less than an inch in diameter. A dull black bed of variable thickness, 1·5 feet at the maximum, appears entirely opaque in thin section except for a series of minute white chert rings, some of which extinguish as a unit, others progressively. Some show a reddish-brown core. A few aggregations of chalcedony with included microscopic oxide particles are also present. The remainder of the rock is black and opaque. By heating to redness it was found to contain considerable carbonaceous matter. This suggests an organic origin for the ring structures.

Spheroidal or lenticular masses of chert appear throughout the series of beds, but in certain of them are particularly abundant and may coalesce to form continuous beds. Some of these are a foot or more thick. The colour is a beautiful blue-grey and the rock breaks with a conchoidal fracture. In thin section it is found that aggregates of siderite averaging about one-tenth mm. in diameter are very numerous. They are usually more or less spherical in form, but several may join to form more irregular bodies. Most of them exhibit a radiating structure, but some have crystallized or recrystallized with definite rhombic forms. The remainder of the rock is chalcedony.

Silver Mountain Area

The only outcrops of these beds in Silver Mountain area appear a short distance north of Whitefish river in Y 4 Strange. A thickness of 8 feet was observed, but the boundaries were not exposed. The beds have the same characteristics as in the other areas.

DIVISION 3

North Lake Area

This division in North Lake area has a thickness of about 170 feet. Exposures are numerous on the west and northwest slopes of the hill east of Bridge bay, on the northwest and north slopes of the hill east of Shekaka creek, and of the outlier farther northeast. The beds fall naturally into three groups as follows:

	Feet
Group No. 3: Greenalite taconite with a flaky appearance in outcrop and containing small magnetite nodules............	50
Group No. 2: Magnetitic and hematitic chert with nodular aggregates of iron oxides and an obscure granule texture............	70
Group No. 1: Altered greenalite taconite with "slaty" sideritic interbeds and cherty taconite toward the bottom............	50

Group No. 1. The intermediate slates of Division 2 pass abruptly upwards into a bed consisting almost entirely of siderite. This bed varies in thickness from a few inches to 1 foot and is persistent throughout the area mapped. The thin siderite bed is succeeded by a 5-foot, massive bed of grey to bluish-grey chert with small amounts of somewhat irregularly distributed carbonate which cause parts of the outcrop to weather to a honeycombed mass of chert. The remainder of the bed is predominantly cherty and on a fresh fracture shows an obscure granule texture. The granules have the outward form and relations of typical greenalite granules. In thin section, however, they are seen to be wholly silica in many cases with a texture identical with that of the groundmass, so that they cannot be distinguished between crossed nicols. In other cases they show a coarser texture than the groundmass. Observed in ordinary light, they are readily distinguished by the presence of a small amount of green pigment. The colour is similar to that of greenalite, but less intense. The individual crystalline particles of the granular mosaic vary in size from such as are just visible to grains 3 mm. in diameter. The granules vary from 1·3 mm. by 0·7 mm. to 0·1 mm. by 0·1 mm. and average about 0·5 mm. by 0·3 mm. No consistent orientation was observed. A few more or less circular areas with spherulitic silica around the outer margin, a coarsely granular interior, and lacking the green pigment, are probably cavities filled by a later generation of chalcedony. Most of the granules include lenticular, vein-like, or more irregular areas of clear chert which are evidently shrinkage cracks filled by chalcedony identical in colour and texture with that of the groundmass. The carbonate of this bed gave tests for iron, but is dominantly $CaCO_3$ judging by the briskness of effervescence with cold dilute HCl. It shows the same textural relations as that in the cherts of Division 1, and is, therefore, considered to be primary.

The cherty taconite bed is overlain by a sill from 4 to 8 feet thick and the immediately succeeding beds are covered. The next exposure, about 20 feet higher, consists of cherty, altered greenalite taconite with "slaty," sideritic interbeds forming a series of more or less distinct beds defined by slight variations in composition and emphasized by weathering. The bedding is less regular than that of ordinary clastic sediments. Beds thicken and thin rapidly or may pinch out altogether and not reappear in the same exposure. The cherty beds average about 6 inches in thickness, but some are as much as 3 feet without a parting. The "slaty" beds are more constant in thickness, and are seldom more than an inch or two thick. The thicker beds always show jointing perpendicular to the bedding. The spacing of the joints varies from a few inches to several feet. No clearly defined systems could be distinguished. They are probably due in part to temperature changes and in part to regional warping or faulting. Weathering brings them out more clearly and also develops a series of closely spaced, discontinuous partings, approximately parallel to the bedding, giving the beds a flaggy appearance in outcrop.

Microscopically the massive cherty beds appear to consist of a multitude of particles usually quite uniform in size and averaging from 0·5 mm. to 1 mm. in diameter. Extremes of from 3 mm. to 0·1 mm. occur locally. These commonly are fairly closely packed in a cement of white or pale grey chert with occasionally a little calcite. The carbonate, when present, mostly occurs as large individuals up to 3 sq. cm. in cross-section, which include several granules and some interstitial chert. The granules are dark brown to black. Their outlines are quite variable, though a tendency toward spheroidal forms is quite pronounced. Occasionally subangular outlines may be observed, and specimens may be selected which have a texture resembling that of a fine-grained, clastic sediment. The microscopic textures, however, show clearly that these rocks have had a different origin. Most of the granules give a brown or red streak and many are more or less pulverulent, showing that oxidation has produced hydrated iron oxides from the original iron-bearing minerals of the rock. No fresh material was available for examination in this area, but it is concluded that greenalite was an important original constituent of these granules since in Little Gull Lake area fresh greenalite taconite was observed to grade into similarly altered material. Some of the granules contain appreciable amounts of magnetite; small aggregates or nodules of magnetite were also observed, but are more abundant in the magnetitic cherty taconite of group No. 2 higher in the series.

In a few thin beds, carbonates predominate. Where they are most abundant, the granule texture is absent or difficult to distinguish. More or less spherical nodules of carbonate are numerous in some of these beds, where they weather out and form pits lined with hydrated iron oxides. Most of these carbonates include some iron in their composition. Some siderite was identified, but $CaCO_3$ is the most abundant molecule.

Under the microscope the granules of the normal cherty beds of this group are almost opaque, except a few which consist of a mat of extremely fine amphibole needles. Their outlines appear more irregular than when observed in hand specimens, but this is due to the presence of microscopic grains and crystals of secondary minerals formed from the materials of the granules, and extending out into the groundmass. These are only visible at high magnifications. They are mainly hydrated iron oxide and minute amphibole needles and in many places appear forming a network between the crystals of the fine-grained groundmass of chalcedonic silica. Calcite appears in similar relations and is probably, in part at least, secondary. The groundmass is holocrystalline and equigranular, with an average grain size of 0·05 mm. The dark granules consist largely of hydrated iron oxides and appear brown or reddish brown in reflected light. At high magnifications small amounts of amphibole can usually be distinguished. The oxides are regarded as products of surface oxidation and the amphiboles are due to metamorphism.

In the "slaty" sideritic beds rhombs of siderite, very finely crystallized, can usually be distinguished. No fragmental material could be identified under binoculars. Hydrated iron oxide is abundant and is probably mostly derived by oxidation from the siderite. Some fine volcanic material may be present.

Group No. 2. Beds of magnetitic chert are present toward the top of the group just described, but first become prominent at an horizon about 55 feet above the base of the division. The lowest of these beds are only a few inches thick and spaced at any distance up to 2 feet apart. Higher in the series they become thicker and more numerous until the individual beds are a foot or more thick and are separated by only thin interbeds of greenalite taconite. They are composed almost entirely of chert and iron oxides, are pronouncedly lenticular in form, and weather less rapidly than the other beds. Greenalite is almost or entirely absent. Granules are rarely prominent and in many cases are indistinguishable.

Commonly, the whole bed is charged with fine, disseminated grains of black to bluish-black iron oxides and local concentrations appear at intervals, giving the rock a peculiar patchy appearance. Some of these concentrations have fairly regular outlines, approximating ovate or circular forms in section, but more commonly they are extremely irregular and grade into the normal chert with a moderate quantity of disseminated oxide. A band of chert with less oxide than the average in many places surrounds these abnormal concentrations. One nodule was observed with a zone of carbonate surrounding a core of nearly pure magnetite. Microscopic textures indicate that the nodules are primary. Many of them have been recrystallized to intergrowths of magnetite and hematite.

In most of these beds chert outweighs all the other constituents. Microscopically, they nearly always exhibit an imperfect granule texture. Granules are commonly marked out by traceries of oxide particles showing the crystal forms of hematite, but composed of intergrowths of magnetite and hematite in about equal proportions. In the majority of cases the inner parts are composed of chert, but carbonates, greenalite, or some alteration product of greenalite may be associated with it, or in rare cases may form the whole. A few granules consist entirely of iron oxides.

In some of the beds carbonates are abundant. In these there are usually distinguishable granule-like forms approximately the same in size and shape as normal granules, but they are in many cases more irregular in detail. Rhombs of carbonate commonly form the borders of such granules, surrounding a centre of chalcedony, or the distribution may be more irregular. The carbonate is undoubtedly variable in composition, but dominantly iron-rich. Most of it shows curved cleavages and is strongly pleochroic, changing from grey to almost black. Some calcite is also present. The oxides, examined in polished sections, were found to be intergrowths of magnetite and hematite. They are always associated with the iron-rich carbonates and this suggests a genetic connexion. From the textural relations, it is difficult to decide whether these carbonates are primary or secondary. They have not been replaced by the other minerals, for they always show characteristic rhombic forms. In a few instances rhombs were observed protruding through the oxide borders of chert granules otherwise perfectly formed. This suggests replacement, but the same texture would be produced if the carbonate crystallized while the silica was still gelatinous or only partly crystalline, or by recrystallization of the original constituents of the bed without addition of new materials. The facts that the carbonates are confined to relatively thin beds of fairly uniform composition, and that the other common minerals which they might have replaced are found in abundance both above and below showing no signs of partial replacement, seem to indicate that the carbonates are original constituents.

Group No. 3. The massive, oxide-rich, cherty beds gradually give way above to beds resembling the altered greenalite taconite already described. Their appearance in outcrop differs chiefly in that they show a much greater development of the discontinuous partings approximately parallel to the bedding. In many places these are so abundant as to give the rock a flaky appearance. Magnetite nodules are locally quite numerous, but seldom exceed one-quarter inch in diameter.

Microscopically the textures are identical with those of the lower beds, except that the granules have suffered less alteration. Some of them consist entirely of chalcedony except for a small quantity of green pigment; others are composed almost wholly of greenalite. Intermediate between these, granules showing a variety of internal textures may be observed. The greenalite, which is always present as extremely fine particles, may be: (1) evenly distributed through the chalcedony; (2) segregated into more or less spherical groups with a gradational change outward to chert with dispersed greenalite or a border of chert almost free from greenalite, in many cases made up of radiating crystals; (3) grouped in more or less stringy aggregates forming a rude network, the intervening spaces being filled by chert with dispersed greenalite.

All granules show contraction fissures filled by chalcedony similar to that forming the groundmass.

Bishop Lake Area

The beds of Division 3, in Bishop Lake area, are best exposed in the northward-facing slope just south of the railway and in the vicinity of the main line of section. Other exposures appear in a railway cut just east of the 53 mile-post, in another cut at the west end of Addie lake, in the butte at the extreme western side of the map-area, and in a down-faulted block of iron formation preserved about a mile northeast of the butte. The total thickness is approximately 160 feet.

The rocks present some striking differences from those of the corresponding division in North Lake area. They are composed dominantly of chert and carbonates. Greenalite is prominent only locally. The most pronounced feature of their outcrops is the abundance of approximately circular pits due to leaching out of carbonate nodules. These vary in size from one-tenth to three-quarters of an inch and may be spaced from many per inch to several inches apart. The composition of the carbonate is variable, as is shown by the differences in the manner of weathering of different nodules. In practically all cases some $FeCO_3$ is present, but the proportion varies, and locally nearly pure $CaCO_3$ is present both as nodules and intergrown with chert in the main mass of the rock. Weathering most commonly gives a porous, powdery mass, coloured yellow, brown, or red by hydrated iron oxides, partly or wholly filling the space formerly occupied by the nodule. In general the segregations are smaller in the lowest beds.

Like the greenalite taconite beds, the strata exhibit a wavy bedding with a tendency toward lenticular forms, irregular discontinuous partings approximately parallel to the bedding, and numerous joints perpendicular to the bedding. The oxidation of the iron-rich carbonates to hydrated iron oxides usually imparts a brown or reddish colour to the outcrop. In the upper beds there is a notable increase in the proportion of magnetite and hematite, and the beds become more massive. A massive, mottled, blue-grey, cherty carbonate bed with an obscure granule texture occurs at the very bottom of the division, overlying the Intermediate slate. In one instance a gradation was traced from beds composed of limonitized carbonates and chert, with decomposed carbonate nodules distributed through it, to greenalite taconite with a little more carbonate in the groundmass than in normal greenalite taconite and a few carbonate nodules and small bedded seams of carbonate-rich material.

Thin sections of these beds exhibit a wide range of textures. A section of one of the beds richest in carbonates and not showing distinct nodules, showed it to consist of an irregular aggregate of carbonates and chert with a tendency toward segregation of these constituents, but not in regular forms. Some areas have outlines resembling granules, but the boundaries are irregular in detail. The carbonates are in part twinned and untwinned non-pleochroic, in part untwinned pleochroic. The former is probably almost pure calcite, the latter almost pure siderite, and gradations between the two exist. Small amounts of a greenish substance resembling greenalite were observed, usually along boundaries between grains, along the cleavages of the iron-rich carbonate, or as distinct veinlets traversing the chert and carbonate areas alike. This substance is undoubtedly secondary and is probably an iron-rich chlorite. Oxides are not abundant. Magnetite appears as isolated grains or groups of grains, many with sharp boundaries and rhombic outlines, clearly derived from the iron-rich carbonates by oxidation.

A thin section of the greenalite taconite shows many of the textural features characteristic of that rock as described from the North Lake beds. The granules are not always homogeneous. The commonest type shows minute spherical segregations of greenalite about 0·02 mm. in diameter. These vary in colour from emerald green to brown or almost black, according to the degree of alteration of the greenalite. In a few granules they are closely packed and may even appear to form an almost uniform mass of greenalite. Their composite character can usually be detected under higher magnifications. Usually these minute segregations serve as nuclei for spherulites of silica with radially arranged fibrous microcrystals. Locally, recrystallization to matted fibrous amphibole has occurred. The groundmass is almost clear chert, much more coarsely crystallized than that of the granules. Grains average about 0·1 mm. A few scattered spherulites with greenalite toward the centre, identical with the spherulites within the granules, appear in it locally. Small amounts of calcite are present, usually about the borders of granules. In a few instances it appears to have replaced spherulitic silica.

As already mentioned, the upper beds are richer in magnetite and hematite, which in polished sections appear most abundantly about the borders of greenalite granules or carbonate segregations from which, in most cases, it seems clear that the iron oxides have developed by decomposition and oxidation. In carbonate-rich beds the oxides in many cases form areas with rhombic outlines. On the whole, magnetite is the more abundant oxide, though locally hematite preponderates. The two may be observed intergrown and in such instances either may appear to have been formed from the other. More generally the probability is that they formed at essentially the same time. This development of magnetite and the formation or recrystallization of part of the hematite is believed to have occurred in connexion with the sill intrusions. A small amount of downward migration of iron has resulted in the formation of veinlets of limonite and goethite, transverse to the bedding.

Little Gull Lake Area

Exposures of the beds of Division 3, in Little Gull Lake area, are quite numerous in an area extending northwesterly across the map-area. They form a series of more or less prominent benches or ridges along the northwest slopes of Mink mountain. Owing to the presence of a number of faults, the total thickness of this division is not known. It is certain the throw of the faults has been small. In none seen has the movement been great enough to bring beds of different divisions into juxtaposition. In all cases, the beds of the opposite walls of the fault were almost identical. Three faults were observed which would cause an apparent thickening of the beds of this division. Assuming a total downthrow to the north of 60 feet along these faults, and an average dip of 4 degrees, the thickness of the division is 160 feet.

The beds immediately above the intermediate slate are nearly pure chert, but possess a granule texture defined by small amounts of greenalite either dispersed or locally tending to form minute spherical segregations as in greenalite taconite. In none of the granules has this segregation proceeded very far, and the greenalite content is small in all cases. Siderite appears locally, forming small segregations as in the chert associated with the intermediate slate, and also in a few instances as grains arranged in disconnected strings about the borders of chert granules. Locally, the rock may be composed entirely of this combination of minerals and the carbonate then appears as a rude network between the granules. Calcite of a later generation appears in veinlets and has clearly replaced some of the original chalcedony. One chert granule was observed to have crystallized to a somewhat coarser grain than the normal and the quartz individuals are charged, toward their centres, with finely divided hematite particles. Crystallization has evidently taken place about these minute clots as nuclei.

The cherty taconite beds, described above, grade upward to greenalite taconite by increase in the proportion of greenalite in the granules. These beds may be several feet thick without a break, but usually the weathered surface shows a series of closely spaced, discontinuous partings. When fresh the rocks are green, the depth of the colour depending on the proportion of greenalite in the granules. On weathering, the colour fades to a pale green, then to dark brown, and finally black. The upper few inches of exposed rock show further oxidation and the granules appear as powdery bodies of brown or reddish hydrated oxides of iron.

The many open-cuts on the McGugan-Dowler property expose rock much fresher than is found elsewhere. Microscopically, this material agrees in every detail with the more altered greenalite taconite already described, except that the darkening of the granules has been less pronounced. The fresher material can be traced into that in which the granules are opaque and composed largely of hydrated iron oxides. By far the most common texture within the granules is that made up of a number of minute spherical segregations of greenalite grading outwardly to clear chert, often radiating about the greenalite centre, and showing a black cross between crossed nicols. The closeness of packing of these segregations varies. In many cases at the margin of a granule they coalesce to form an almost continuous shell of greenalite. The groundmass is of the usual microgranular or spherulitic chalcedony. Calcite replaces this in varying degree. Veining by both calcite and chert has occurred, probably at several periods. Hematite and magnetite occur locally, but were nowhere observed to be quantitatively important.

At about 60 feet above the base of the division, beds rich in hematite and magnetite begin to appear, alternating with thin (4 to 6 inches) beds of greenalite taconite. These oxide-rich beds are ordinarily less than 1 inch thick, but a succession of them with only very thin cherty partings may attain a thickness of a foot or more. A few beds up to 3 inches thick appear in cut No. 14. In most cases, they were found to contain a good deal of siderite and it, therefore, seems probable that at least some of the oxides have resulted from alteration of siderite. In a few instances the oxides form shells about greenalite granules, and distinct granules composed almost wholly of oxides are occasionally present. In these instances decomposition and oxidation of greenalite may have produced some of the oxides. A few thin beds are composed of an extremely fine-grained intergrowth of siderite and greenalite with only a few scattered grains of magnetite and pyrite and a little secondary chalcedony. The siderite shows clearly defined crystal outlines, to which the isotropic greenalite is interstitial. By loss of CO_2 and oxidation these beds would readily go over to magnetitic beds similar to those mentioned above. Polished sections show under the microscope that both hematite and magnetite are present in all cases, usually intergrown indicating contemporaneity. Locally, either may predominate. Though oxides and siderite-rich beds are much more numerous than in the lower beds, the typical greenalite taconite which contains only a minor proportion of oxides greatly exceeds them in bulk. Probably not 10 per cent of these beds have an iron content exceeding 30 per cent.

The succeeding 40 feet of beds show a great abundance of carbonate nodules and closely resemble the equivalent beds in Bishop Lake area. Greenalite taconite with carbonate as nodules and forming part of the groundmass is the most common rock type. The spacing of the nodules varies in different beds and at different points in the same bed, but one per square inch cross-section is not uncommon. Locally beds consist entirely of intergrown carbonates and chert. Some of these show an obscure granule texture. Much of the carbonate shows darkening by partial oxidation. Some of it also shows pleochroism from white to grey or almost black. The formation of a yellowish or brownish pulverulent mass in decomposition of the nodules shows that the iron content is considerable in some of them. However, the briskness of reaction with dilute HCl indicates that $CaCO_3$ is the most important constituent.

The uppermost 30 feet of the division is made up dominantly of greenalite taconite. A few thin beds have greenalite granules up to one-sixteenth inch diameter, some of which are markedly flattened. Certain beds are comparatively rich in magnetite, which appears as lenticular patches elongated parallel to the bedding and up to three-quarters inch long. Three feet of this material is exposed at the bottom of the face of cut No. 9.

Silver Mountain Area

The beds of Division 3 in Silver Mountain area are well exposed in the bed of Whitefish river at the falls in R 190, concession IV, Strange township, and above the falls, to a point well above the dam. Farther north they are again exposed in the bed of a small stream flowing eastward to join North river about 1·5 miles above its junction with the Whitefish (lot 4, concession V, Strange). At the junction just mentioned and along the fault scarp to the east, a number of exposures appear, most of them showing some disturbance connected with the faulting. A small outcrop was found at the base of the shelved eastward slope of the sill-capped hill in lot 4, concession III, Strange. Other outcrops were observed in the bed of Whitefish river east of Hillside, where they appear intermittently as far east as Nolalu and probably beyond. A few were also seen during a rapid trip to the north of Nolalu. No satisfactory estimate of the thickness of these beds in this area can be made, because of the sparsity of outcrops and the probable presence of faults in the covered areas.

All the beds exposed are typical greenalite taconite. They show no features not already described from similar rocks in other localities. Massive beds with only thin partings of carbonate rock or slate are the most common. Locally, magnetitic phases or beds containing pyrite as veinlets or nodules may be present. The latter are quite numerous near the dam on Whitefish river.

Toward the top of the division, a few beds contain numerous carbonate nodules and have a carbonate cement. Some of the thin interbeds at this horizon are composed almost wholly of carbonates. This material, as in most other occurrences, is predominantly calcareous, but contains some iron probably as $FeCO_3$.

DIVISION 4 (ALGAL LAYER)

North Lake Area

Though Division 4 is relatively thin, the exposures in the vicinity of North lake are quite plentiful. The strata form a prominent bench on the western side of the hill east of Bridge bay and exposures are continuous from an elevation of 1,800 feet, down the dip to the railway. Other outcrops appear west of Shekaka lake and in the valley of Shekaka creek, just south of the lake. Four members are readily recognized and are traceable over long distances. In this area the type section is as follows:

	Feet
Massive chert with algal structures	7
Siliceous pisolite	1·5
Siliceous oolite, chert with algal structures, and intraformational conglomerate	5
Massive magnetitic greenalite taconite with jasper seams	2

The massive, magnetitic greenalite taconite at the base of the division is almost identical with the altered greenalite taconite of Division 3, but lacks the closely spaced partings. It is grey and weathers to a minutely pitted surface. Part of the greenalite has altered to magnetite and chert, the magnetite in many cases appearing as groups or strings of grains about the borders of the granules. Limonite is usually present as a product of recent oxidation. Small, lenticular jasper seams, oriented with their long axes parallel to the bedding, mark the beginning of the period of superabundant silica deposition which culminated in the deposition of the algal chert. Other seams of brick-red jasper appear running in almost every direction, and have obviously formed later than the other constituents of the bed.

Siliceous oolite forms part of the lowest member but one of the division, where it is associated with banded chert, some of which shows algal structures. In outcrop it displays a granule texture resembling that of greenalite taconite, but the granules weather, by leaching of iron, to clear white or grey silica and the rock assumes a peculiar speckled appearance. Under the microscope the granules exhibit textures resembling those of normal greenalite taconite or cherty taconite, but many of them have an additional concentric structure due to a later deposition of silica, with rhythmically banded greenalite, about the original granules.

In general appearance, the siliceous pisolite bed resembles a grit with pebbles or grains up to one-quarter inch diameter and averaging about one-eighth inch. The grains, however, are remarkably well rounded and close examination of a grain which has been broken across will often reveal a concentric structure. In thin sections they appear as circular, oval, or more flattened forms of cryptocrystalline silica with concentric shells of black oxide, usually more abundant in the outer half of the grain. The chert is pervaded by minute flocculent particles of greenalite, which in some spherites is rhythmically banded. The oxide is always most abundant in the bands in which greenalite is most abundant and has probably developed from the latter by decomposition and oxidation. A few of the sections of spherites examined have cores which resemble in size, shape, and composition the normal granules in cherty taconite. These show no concentric banding and are more coarsely crystallized than the outer added shells. It seems probable that if the other spherites had been cut through the centre, they would have shown similar cores and that the spherites are normal cherty granules with added shells of rhythmically banded silica and greenalite developed under special conditions of precipitation. Most of the spherites show contraction cracks filled with chert similar to that of the groundmass. These may be concentric, radial, or more irregularly arranged. The groundmass is entirely composed of silica varying from spherulitic and microgranular chalcedony to granular quartz with grains up to 2 mm. diameter. Fragments of banded chert are present, but not numerous. A remarkable thing about this bed, in addition to its exceptional texture, is its persistence horizontally. Though locally it may give way to algal chert, it is found at the same horizon and with the same average thickness as far east as Little Gull Lake area.

Chert with algal structures is most abundant in the upper member of the division and consists of almost pure, microgranular chalcedony with very fine red and white lining and an occasional streak or band of green. The lining is due to finely divided hematite and greenalite in varying proportions. Rarely the banding is straight and parallel to the bedding. In the majority of outcrops it is wavy or even highly contorted, often without any systematic arrangement, but in some it shows structures which are frequently repeated and are difficult to explain unless they be attributed to the work of organisms.

Grout and Broderick[1] have described structures believed to be organic in origin from what is undoubtedly the equivalent horizon in Mesabi district. These "resemble little piles of thimbles or inverted bowls. They are half an inch to three-fourths of an inch in diameter, piled in irregular columns about 6 to 12 inches high. The lower parts, like the sides and upper parts, seem to merge into the fragmental material of the conglomerate." Gruner[2] described similar structures from the western part of Mesabi district and Broderick[3] found them in Gunflint district, Minnesota. The writer observed structures fitting the above description at a number of places in the vicinity of North lake and also in the other areas examined. All gradations occur

[1]Geol. Surv. of Minn., Bull. 17, p. 21 (1919).
[2]Geol. Surv. of Minn., Bull. 19, pp. 16–17 (1924).
[3]Econ. Geol., vol. XV (1920).

from straight banded chert to the highly contorted variety. This gradation may take place horizontally or vertically. The irregularities may appear as simple corrugations, broad arched structures, or the inverted bowl type. Granules of the normal type, some of which have outer concentric shells of silica and greenalite, are associated with the chert in varying abundance. Usually they are concentrated in the troughs between the arched or domed structures, but odd ones occur within and disturbing the banding of the otherwise smooth curves of such structures. In many places the minutely domed parts of the structures appear as individual growths resembling heaps of inverted bowls or thimbles in a matrix of oolite or taconite. However, in all cases observed by the writer, the banding could be followed at intervals across the troughs. Some specimens broken along one of these more or less continuous bands present a surface showing a series of dome-shaped prominences and these, cut in horizontal section, appear as more or less circular forms with concentric lining.

Larger structures up to 2·5 feet across are not uncommon and they usually merge into one another without intervening areas of granules. Many of these resemble the smaller forms. The lining is identical with that of the smaller structures. Locally hematite bands are particularly prominent and give the rock a black or bluish-black appearance. Magnetite may also be present in small amount, usually as minute, well-formed octahedra. It is probably secondary. Magnetite was also observed filling veins and associated with quartz. In these relations, it frequently has a radiated structure, with needlelike crystals up to three-quarters inch long, and is, therefore, clearly secondary and pseudomorphic after hematite or goethite.

At one place on the dip slope underlain by algal chert, what is probably part of the upper surface of this massive layer has an extremely irregular or hummocky surface with dome-shaped prominences several feet across. It is partly covered by a few inches of oxide-rich taconite. This irregularity of the surface seems to be characteristic of both the upper and lower beds of algal chert.

The lowest member but one of Division 4 contains a considerable proportion of distinctly fragmental material. The fragments are sharply angular or only partly rounded and vary from a fraction of an inch to several inches in length. It is evident from their relations that they represent parts of beds broken up by some slight disturbance, but not transported any great distance from their original positions. The fragments are of banded chert which may or may not show algal structures, cherty taconite, almost pure hematite or magnetite, or both oxides. The pebble-like masses of cherty taconite usually show more rounding than the other fragments and, therefore, were probably less consolidated than the banded chert and oxide-rich beds at the time of the disturbance. The matrix in which the fragments are set is largely of siliceous oolite. Chert and small amounts of amphiboles form veinlets which cut all the other constituents. Chert veinlets of several generations can be distinguished. These are colourless or jasper red. At a few points within this bed, masses of algal chert several feet in length occur apparently in situ. In these the structures in most cases are of the simple wavy variety.

Bishop Lake Area

The beds of Division 4 are best exposed on the northward slope just south of the railway and east of the north-south fault. Another small exposure appears in the northwestern part of the map-area where a block of iron formation has been preserved by downfaulting.

The detailed subdivision of the beds in this area is as follows:

	Feet
Massive chert with algal structures	6
Siliceous pisolite	1
Algal chert and cherty taconite, with locally intraformational conglomerate	5
Massive cherty taconite with jasper seams and locally intraformational conglomerate	15

The general appearance of all of these beds is much the same as described for equivalent beds in North Lake area. The cherty taconite beds of the lowest subdivision attain thicknesses up to 6 feet, appear dark grey in outcrop, exhibit a distinct granule texture, and contain irregular, small, often lenticular masses of hematite and magnetite, usually intergrown, and many small, bedded, usually lenticular seams of brick-red chert. These beds also include thin intraformational conglomerates in which some of the fragments are of banded chert. Thin sections show that the granules, which have the usual sizes, shapes, and packing, and tend toward orientation with their long axes parallel to the bedding, are composed dominantly of chert, but most of them have borders defined by the presence of oxide particles in irregularly shaped groups, strings, or isolated grains. Many of them have a few scattered grains or groups of crystals in their central parts, and a few are composed almost wholly of iron oxides. Only partial crystal outlines are visible in these oxide grains. Even the smallest particles are usually found to be made up of groups of smaller individuals. A few octahedrons of magnetite were observed. Commonly hematite and magnetite appear in intergrowth with mutual boundaries.

The cherty taconite associated with algal structures in the next higher subdivision is practically the same in texture and composition. One slide showed calcite appearing in both granules and groundmass. Individual crystals of this mineral were observed to cross granule boundaries and protrude into spherulites of silica. Such relations clearly indicate replacement. The oxides were not affected, however, for magnetite octahedrons appear within the calcite areas and retain perfectly sharp boundaries. A few jasper granules may be present locally. The algal chert is practically identical with the equivalent beds in North Lake area. A number of druses were observed, filled with minerals, the most prominent of which is a green amphibole occurring in a matted aggregate of tiny hair-like crystals or in radiating groups with crystals up to one-quarter inch long. In part this mineral weathers to a mass of limonite, but in a few places there have been left skeletons of silica in the forms of the original crystals. Intergrown with this amphibole, which is probably iron-rich actinolite, glassy quartz, calcite, and a black carbonaceous substance, probably anthraxolite, were identified. At least part of the quartz is later than the amphibole, for it was observed in veinlets which frayed out on passing into these matted aggregates. Calcite occurs as distinct rhombic crystals and is probably also later in origin. The anthraxolite is present only in very small amount. It is soft, black, and has a brilliant sheen. Its origin is in doubt. Magnetite occurs intergrown with amphibole and also as distinct veinlets cutting both it and the chert.

The siliceous pisolite bed is almost identical with that occurring in North Lake area at a corresponding horizon. The pebble-like grains vary considerably in outward form. In general the smaller grains are more nearly spheroidal. Many of the larger ones are flattened parallel to the bedding. Egg, gourd, disk, and sausage-shaped forms are common.

Veinlets of jasper, usually discontinuous, appear in all the beds of the division. Quartz stringers, approximately normal to the bedding, fill cracks developed in connexion with the faulting which has affected the region. Two distinct generations of quartz can be distinguished in these veinlets.

Little Gull Lake Area

The algal chert of Division 4 in Little Gull Lake area, as in the areas already described, stands out in relief, and, consequently, exposures are quite numerous. It forms a pronounced bench from 20 to 100 paces wide around the west and northwest sides of Mink mountain and a less clearly defined one to the north. Finally, it outcrops near cabin No. 2, on the east side of the map-area, and there passes under the drift to the south.

The type section for the area is as follows:

	Feet
Banded chert, with or without algal structures	7
Siliceous pisolite (locally present)	2
Lava flow (present in part of the area)	0–50
Mixed cherty taconite and banded chert, grading downward into massive cherty taconite with jasper seams	9

The textures and relations of the cherty taconite are identical with those described for the equivalent beds in the North Lake and Bishop Lake sections, but the amount of associated banded chert is much less than in the other two areas mentioned. A bed of siliceous pisolite, varying from 1·5 to 2 feet in thickness and composed of coarse granules with a concentric structure, is present here as in the other two sections already described. The internal structure of the granules of the lower 10 inches and the upper 4 inches is the same as in the other areas, but the granules of the intervening 8 inches are composed almost altogether of greenalite, and, consequently, this part weathers much more rapidly and has a yellow or brown, granular outcrop.

The banded chert of the uppermost part of the division appears identical with that already described from corresponding horizons in the other map-areas. In the eastern part of the area this banded chert overlies a bed of lava and where exposed the algal structures are wanting. Near the western margin of the lava, a 7-foot exposure showed straight banded chert making up the lower 6 feet, with small algal structures appearing in the upper foot. The other exposures to the west showed the usual variety of contorted structures and all the other peculiar features already noted in the preceding descriptions.

Microscopically, the chert with the straight banding has the same composition as has the rock with the contorted banding. The differences are entirely in the arrangement of the various components. The banding is defined by varying concentrations of greenalite and oxides within the chalcedony, which forms the main mass of the rock. Granules are present, but instead of being concentrated in troughs between arched structures, or in larger, irregular patches, they appear oriented with their long axes roughly parallel to the bedding, distributed at intervals through the chert, and not at all closely packed as is usually the case in greenalite taconite. The greenalite bands in the groundmass do not in general bend around the granules, but are cut off by them or else die out near a granule, leaving a band of pure chert surrounding it. The granules themselves are the same in size and shape as those of normal greenalite beds. They consist of greenalite, silica, and oxides with varying distribution. Spherulites of silica up to 0·2 mm. diameter are common. Greenalite is either interstitial to the spherulites of silica or segregated into more irregular patches.

The fact that the chert above the lava does not show the algal structures characteristic of all other exposures of this bed more than a few feet in length and found in abundance in this area in outcrops about a mile distant from the lava, may mean that the organisms directly responsible for their formation were locally unable to exist, owing to the high temperatures in the vicinity of the flow during and for some time after its extrusion. But since there is no diminution in the thickness of the chert, even though the algal structures are absent, and since granules are present in about the usual abundance, though differently distributed, it appears that organisms played no essential part in the precipitation of the minerals making up the bed or in the formation of the granules. High temperature did not prevent the formation of the granules, for they are found even in the chert between the pillows in the upper surface of the lava.

The lava is the only flow of Animikie age known within the Gunflint or Biwabik formations, so far as the writer is aware. It appears toward the bottom of Division 4, above cherty taconite with jasper seams and below chert with uncontorted banding. Its relations are clearly visible just northwest of cabin No. 2, where it apparently wedges out, and again in a low escarpment on the south side of Whitefish River valley due north from this cabin, where the lower contact is well exposed. The upper surface shows pillow structures and between the pillows red, green, and blue chert has been deposited. Next to the lava there is ordinarily a bleached border about one-half inch wide. This is grey and grades outward into green, and finally to red, chert, which forms the bulk of the filling. Small reticulating veinlets of grey chert are abundant throughout the upper part of the flow, apparently following contraction fissures. In all except the lower few feet of the flow, amygdules are abundant, varying from microscopic sizes to 4 mm. diameter or more. The main mass of the rock is made up of twinned plagioclase laths up to $\frac{1}{2}$ mm. long and augite phenocrysts up to 2 mm. long set in a glassy or partly devitrified zeolitized (?) groundmass. A slide cut from a specimen from the upper part of the flow proved to be highly vesicular and thoroughly silicified.

Silver Mountain Area

The best exposures of the beds of Division 4 in Silver Mountain area occur along the base of the cliffs north of the railway in lot 5, concession II, Strange township; at Whitefish falls in R 190, concession IV, Strange township; and along the north-south road between lots 4 and 5, concession V, Strange township. The thickness of the bed characterized by abundant chert with algal structures is less in this area than in the others already described and the usual fourfold division cannot be made. In general the thickness may be stated to vary between 4 and 10 feet, with both the upper and lower surfaces irregular. The usual hummocky upper surface is present and there is a gradational change upward to the lowest bed of Division 5.

The usual speckled cherty taconite accompanies the algal chert and the granules locally show concentric banding due to the addition of rhythmically banded chalcedony and greenalite to granules of the normal type. The lower boundary of the algal chert may appear quite sharp or there may be a rapid gradation to the massive beds which underlie it. The latter are from 3 to 5 feet thick, weather grey or greenish grey, and contain a few elongated lenticular jasper seams. Microscopically, the algal chert has the usual composition, but the proportion of hematite to greenalite is higher than in most of the other occurrences.

DIVISION 5 (UPPER SLATY)

North Lake Area

Division 5 comprises all those rocks which lie above the algal layer and below the Rove slate. To the north of North lake, only the lower 60 feet of the beds have been preserved. The total thickness of the division is estimated from sections east and west of North lake to be about 200 feet. A diabase sill intruded at an horizon about 60 feet above the base of the division forms precipitous cliffs on its north, northeast, and northwest sides, and in these cliffs, below the sill, are all the exposures of the beds in question. Naturally those near the bottom are covered by talus material and the lowest beds appearing in outcrop are about 20 feet above the base of the division.

The 40 feet of beds exposed include a variety of rock types. In outcrop they appear as fine-grained, compact, somewhat reddish to almost black, thin-bedded rocks, resembling argillites in appearance, but differing widely from them in composition. From their high specific gravity and general appearance, it is clear that many of them contain a high but widely varying proportion of magnetite and hematite. Surface oxidation and hydration have produced locally patches of hydrated iron oxide. Jointing is much more pronounced than in the other beds of the formation. Two sets are prominent, with directions approximating north-south and east-west. They are spaced from 1 to 2 inches apart on the average. With the bedding planes, they divide the beds into small prismatic blocks which give the outcrop a very striking appearance. Bedding planes usually mark an abrupt change in composition. Beds vary in thickness from a fraction of an inch to 1·5 feet. Some of them are lenticular in form.

One variety of rock is a mottled, ferruginous chert, very dense, hard, greenish-black, and made up of many minute, somewhat irregular, but usually rudely lenticular, masses differing from one another not in the nature of their constituents, but in the proportions in which they are present. These interlock and are arranged with their long axes approximately parallel to the bedding. The minerals present are chalcedony, magnetite, and a dark green iron-rich silicate, probably greenalite. Some of these masses are made up of greenalite and chert, the latter tending to form segregations; others are largely of chert with disseminated magnetite. The magnetite retains the crystal form of original hematite in many cases and probably most of it has formed from that mineral, though only a few microscopic remnants of hematite now remain.

A magnetite taconite is present and in outcrop resembles the ferruginous chert, but is more homogeneous, and higher in specific gravity. In thin sections it is seen to possess a distinct granule texture, though many of the granules are imperfectly formed and have obviously suffered modification by recrystallization and perhaps replacement of certain minerals. A few preserve relatively perfect spheroidal forms. Practically all of them are composed of magnetite with only a few specks or tiny vein-like areas of chalcedony. The groundmass is granular chalcedony with which is associated a pale yellow or colourless mineral crystallizing in needles about 0·05 mm. long. These are too fine for exact determination, but probably belong to the amphibole group. They are obviously secondary products, doubtless formed in connexion with the intrusion of the sill. Migration of magnetite into the groundmass, probably at the same time, has been the chief factor tending to obliterate the original texture. The magnetite obviously has formed by partial reduction of hematite. A few granules still retain enough dispersed hematite to give them a jasper red colour. Lenticular masses of jasper were also observed at a few points. Pyrite has replaced hematite crystals in a few places. More rarely it develops its characteristic forms.

Hematite taconite occurs. It probably is related in origin to the magnetite taconite, but is not so rich in iron and has suffered less alteration. In outcrop it is jasper red, due to innumerable closely packed jasper granules. The beds thicken and thin rapidly along the outcrop. Those exposed average about 5 inches in thickness. In thin sections the granules are found to be composed of varying amounts of microscopic particles of hematite dispersed through chalcedony. Some granules are apparently a solid mass of hematite, others are of chalcedony nearly free from hematite. In those of intermediate composition either constituent may locally predominate. The black granules often grade out at their borders to extremely fine mixtures of crystalline silica and hematite particles, indicating that the apparently homogeneous central parts may in reality be ultramicroscopic intergrowths of the same minerals in which the opaque hematite particles mask the transparent chalcedony. The granules show shrinkage cracks similar to those in the greenalite granules. The filling is granular chalcedony similar to that making up the groundmass. The chalcedony of the granules appears almost isotropic between crossed nicols. Each granule is surrounded by a shell about 0·02 mm. thick, of more coarsely crystallized silica, with the crystals perpendicular to the periphery of the granule. The remainder of the interstitial spaces is filled by chalcedony partly spherulitic and partly microgranular. Calcite replaces the spherulites locally. Polished sections show that the hematite of the granules has been locally altered to magnetite, but the total quantity of magnetite is small in most of the beds. A few show quite extensive alteration and in such cases the granule texture has been considerably modified and the bed assumes a dark reddish brown colour in place of the normal jasper red. At high magnifications some of the minute particles of hematite may be seen to be grouped in minute rings about nuclei of silica. These rings may be aggregated into larger rings (less than 0·01 mm. in diameter), or into lath-shaped forms resembling cross-sections of hematite crystals; more usually they are uniformly dispersed through the chalcedony.

Tuffaceous shaly beds are present and resemble normal shales much more closely than the other beds of the division. They are black to greenish black, fissile, thin bedded, quite soft, and when scratched yield a white powder. They do not show rapid thickening and thinning, so characteristic of the other beds. Under the microscope the texture is seen to be decidedly fragmental. Angular particles such as would be produced by disruption of an igneous rock are distributed through a fine-grained matrix, probably mostly greenalite or some closely related chloritic substance. A few scattered grains of magnetite are commonly present. Mica flakes are locally abundant, lying parallel to the bedding. Their ragged outlines indicate that they are original and not developed by metamorphism.

A more massive tuffaceous bed, 18 inches thick, is exposed at one point near the base of the sill. It is especially interesting because it possesses a granule texture, and is very persistent. It outcrops at the same horizon in both Little Gull Lake and Silver Mountain areas. The unique texture of this bed and the fact that the compositions in the three cases are almost identical, leave little room for doubt as to the validity of this correlation. In outcrop it is a dark greenish grey to greenish black rock with an irregular fracture. A few mica flakes can be distinguished in hand specimens, but otherwise the texture is microscopic. There is a gradational change upward to finer grained, more cherty material holding numerous lenses of almost pure white or yellowish chert. In thin sections it is found to be composed of a multitude of microscopic fragments cemented by a dark green amorphous substance probably closely related to greenalite, and a paler green, crystallized, matted aggregate of a mineral too finely crystallized for precise determination, but probably belonging to the amphibole group. In many cases it replaces fragmental particles, particularly orthoclase, and also occurs interstitial to well-formed granules. The granules have as a base the greenalite-like substance and at high magnifications are seen to be heavily charged with very fine, partly altered, angular particles. Small amounts of the greenalite-like mineral appear outside the granules. The pale green amphibole is very rarely developed within the granules. The fragmental particles, which are abundant both within the granules and the groundmass, include: orthoclase, remarkably fresh, except where partly replaced by matted amphibole; plagioclase feldspar, identified by twinning in only one instance, but untwinned varieties are probably present; a few flakes of muscovite; and clear quartz grains, sharply angular. In addition to these, lava fragments with white, microlitic laths, probably plagioclase, and others of partly devitrified glass, are present, many of the latter partly altered to greenalite. That this material is mainly pyroclastic in origin can hardly be doubted.

Of the beds described above, mottled ferruginous chert, magnetite taconite, and tuffaceous shaly beds are the most abundant. Hematite taconite makes up only about 3 feet of the thickness exposed. In the other areas mapped, the lowest bed of the division is a conglomeratic cherty taconite. An equivalent bed is probably present in this area, also, but not exposed.

Bishop Lake Area

In Bishop Lake area all the exposures of Division 5 appear in the east-west cliffs just south of the railway and in the southeast part of the area. The strata have been intruded by three sills which have effected some very marked changes in their textures and in the minerals composing them. The total thickness of the beds preserved is estimated at 105 feet. Of these, only 5 feet at the bottom and the upper 20 feet are exposed. A considerable thickness has been removed by erosion. It is estimated from the other sections that the original thickness was about 220 feet.

The basal 4 feet of massive, cherty, and magnetitic beds have a very striking appearance. Stringers of quartz about one-eighth inch wide surround masses of cherty hematite taconite more or less circular or oval-shaped in section, and locally the rock resembles a conglomerate. In some places rays of quartz pass out from the above stringers, wedging out within short distances as in septaria. The cherty taconite holds some jasper granules and is identical with some of the taconite associated with the algal chert. In parts of the bed magnetite is quite abundant and in places forms lenticular masses, some outlined by quartz veinlets. Toward the top a one-foot bed, rich in magnetite, holds lenticular and more irregular masses of chert distributed in such a way as to suggest partial replacement of an original bed of different composition. That at least some of the magnetite is secondary is shown by the fact that it appears as minute veinlets cutting the chert. Amphibole appears at many places within the bed, intergrown with chert and magnetite or as distinct veinlets.

Angular fragments of hematite-taconite in the drift indicate the occurrence of at least a moderate thickness of beds of this type corresponding to those appearing in the North Lake section and more prominently developed in the sections farther east.

In the upper 20 feet, beds up to 14 inches thick occur, but usually they are 6 inches or less. Beds of massive white or yellowish chert are interbedded with others green or black in colour. Veinlets of goethite, or of quartz and actinolite or grünerite, appear locally. The light-coloured cherty beds, frequently discoloured by small amounts of limonite, are seen in thin sections to be composed almost entirely of crystalline silica of varying texture. Matted patches of amphibole needles appear locally. These beds are much more numerous towards the top of the exposures. Near the bottom they are discontinuous and finally are represented by a series of small lenses confined to definite beds of the darker variety. In the dark-coloured beds, the green colour is due to amphiboles and the black to magnetite. All gradations of colour exist. Pyroxene has developed locally, but is seldom very prominent. The fine banding which is common in these dark beds is due to slight variations in the proportions of the above minerals. Bedding planes mark sharper changes in composition, such as from a very siliceous bed with only minor amounts of magnetite and amphibole, to one in which the dark-coloured constituents are dominant. Polished sections show that the magnetite is very finely crystallized. Areas of considerable size are present, but these are invariably made up of a large number of extremely fine crystals. None of the above beds show a granule texture, nor is it likely that they ever possessed it, unless locally, in some of the darker beds, as in a few of those of the corresponding division in Little Gull Lake area.

Little Gull Lake Area

Little Gull Lake area yielded the most complete section of Division 5 ("Upper Slaty" beds). It includes a variety of rocks. Almost pure chert, greenalite taconite, hematite taconite, thin, slaty, tuffaceous, and carbonate-rich beds, siderite-greenalite rock, and magnetitic limestones are the chief types and, in addition, various other beds derived from the above by contact metamorphism are very prominent. The lower beds have the usual gentle dip to the southeast, but the upper beds have been folded and brecciated locally. The presence of similarly disturbed beds in Gunflint Lake district indicates that all the region between these two points (about 35 miles along the outcrop) was affected. An unknown amount of thickening and thinning has doubtless occurred locally as a result of these disturbances.

The detailed subdivision of the section is as follows:

	Feet
Group No. 5: Folded and brecciated chert and amphibolite	110
Group No. 4: Massive amphibolitic greenalite taconite	30
Group No. 3: Thin-bedded, magnetitic and amphibolitic cherty beds with some greenalite taconite and a little siderite-greenalite rock	80
Group No. 2: Thin-bedded, hematitic, in part tuffaceous, "slaty" beds with a few more massive, cherty interbeds toward the bottom	20
Group No. 1: Hematite-magnetite taconite with thin interbeds of hematitic slate. Conglomeratic beds at bottom	30

Group No. 1. The equivalent of the basal cherty beds of Bishop Lake area with their septaria-like structures, outcrop, at one place only. The rocks are very similar to those of Bishop lake. The single outcrop occurs about 150 paces northeast of cabin No. 2. Septaria, and more irregular veinlets of quartz, are quite a prominent feature at this point. Iron oxides, now almost wholly limonite, appear usually as irregularly distributed bands not more than one-half inch thick, but are less abundant than in the Bishop Lake exposures. The bed dips 27 degrees to the southwest. The beds above also show a steep dip, but this gradually dies out giving place in the higher beds to the normal dip of about 5 degrees. The relations seem to show that the abnormal high dips are due to the wedging out of the underlying lava flow and that in this way the beds reflect the irregularity of the bottom produced by the extrusion of a lava just before their deposition.

The hematite-magnetite taconite beds of the lower part of Division 5 exhibit the wavy bedding and variable thickness characteristic of all the cherty beds. Some of the beds attain a thickness of 3 feet, but ordinarily they are less than a foot and average about 6 inches. Red is the most prominent colour and is due to the presence of jasper granules, lenticles, or more irregular patches. Green, grey, and brown granules are also present. The grey and brown granules have resulted by oxidation and hydration from the red and green forms. The average size of the granules is slightly less than 1 mm., but they vary from microscopic sizes to 2 mm. in diameter. The groundmass is in general chalcedony, but carbonates or magnetite may also be present locally. Some of the carbonate may be primary, but some is certainly secondary, for distinct veinlets of it are quite numerous. A few veinlets of magnetite were also observed cutting granules and groundmass alike and all the magnetite in the groundmass is clearly secondary. Thin sections show that these rocks are similar to the analogous beds of North Lake area. Here, however, the iron oxide content is slightly smaller, carbonates are locally more abundant, and greenalite granules are more common in occurrence. The granules are quite sharply defined and present the usual variety of forms. The boundaries are always marked by magnetite and hematite, present either as a swarm of minute grains or groups of interlocking crystals. Usually they form a fairly continuous shell about the granule. Some granules are mainly iron oxide, but polished sections show that the granules are never composed entirely of one mineral. Usually the proportion of silica in the granule is high and the oxides are dispersed through it in fine particles or appear as groups of crystals segregated about the borders. Polished sections show clearly that in most cases the magnetite has been derived from hematite by partial reduction, for it commonly has the characteristic crystal forms of hematite. It seems probable that all of the iron now present as oxides was originally in the form of ferric oxide. Toward the top the proportion of iron oxides increases markedly, the development of granules is less perfect, and, instead, larger lenticles and clots of jasper appear in considerable abundance. Elongated granules or lenticles are always oriented with their longest axis parallel to the bedding. Greenalite was observed in one slide as shred-like patches in the groundmass.

Under high magnification many of the minute particles of hematite in the jasper granules show ring-shaped forms, some distinct, homogeneous, lath-shaped crystals are usually present, and many cellular laths with the same outward form were observed. These cellular crystals lose their pitted appearance on changing to magnetite, for magnetite pseudomorphs after hematite are always homogeneous.

The groundmass of one of these rocks has been recrystallized to an unusually coarse-grained aggregate of quartz crystals. Several of the large individuals, though themselves irregular in outline because of interference with adjacent crystals, have their inner two-thirds charged with a multitude of microscopic greenalite particles. In the case of one crystal which happened to be cut parallel to the base, this greenalite-charged part has a clearly defined hexagonal form, showing that the distribution of the particles has been controlled by the crystallographic forces of the quartz.

Most of these massive beds, and particularly the lower, more siliceous ones, are traversed by a great many incipient or clearly-defined joints. Some of these have been filled and the walls partly replaced by carbonates. A veinlet one-quarter inch wide may be seen to pass from the upper surface of a bed half-way through it and then be cut off sharply. Such abrupt endings are in all cases caused by abrupt changes in the texture or composition of the bed. In one case the change was observed to be from normal granules or iron oxide and chalcedony to greenalite granules; in another from a spherulitic groundmass to a coarsely granular one. If the bed is uniform in composition and replacement has been slight, the veinlets may wedge out as with normal veining. Irregular swells may occur at any point where the composition of the bed made it particularly susceptible to replacement. Selective replacement of the finer textured silica can in many cases be observed to have occurred. In such cases, patches of abnormally coarse-grained chert remain, whereas all of the spherulitic and finely granular chalcedony both in the groundmass and granules has been replaced by the carbonate.

Group No. 2. The ferruginous and in part tuffaceous slates are extremely fine grained, reddish to almost black, and have usually many closely-spaced partings parallel to the bedding. Many of the lower beds have weathered to a limonite-stained mass and these proved to be much more ferruginous than the others when polished sections were examined. Both hematite and magnetite are present. Hematite usually appears as remnants in the magnetite, but it is also present as fine, disseminated particles locally arranged in minute rings as in the massive beds. Pyrite has replaced hematite in a few instances and in one case was observed to have inherited the ring structures of the hematite. The total amount of pyrite is extremely small. The bulk of the beds is composed of extremely fine material which could not be determined accurately, but some of which, at least, is believed to be volcanic ash, altered perhaps to chloritic material as in the tuffaceous bed mentioned below. In certain beds fragmental particles of microscopic sizes, identical with those appearing in the tuff, were observed, and the presence of finer pyroclastic material, therefore, seems the more probable. Near the top of this group of beds there is a 1·5-foot tuffaceous bed with an obscure granule texture, which, from its general appearance and microscopic texture, is undoubtedly the equivalent of the massive tuffaceous bed found at about the same distance above the algal chert in North Lake area. The description given for that occurrence applies equally well to this.

Group No. 3. The succeeding group of beds listed in the above section, about 80 feet in all, includes a variety of rock types. The grouping is made rather on the prevalence of thin beds than on any close similarity of composition throughout. In general there is a rapid alternation of cherty and slaty beds. The former vary from an inch to a foot in thickness and have the other characteristics of cherty beds. The slaty beds vary from paper-thin to one-half inch and many are heavily charged with magnetite. One of the most common rock types in the lower part of the group is a siderite-greenalite rock, fine grained, brown-weathering in outcrop, and greenish grey on fresh fractures. Usually it is so fine in grain that individual particles cannot be distinguished in hand specimens, but occasionally recrystallization has occurred and it is seen then to be a matted aggregate of extremely fine amphibole needles. A thin section of the unaltered phase showed it to consist of an intimate intergrowth of siderite crystals and a grass green isotropic substance, probably greenalite. The siderite forms distinct rhombic crystals and the greenalite is interstitial. A few angular particles of quartz and a little secondarily introduced chert with associated magnetite were also observed in this slide. Banding in the individual beds results from variations in the proportions of the constituents. A few beds from $\frac{1}{8}$ inch to 2 inches thick are almost pure siderite. The slaty partings separating the beds of the above type are seldom more than $\frac{1}{16}$ inch thick and usually include more iron oxides. They probably also contain small amounts of pyroclastic material.

Chert lenses appear at intervals, but are particularly abundant at certain horizons. In places several have coalesced to form continuous beds 10 feet or more long, but usually they do not exceed a foot in length and in more cases are only a few inches. Some of them appear flinty and homogeneous throughout, others have a distinct granule texture. A thin section of the flinty material shows a multitude of microscopic segregations of greenalite (about 0·01 mm.), somewhat irregular in outline, but approximately equidimensional, distributed fairly uniformly through the chalcedony, which may be either spherulitic or microgranular. The greenalite segregations in many cases form nuclei for silica spherulites. The coarseness of the grain of the chalcedony varies inversely as the concentration of the greenalite segregations in any given field. One set of fractures in these chert beds has been filled by chert and this has been followed by a second veining by a carbonate containing some $FeCO_3$, but dominantly $CaCO_3$.

At a point about 10 feet above the base of the group a 3-foot bed of typical greenalite taconite appears. Higher in the series beds with a similar texture appear, but in most cases they have suffered considerable alteration. In part of the massive 3-foot bed, the groundmass and part of the granules have been replaced by carbonates and, consequently, it weathers out rapidly to a cellular mass at such points. Some of the granules are exceptionally large. The maximum observed was 2 mm. by 1 mm. in cross-section.

Toward the top of the group the thin, slaty beds become richer in iron oxides. Some of these show a granule texture locally and under the microscope it is seen that magnetite forms a large part of the granules. Some of this is in the form of fine particles suggesting development from original jasper granules. More typically the granule texture is absent and the beds consist of scattered microscopic particles of magnetite in chert. The borders of these particles show straight-line elements, but no individual crystals could be picked out in the specimens polished and examined microscopically.

The upper beds of this group commonly show signs of disturbance whereby the dip has been increased locally. This becomes much more pronounced in the beds above.

Groups Nos. 4 and 5. Massive, cherty, calcareous, and amphibolitic beds form the upper part of the iron formation. The beds vary less in composition and are thicker than the strata of the group just described. The lowest beds of the group are dominantly cherty, some magnetitic limestone beds appear near the middle, and the upper beds which were probably originally calcareous, with interbeds of cherty and greenalite taconite, are now amphibolites with a great many angular fragments of the cherty beds distributed through them in a very irregular manner. Evidently these beds have been subjected to violent disturbances which have disrupted the brittle cherty beds, whereas the calcareous beds have yielded plastically. Some of the lower, massive beds have simply buckled, large slabs acting as units. Contact metamorphism at the time of the intrusion of the large sill which caps Mink mountain has resulted in the development of great quantities of amphiboles and smaller amounts of magnetite and other minerals. The intensity of this alteration decreases as one proceeds downward in the series away from the base of the sill.

The lowest beds in this group are thick, massive, amphibolitic taconite beds, grey or brownish grey in outcrop. They include many irregular patches of amphibole, green on fresh fractures, but weathering to black or bluish black. In thin section the rocks show a distinct granule texture, though this has been partly obscured by alteration. The granules consist of a matted aggregate of green to bluish green amphibole needles which show a marked tendency to form radiating groups. The optical properties indicate that this mineral is iron-rich actinolite. The development of a certain amount of amphibole in the groundmass is the chief factor causing obliteration of the original texture. A certain amount of veining by amphiboles has also occurred. Oxides of iron are not prominent, but, locally, bands quite rich in magnetite may be present. Such bands appear under the microscope as a confused mass of silica, magnetite, and matted amphiboles. Limonite is usually present as a product of recent oxidation. Thin carbonate beds appear as partings between the thick, cherty beds. They seldom exceed 2 inches in thickness and are composed almost wholly of carbonates, dominantly $CaCO_3$, though some iron carbonate is almost always present, and they probably approach most nearly to ankerite in composition.

Several feet of grey, magnetitic limestone occurs near the middle of the group. The thickness cannot be determined accurately, nor can individual beds be traced for any distance because of disturbance, which has caused local thickening and thinning and in places has pinched some of them off altogether. Beds up to 3 feet in thickness were observed. They usually contain angular fragments of associated cherty beds. A thin section showed the grey limestone to be heavily charged with microscopic magnetite particles (about one-thirtieth mm. in diameter) quite uniformly distributed and many showing octahedral outlines or combinations of the octahedron and cube. The remainder of the rock is made up of interlocking grains of calcite about 0·1 mm. in diameter. A small amount of amphibole is visible at high magnifications.

The fragments of cherty taconite and greenalite taconite in the uppermost beds have suffered considerable alteration, the principal change being the development of amphiboles. A few of them retain a recognizable granule texture, but most of them are composed of chert with disseminated grains of magnetite and irregularly distributed bands and patches of amphiboles. The amphiboles which form the major part of the matrix in which the chert fragments lie, vary considerably in composition, but the most common variety is pleochroic, with X=yellow-green, Y=green, Z=blue-green. The maximum extinction angle is 12 degrees. The mineral usually appears as acicular crystals forming radiated groups. Varieties with less pronounced pleochroism are locally present. Their extinction angles vary from 11 to 15 degrees. These optical properties do not agree precisely with any of the members of the amphibole group listed in the text books, but they resemble actinolite most closely. All of them are doubtless rich in iron and low in magnesium. Small amounts of magnetite are distributed as microscopic grains through the amphibolite and locally a little pyroxene may be present. No other minerals were identified from this locality.

Silver Mountain Area

Many excellent exposures of the beds of Division 5 appear in Silver Mountain area in the cliffs and steep slopes below the sills which cap the hills in the area. The distribution of these outcrops is such as to give no continuous section from which the total thickness of the beds could be calculated. The heavy drift cover in the valleys and the presence of faults, make it difficult and in many cases impossible to determine the relationship between exposures separated by comparatively short distances, for the beds of this division vary quite rapidly in composition horizontally. The best information regarding the thickness of this division is that made available by mining operations on Silver mountain. Shaft No. 3 of the Silver Mountain mine, which is the deepest, has been abandoned for a number of years and is not accessible, but Mr. M. L. McEwen, who was in charge of the work during the sinking of the shaft, gives the following figures, which agree fairly well with the writer's observations on the north slope of the mountain and with statements made by other men familiar with the mine. The amount and nature of the material on the dump are also in agreement with these figures, so they may be regarded as fairly accurate.

	Feet
Diabase	60
Slate	340
Cherty beds with jasper toward the bottom	490
	890

Combining this information with that obtained in the field, the section is approximately as follows:

	Feet
Group No. 5: Magnetitic greenalite taconite interbedded with ferruginous limestone and dolomite	120
Group No. 4: Massive, cherty carbonate beds with thin cherty interbeds and lenticular masses of chert	20
Group No. 3: Thin, lenticular beds of hematite-greenalite taconite with carbonate-rich partings	10
Group No. 2: Massive, thick beds of greenalite taconite, locally magnetitic, with thin carbonate-rich and magnetitic interbeds. Probably thinner cherty and slaty beds toward the bottom, as in group No. 3, Little Gull Lake area	190
Group No. 1: Hematite taconite, locally magnetitic. Interbeds of black, slaty, in part tuffaceous material	60

Group No. 1. The hematite taconite of this group is identical with the hematite taconite of North Lake area. The best exposures appear in the cliffs in lots 4 and 5, concession II, Strange township, and in the beds of Whitefish river just below the falls (R 190). At these points, however, contact metamorphism has altered most of the original hematite to magnetite. The lowest bed, which overlies the algal chert of Division 4, is conglomeratic in appearance. More or less rounded, pebble-like masses and somewhat irregular patches appear within material of slightly different composition. Usually granules are visible in all parts of the rock. The distinction between the pebbles and the matrix is brought out more clearly on weathered surfaces, where it may sometimes be seen that the cement in the pebbles is calcite, whereas that of the remainder of the rock is chert. Locally, septaria are present. In the 10 feet of similar beds, higher in the section, which also contain a few greenalite granules, they are abundant.

The slaty and tuffaceous beds vary from a fraction of an inch to several inches in thickness, are extremely fine grained, and either black or reddish brown. Many beds, originally hematitic, have been changed to black magnetitic phases by contact metamorphism. Probably all contain a certain amount of tuffaceous material. A 20-inch tuffaceous bed with a granule texture appears in outcrop at both of the localities named above. The materials forming this bed are identical with those described from the North Lake occurrence, but the granules are locally much larger, giving a pisolitic appearance to the outcrop. In the exposure in the bed of Whitefish river, joint blocks about 2 inches on the side show concentric weathering. When the outer earthy coatings are removed and the core broken open, the coarse green granules up to one-quarter inch in diameter are barely visible, in a groundmass of only slightly different colour. If the specimen is wet the large granules may in many cases be seen to contain a number of smaller ones. Some of the granules show a rude concentric banding produced by varying concentration of magnetite particles, none of which was observed to show crystal outlines. The magnetite probably was originally ferric oxide, for the definite concentric arrangement cannot be readily explained by alteration of the other constituents of the granules, which are evenly distributed chloritic material resembling greenalite and fragmental particles of igneous rock minerals.

Group No. 2. The only exceptional feature of the greenalite taconite beds, when unaltered, is the unusually large size of the granules, which average well over a millimetre in diameter. The exposures on the north side of Silver mountain and in the hills to the eastward are quite rich in magnetite, which has probably been developed from greenalite. Some beds are as much as 6 feet thick without a parting. They are separated by thin amphibolitic and magnetitic beds, which commonly weather to limonite. In the north part of R 104 a section of beds 153 feet thick is exposed. The upper 35 feet has been extensively metamorphosed, but the lower 120 feet is practically unaltered.

Group No. 4. The massive, cherty carbonate beds of this group in some cases are 4 feet or more thick, grey or yellowish in outcrop, and are composed almost entirely of chert and carbonates in variable proportions. Locally either may dominate, but usually the chert is the more abundant. Microscopically a few greenalite granules are distinguishable, scattered at wide intervals, and granule-shaped areas may be outlined by the varying coarseness of grain of the chalcedony, but ordinarily there is a confused variation from spherulitic to microgranular chalcedony, with variable amounts of carbonates, partly secondary and partly primary. Some exceptionally well-formed spherulites of silica are present. Rhombic crystals of siderite were observed locally, partly altered to magnetite. The development of their characteristic form is not affected by change of texture from granule to groundmass and they are, therefore, regarded as earlier in crystallization than the chert. Secondary calcite, locally ferruginous, probably related to the Keweenawan veins which cut the area, is locally abundant.

Group No. 5. The beds vary from pale grey to almost black and contain a variable amount of impurities, particularly iron, probably as $FeCO_3$ in isomorphous mixture with the other carbonates, and chert. Most of them weather rusty reddish brown. All gradations between these and the cherty carbonate beds described above are present. It seems probable that some at least of the $CaCO_3$ in these beds is secondary. Only a few isolated outcrops were seen and it was not possible to judge as to their continuity horizontally. Ingall[1], speaking of the iron formation—which he called the lower, predominantly cherty division of the beds in Silver Mountain area—says: "The calcareous and dolomitic portions are only developed to any extent locally, although the whole formation contains more or less of these minerals distributed through it." On the same page he states that Mr. G. C. Hoffmann made a chemical examination of a nodular bed and found that the nodules were distinctly dolomitic, whereas the remainder of the rock contained no magnesia. Similar variations in composition were observed by the writer, though none of the beds observed could be said to have "the appearance of a conglomerate". These variations are brought out clearly by weathering. Lenses of flinty chert, and cherty taconite were observed within these beds in one or two places. Many of the thin interbeds separating the more cherty beds described above are composed largely of carbonates. These are dominantly calcareous in most cases, but a few are nearly pure siderite.

CONTACT METAMORPHISM

Intrusion of the sills has had a marked effect on some of the beds of the iron formation. In general, the greenalite taconite beds show the most profound changes, but the other rocks have also suffered pronounced alteration locally. In most cases both recrystallization and the development of new minerals occurred and this partly obliterated the original textures.

The effects of contact metamorphism on the greenalite taconite beds are best displayed by the beds between the two sills in the hill just east of Shekaka creek in North Lake area. The greatest changes have taken place in the beds immediately below the larger sill, which caps the hill.

[1]Geol. Surv., Canada, Ann. Rept., vol. III, pt. H, p. 83 (1887).

Here the original texture of the rock has been entirely obliterated and it consists almost entirely of finely crystallized, matted amphibole needles. Lower down the alteration has been less intense and the granules are still distinguishable. Pale yellowish green amphibole, in hair-like crystals with an extinction angle of 10 degrees and moderate double refraction, is developed in great abundance. Magnetite is prominent and most commonly appears about the borders of the granules, though it is also present as scattered grains within the granules. Both magnetite and amphiboles have developed to some extent within the groundmass.

The beds of the Upper Slaty division show similar alteration, but less amphibole has been developed. The change from hematite to magnetite seems to be the most pronouncd. Some recrystallization of the chert has also occurred.

In Bishop Lake area, the relationship between the distribution of the amphibolitic beds and the positions of the diabase sills in the section is so marked as to leave no doubt as to their connexion with the formation of the amphiboles and pyroxene. The conspicuous development of magnetite to the exclusion of hematite in the above beds is also attributed to contact metamorphism. All of these are high temperature minerals. Remnants of a sill cap beds of Division 3 in the butte and downfaulted block in the northwest part of the area. The alteration here has been less intense, but there has been a complete recrystallization within the granules, which are a matted aggregate of amphiboles with a few lath-shaped crystals of epidote charged with oxide particles. The groundmass has assumed a coarser grain and amphiboles have developed between the grains.

In Little Gull Lake area, the most conspicuous changes have occurred in the uppermost beds of Division 5, due to contact metamorphism by the large sill, part of which caps Mink mountain. Actinolite has been developed in great abundance in the calcareous parts. Greenalite taconite has been changed to amphibolitic chert. Magnetite has developed in considerable amounts locally. Further details are included with the descriptions of the beds.

In Silver Mountain area, the beds adjacent to the sills show pronounced changes which undoubtedly took place during the period of intrusion. The thickness of beds affected varies considerably from place to place along the same sill and is much more marked near the larger ones than near the small ones.

In general the new minerals developed are such as could readily form from the constituents originally present in the rocks, and no good evidence of any considerable addition of materials from the magmas has been found.

Greenalite near the sill contacts has, in all cases observed, been recrystallized, possibly with the addition of other elements, to amphiboles. Farther away it appears in many cases to have broken down under the influence of the high temperature to form magnetite and quartz. Where carbonates were present in the original rock, calcium-iron amphiboles, containing locally some magnesium, formed in great abundance. If aluminous silicates were present epidote and chlorite may have formed, but this was observed to have occurred only in two places, and in these it is not certain that the alumina was not derived from the magma. The chert of the groundmass, if it has not united with other elements to form silicates, has in general been recrystallized to a coarser-grained aggregate of interlocking quartz crystals.

In a few places, notably in the northward-facing cliffs of Silver bluff and Divide ridge, there has been fairly complete assimilation of the sediments for a few feet from the contact and the change has been so complete that it is impossible to say just where the sediments end and the sill commences. There is a perfect gradation from one to the other. On the south side of Divide ridge, the alteration is much less striking. The original hematite taconite, with perhaps a few greenalite granules, has been changed to a rock rich in magnetite. That the magnetite has practically all been derived from hematite is clearly shown by the many pseudomorphs of the former after the latter. Other changes have been slight. The remarkable difference between the alteration on the north and south sides of this hill suggests the possibility that volatile constituents have played a part in the more extensive alteration on the north side. The other alternative is that the original compositions of the beds varied sufficiently between the two points to have caused this marked difference in reaction to conditions of metamorphism essentially the same. The beds on the north side are more massive than those exposed beneath the sill on the south side and the products of alteration are identical with those formed by metamorphism of greenalite taconite. It seems probable, therefore, that the sill has risen somewhat in the series toward the north and the beds exposed beneath it on the north side belong to a higher horizon than those appearing beneath it on the south side. The former were probably originally greenalite taconite with thin, slaty interbeds.

CORRELATION

Broderick[1] in a paper on the part of the Gunflint formation in northeastern Minnesota, says, "The propriety of correlating the Gunflint iron-bearing formation with the Biwabik formation of the Mesabi Range is no longer questioned." "The most recent detailed studies of the region lead to the conclusion that both formations are the middle member of the Upper Huronian or Animikie group."[2] The correlation table shows the general similarity between the stratigraphy of the two formations and is convincing proof of their contemporaneity and probable former connexion. Three excellent horizon-markers appear in both formations, all of which are persistent throughout the Gunflint formation so far as examined by the writer and throughout the greater part of the Biwabik formation. These are the two horizons of algal chert, one at the very base of the formation associated with and overlying the basal conglomerate, the other at the top of the Upper Cherty division in Mesabi district, designated Division 4 in this report; and the thin, slaty member at the base of the Lower Slaty of Mesabi district, known as the Intermediate Slate and designated Division 2 in this report. All three of these have persistent characteristics which are readily recognized in the field.

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[1] Broderick, T. M.: "Economic Geology and Stratigraphy of the Gunflint Iron District, Minnesota"; Econ-Geol., vol. 15, p. 435 (1920).
[2] Grant, U.S.: Final Rept., Minn. Geol. and Nat. Hist. Surv., vol. 4, pp. 462–490.

Total Thickness

Location	Feet
Buhl. Sec. 21, tp. 50 N, range 19 W. Minn. Survey (after Gruner)	710
East of Mesaba. Range line 14–13 W. Minn. Survey (after Grout and Broderick)	419
East of Dunka river. Range 12 W. Minn. Survey (after Grout and Broderick)	340
Gunflint district, Minnesota. Minn. Surv. (after Broderick)	310
North lake, Ontario	413
Bishop lake, Ontario	441
Little Gull lake, Ontario	477

Buhl. Sec. 21, tp. 50 N, range 19 W. Minn. Survey (after Gruner)

	Bed	Feet
Upper slaty	Slate and lime carbonate	10
	Slate and chert Greenalite, slaty, and cherty taconite; conglomerate	85
	Conglomerate Cherty taconite	93
Upper cherty	Conglomerate and algal chert	5
	Conglomerate and cherty taconite Cherty taconite	107
Lower slaty	Red slate and slaty taconite	55
	Greenalite slate and slaty taconite	20
	Cherty taconite	27
	Greenalite slate and black slate	43
Lower cherty	Greenalite and mottled taconite	80
	Irregularly banded taconite	120
	Slaty and cherty taconite	53
	Quartzite	12

East of Mesaba. Range line 14–13 W. Minn. Survey (after Grout and Broderick)

Bed	Feet
Calcareous bed	10
Lean, quartzose taconite	45
Thin-bedded taconite	30
Septaria and thin beds	40
Conglomerate taconite	10
Algal jasper	5
Conglomerate taconite	22
Bedded taconite Granules and conglomerate	105
Siliceous taconite (amphibole)	65
Black slate	25
Algal chert	10
Cherty taconite (magnetite)	42
Basal conglomerate	10

East of Dunka river. Range 12 W. Minn. Survey (after Grout and Broderick)

Bed	Feet
Lean quartzose taconite	40
Thin-bedded taconite	50
Magnetite Bedded taconite Conglomerate	95
Siliceous taconite (amphibole)	70
Altered slate	15
Ferruginous, cherty taconite	60
Basal conglomerate	10

Gunflint district, Minnesota. Minn. Surv. (after Broderick)

Bed	Feet
Limestone	10
Thin-bedded quartz-amphibole-carbonate rock with lenticular interbeds of almost pure chert. All beds drag-folded	140
Massive chert, algal chert, some conglomerate, and a little magnetite	20
Lenticular cherty beds Thin beds of magnetite	25
Thin-bedded cherty, amphibole-magnetite rock	45
Massive chert and a few slaty seams	25
Black slate	15
Massive chert	15
Magnetite-amphibole rock	10
Algal chert and conglomerate	5

North lake, Ontario

Bed	Feet
Unexposed (estimated)	135
Diabase sill	
Magnetitic and tuffaceous slates Hematite-magnetite taconite	60
Conglomerate taconite	5
Conglomerate and algal chert	15
Greenalite taconite with small magnetite nodules	50
Cherty taconite with nodules and irregular patches of magnetite and hematite; interbeds of greenalite taconite	70
Greenalite taconite with sideritic slaty partings	50
Cherty taconite	5
Intermediate slate	8
Cherty taconite, algal chert, and conglomerate	15

Bishop lake, Ontario

Bed	Feet
Unexposed (estimated)	115
Diabase sill	
Thin-bedded magnetite-amphibole chert; lenticular interbeds of almost pure chert. Two sills (8 feet and 10 feet) near the top Hematite-magnetite taconite	105
Conglomerate taconite	5
Algal chert	6
Conglomerate cherty taconite	20
Magnetitic and cherty taconite	35
Carbonate-rich cherty beds. Carbonate nodules abundant, up to $\frac{3}{4}$-inch diameter Small amount of greenalite taconite	120
Cherty taconite	5
Intermediate slate	10
Algal chert	5
Greenalite taconite and conglomerate	15

Little Gull lake, Ontario

Bed	Feet	
Brecciated, cherty taconite in matrix of amphibolite Magnetitic limestone, folded and including chert fragments	110	Division 5
Massive amphibolitic chert. Thin carbonate partings	30	
Thin amphibolitic cherty beds, magnetite towards the top Greenalite taconite Greenalite-siderite slate	80	
Ferruginous, in part tuffaceous, slates Hematite-magnetite taconite	50	
Conglomerate taconite	5	
Algal chert	7	Division 4
Cherty taconite	10	
Magnetitic greenalite taconite and cherty taconite	30	Division 3
Greenalite taconite with abundant carbonate nodules Thin carbonate beds	40	
Greenalite taconite; cherty taconite; partings of greenalite-siderite and magnetite-siderite slate	75	
Cherty taconite	5	
Intermediate slate	15	Division 2
Cherty taconite	10	Division 1
Algal chert and conglomerate	10	

The fourfold division used in Mesabi district can be applied to the Gunflint formation as far east as North lake, if no particular significance is attached to the terms " cherty " and " slaty." Farther east there is no basis for dividing the group of beds between the Intermediate Slate and the upper layer of algal chert. This is well exemplified by the Bishop Lake section where a continuous sequence of beds, almost indistinguishable from one another as seen in outcrop, extends from the Intermediate Slate to within about 35 feet of the algal chert horizon. The upper 45 feet are somewhat more magnetitic than those below and lack the abundant carbonate nodules which characterize the lower beds. The other dividing lines, since they are placed at the Intermediate Slate and the upper algal chert horizons, are readily located. It should be pointed out, however, that the so-called " slaty " divisions, as well as the " cherty " divisions, are dominantly composed of cherty beds.

The table shows that the formation is thickest toward the extreme east and extreme west of the length of outcrop represented by the sections[1] —and that it thins gradually from these extremes toward Gunflint Lake district. The gradual thinning of the beds below the Intermediate Slate seems to indicate a progressive overlap from west to east, but it may simply represent a progressive decrease in the rate of precipitation from west to east, possibly dependent on nearness to source of supply. Later, deposition was obviously most rapid in the extreme east and extreme west, which seems to indicate at least two main sources of supply during this time.

ECONOMIC GEOLOGY

ORE DEPOSITS IN THE BIWABIK FORMATION

Iron ore deposits which have been exploited commercially on the Mesabi range may be grouped broadly according to origin as follows:

(1) Hematite-limonite ore-bodies, dependent for their concentration upon surface oxidation and solution of valueless materials.

(2) Magnetite deposits, representing beds of the iron formation originally rich in iron, modified by contact metamorphism, but with a bulk composition essentially the same as before alteration.

The processes by which the large and extremely important hematite-limonite deposits have been developed from the original iron formation are fairly well understood and have been described by Van Hise and Leith[2], from whose work a large part of the information given here has been drawn. The concentration appears to have taken place in two stages more or less distinct from one another. In the first stage, the main processes were decomposition and oxidation of the ferrous iron compounds, greenalite and siderite, to hematite, which, in part, by hydration formed limonite. This gave rocks such as those at present appearing in the walls and floors of the open pits from which the ore has been partly removed, locally known as " ferruginous cherts." The change from greena-

[1]The thickest section of the Biwabik formation (750 feet) is found in the vicinity of the "Virginia Horn", several miles to the east of the Buhl section.

[2] Van Hise, C. R., and Leith, C. K.: Mon. U.S. Geol. Surv., vol. LII, pp. 186-197 and 529-546 (1911).

lite and siderite to limonite and hematite involves a decrease in volume of from 3·6 to 19·7 per cent. This change was undoubtedly accompanied by the removal of some silica, but the oxidation of greenalite and siderite occurs so much more rapidly than the latter process that it was probably complete before much silica had been dissolved. The removal of the silica, by which the greater part of the concentration has been effected, occurred mainly during the second stage, which followed and was greatly facilitated by the development of porosity by oxidation of the iron-bearing minerals. Enrichment by solution and redeposition of iron is thought to have occurred only to a minor degree and was most important in the sideritic beds.

The localization of the decomposition and solution producing the ore-bodies was dependent on rock structures and topographic features, which controlled the circulation of ground water, and partly also on the composition of the water. The compositions and textures of the original beds doubtless had some influence, certain beds being more susceptible to alteration than others, but in general this cannot be considered as one of the most important factors, for ore deposits have been found to have developed locally from all of the several divisions of the original beds. It has been found possible to correlate the stratigraphic changes in the original beds with corresponding changes in the ore-bodies[1] and the chief influence of original composition seems to have been in determining the grade of ore developed rather than where it would develop. An exception to this statement are the so-called "flat-layered bodies," which are commonly found as extensions down the dip from "trough-bodies" and have apparently had their location determined by the presence of impervious "slaty" layers and the greater susceptibility of certain beds to decomposition.

The conspicuous structural feature which has controlled the localization of ores seems to have been more extensive fracturing in localities now occupied by ore-bodies than in the remainder of the district. The impervious basement is so gently flexed as to make it difficult to ascertain whether or not it forms pitching troughs such as have been of prime importance in localizing the ores of more steeply inclined deposits in some of the other iron-producing districts of Lake Superior region, such as the Marquette and Gogebic ranges. Wolff[2] from a correlation of data over a large part of the Mesabi range, concluded that "in the central part of the range, great broad flexures, rather than merely local ones, seem to have determined the locations of the ore-bodies. The formation was very generally cracked up and the broad structural basins directed the flow of underground waters," but Gruner[3] was unable to determine any definite relationship between the locations of ore-bodies and such broad flexures. Writers seem to agree, however, that in the Alpena and Biwabik mines the ore-bodies are related to special structures, a monocline and a normal fault, respectively. Locally, impervious rocks, such as some of the "slaty" layers in the iron formation, the underlying quartzite, dykes, etc., have doubtless had an important influence by causing convergence of circulating ground waters.

[1] Wolff, J. F.: Trans. Am. Inst. Min. Eng., pp. 1775–1777 (1917).
[2] Idem, p. 1779.
Gruner, John W.: Minn. Geol. Surv., Bull. 19, p. 65 (1924).

The area of exposure is also important, since a broad outcrop gives greater accessibility to altering solutions. The low angle of dip of the formation in Mesabi district is particularly favourable in this respect and the result has been the formation of ore-bodies with large horizontal dimensions.

Removal of silica on a large scale requires alkaline solutions. In Lake Superior region all the ore deposits are close enough to masses of igneous rocks to have been altered by waters which flowed over and derived an alkaline content from them by solution. In Mesabi district, these rocks are the Giant's Range granite, dykes, and other intrusives which form the long, narrow ridge to the northwest of the iron formation outcrop.

The supply of waters for sub-surface circulation is dependent upon climatic conditions and topographic configuration. In Lake Superior region, by far the greater number of ore deposits occur on the middle slopes of hills, where the circulating waters have considerable head and the downward flow of surface waters should be at a maximum. Exceptions to this rule occur, notably in Cuyuna district, Minnesota, but these deposits may have borne a similar relationship to an older topography. In Mesabi district, this relationship is conspicuous. The ore deposits occur flanking the Giant's range on the south side.

Only small amounts of ore are found south of the northern boundary of the Virginia slate, which overlies the iron formation. This has been explained by Leith[1] to be due to the ponding effect of the impervious slates, which prevent vigorous circulation for any considerable distance beneath them.

The ore-bodies themselves present a variety of shapes and have been aptly described by Leith as "amoeboid". The most common type is the "trough-body" which may be as much as 1,000 feet wide, nearly a mile long, and from 200 to 400 feet deep. "Fissure-bodies" are very similar to " trough-bodies " except for size, and " flat-lying bodies " are usually offshoots down the dip of the formation from "trough-bodies". The sag, due to the diminution of bulk by removal of valueless materials during concentration, is conspicuous in many of the open pits. It is usually not so in the surface configuration before the pits have been opened up, due to filling in by Pleistocene drift, which may be as much as 300 feet thick in this district. The rock walls are sharply defined and usually quite steep. A relationship between the shape of an ore-body and the directions of major joints is in some cases conspicuous.

The best information available[3] indicates that some concentration has occurred in the eastern part of Mesabi district before the intrusion of the Duluth gabbro in late Keweenawan time. The major part of the concentration in the principal productive parts of the district is believed to have occurred following the post-Keweenawan folding. This was well advanced by the Cretaceous and has probably continued to the present,

[1]Leith, C. K.: Mon. U.S. Geol. Surv., vol. XLIII, pp. 266-267 (1903).
[2]Van Hise, C. R., and Leith, C. K.; Mon. U.S. Geol. Surv., vol. LII, p. 197 (1911).

though Gruner[1] thinks that during the earlier periods " Conditions of weathering . . . must be assumed to have been somewhat different from those known to us today".

At the present time, the quantity of magnetite ores mined in Mesabi district is very small in comparison with the tremendous tonnages of the hematite ores which have been removed, but their exploitation has been commenced by the Mesaba Iron Company at Babbitt, Minnesota, and it is certain that, with the gradual depletion of the hematite ores, they will come more and more into prominence. In general, these deposits represent parts of the iron formation which, as originally deposited, contained an unusually high proportion of iron. Whatever may have been its original condition, this iron has been converted to magnetite or to intergrowths of magnetite and hematite and may now be readily concentrated by virtue of its magnetism. The beds being utilized by the Mesaba Iron Company belong to the "Upper Cherty Division" and mining has been commenced at a point where these beds have been altered considerably by the intrusion of the Duluth gabbro. Extensive recrystallization of the formation as a whole has occurred in this vicinity and the magnetite now appears concentrated in fairly well-defined bands, intergrown with small amounts of quartz and amphiboles. Bodies fairly rich in magnetite occur at various points throughout the range and tend to persist for considerable distances at definite horizons, as has been pointed out by Grout and Broderick[2] and by Gruner[3]. This persistence is in marked contrast with the hematite deposits, which bear a definite relation to the present surface and extend for comparatively short distances along the strike of the beds. However, the greater extension of the magnetite deposits down the dip adds but little to their value under present conditions, because of the necessity for using large-scale open-pit methods of mining in order to compete with the mines producing hematite ores. The depth to which mining can be carried is thus limited by practical considerations. Underground methods are too costly to be applicable to ores of this type under present conditions.

POSSIBLE IRON ORE DEPOSITS IN THE GUNFLINT FORMATION

In discussing the hematite-limonite deposits as they occur in Mesabi district, the following factors were emphasized as being of importance in causing their formation and determining their locations:

(1) Composition and textures of the iron-bearing beds
(2) Climate
(3) Topographic relations
(4) Composition of circulating ground waters
(5) Presence of impervious rocks
(6) Rock structures

In attempting an appraisal of the possibilities for the occurrence of deposits of this type in the Gunflint formation, a seventh factor must be considered:

(7) Erosion since the development of the ore-bodies

The above factors will be discussed in the order given.

[1] Gruner, J. W.: Minn. Geol. Surv., Bull. 19, p. 67 (1924).
[2] Minn. Geol. Surv., Bull. 17, p. 31 (1919).
[3] Minn. Geol. Surv., Bull. 19, pp. 28–33 (1924).

(1) The composition and textures of the rocks composing the Gunflint formation are almost identical with those of the Biwabik formation. Such differences as do occur, have to do with variations in the proportions of the constituent minerals and changes in the thicknesses of beds. Similar variations occur within Mesabi district itself. The sequence of the beds is approximately the same in the two districts and all the textures observed in the rocks of the Biwabik formation can be duplicated in those of the Gunflint formation.

The principal differences having a bearing on the problem of ore formation have resulted from contact metamorphism by diabase sills intrusive into the Gunflint formation. Only a few limited areas are free from these intrusives. The changes which have been wrought consisted mainly of decomposition of some of the original minerals and recrystallization to others such as amphiboles, which are much more stable under surface conditions. The total effect has been to retard or prevent any considerable concentration of iron by the processes which operated to form ore-bodies in Mesabi district. The smaller sills have ordinarily affected only a few feet of beds adjacent to their contacts, but the larger ones have been observed to have caused marked alterations in 50 feet or more of the underlying beds.

(2) There is no reason to believe that the climates in Gunflint and Mesabi districts have ever differed very markedly from one another.

(3) The relation of the iron formation to the bordering upland is the same in the two districts, that is, it occurs on the southward slope of that topographic prominence, but in the case of the Gunflint formation the intrusion of the diabase sills has resulted in the saw-tooth or cuesta topography, the main effect of which has been to reduce the width of surface exposure of the iron formation and hence the accessibility to circulating ground waters.

(4) If, as has been generally assumed, the waters effective in dissolving most of the silica in the concentration of the ores of the Mesabi range were solutions of alkaline carbonates which derived their content of alkalis from the crystalline rocks to the north, solutions equally effective in this respect must have been available along the outcrop of the Gunflint formation in Ontario, but the actual concentration caused by them was probably greatly reduced in many parts of the district by the restricted width of outcrop accessible to them. This was in part due to the topography, as pointed out above, and in part to the impervious nature of the sills, as will be explained next.

(5) The Gunflint formation is, and probably was from a very early date, sufficiently jointed to have allowed a considerable circulation of ground waters, especially if those waters, by virtue of the dissolved salts which they contained, were effective solvents of silica. The sills, however, due to their thickness, the discontinuity of the joints in them, and their relatively great resistance to decomposition, must have been and still are comparatively impervious to ground waters. Thus the lowest thick sill appearing in the iron formation must have caused a ponding of the alkaline solutions from the north similar to that caused by the Virginia slate in Mesabi district and only the beds below it could

possibly have been affected by those solutions in the absence of faults. Similar ponding of the less potent run-off of meteoric waters from the sills would occur beneath each successive sill to the south. It is conceivable that, with higher relief to the north, large rivers might have developed along the iron formation outcrop, and the water have risen above the lower sills. Even in these circumstances, the cuesta topography would have been maintained with steep slopes to the north and a relatively narrow outcrop of iron formation, and the ponding by the sills would have prevented the circulation of ground waters for more than a short distance down the dip.

(6) The effect of joints in promoting the circulation of ground waters has already been mentioned. With the exception of local disturbances thought to have been due to volcanic outbursts occurring toward the end of the period of deposition of the iron-bearing beds, no pronounced folding was observed by the writer, but flexures so slight as to require accurate surveys over long distances for their detection may exist. Near the base of the formation, local changes in strike may have resulted from slight irregularities of the floor upon which the sediments were deposited.

Post-sill faults are quite numerous. In all but one instance, where the actual fault-planes could be observed, they were found to have been sealed by vein material, mostly quartz and calcite, and little or no evidence of oxidation was present. This does not necessarily mean that conditions were not favourable for such decomposition at that time, but may be taken as simply another argument in favour of the general belief that the formation of these veins followed closely after the intrusion of the sills. The sole exception is a very small, post-Pleistocene fault detected in an area underlain by granite and, therefore, gives no evidence for or against concentration of iron along post-Keweenawan faults. It is quite possible that some concentration has occurred along faults later in age than the late Keweenawan set mentioned above, in fact such alterations have been observed in Loon Lake district.[1] No faults which could be definitely so dated were observed by the writer to cut the iron formation.

(7) No great difference between the rapidity of erosion in Mesabi district since the main period of ore concentration and that in western Ontario during the same period can be postulated. Opinions have differed as to the actual depth of erosion by Pleistocene glaciation. Lawson[2] thought that there is no good evidence of there having been any material reduction in level in consequence of the conditions of that period, whereas Van Hise[3] believed the erosion due to that cause to have been considerable, and stated: "If the Animikie rocks were once deeply altered and contained large ore-bodies, these appear to have been largely swept away, thus exposing the little-altered rocks." There is evidence that at least some of the bedrock was removed by scouring and plucking. Parts of some of the Mesabi ore-bodies were undoubtedly removed in this way, though that district was one of dominant deposition, as shown by the thick deposits of drift. Evidence has been submitted to show that in

[1] Smith, W.N.: "Loon Lake Iron-bearing District"; Ont. Bureau of Mines, Ann. Rept., vol. XIV, pt. 1, pp. 254-260.
[2] Lawson, A. C.: Geol. Soc. Am., Bull. I, p. 169 (1890).
[3] Van Hise, C. R., and Clements, J. Morgan: "The Vermilion Iron-Bearing District"; U. S. Geol. Surv., Ann. Rept., vol. XXI, pp. 411-412.

Ontario, in the valley which follows the iron formation outcrop, local scour by the Pleistocene ice-sheets is the only satisfactory explanation for the formation of some of the larger lake basins. It is possible that some of these depressions represent former decomposed areas which would naturally have been more readily eroded than the unaltered or only slightly altered rocks. Though erosion seems to have been more intense in this region than farther south, it does not necessarily follow that all the concentrations which may have formed in earlier epochs were removed in this way.

The areas mapped were not selected because they were considered favourable for the occurrence of ore deposits, but because they contain the most numerous and extensive outcrops, and supplied the data necessary for a comparison between the Gunflint formation in Ontario and the Biwabik formation in Mesabi district. The possibilities for the occurrence of hematite-limonite ore-bodies in these areas can be fairly definitely stated. North Lake and Bishop Lake areas are considered hopeless for the occurrence of extensive ore-bodies of this type. Small concentrations may have formed along the north-south fault shown on Bishop Lake sheet, but there is no evidence that such is the case. In Little Gull Lake area, small concentrations may be present in the low-lying area around Heart lake, and in the valley of Sand river, but no extensive deposits are to be expected. South of the area mapped, toward Round lake, there is some evidence that faulting has occurred, causing the bold cliff which faces the lake on the east. There is, therefore, a possibility that some concentration may have occurred in this area. In Silver Mountain area, greater breadth of outcrop and the absence of sills below the upper division (No. 5) of the iron formation make this area seem the most favourable, particularly to the east of the area examined in detail. A rapid trip was made north of Nolalu and the width of the outcrop determined to be at least 4 miles, with no evidence of sill intrusions. Apparently the beds have been repeated by downfaulting to the north. Outcrops are scattered, for the whole area has been covered by stratified Pleistocene deposits. Part of these have been removed by post-Glacial erosion, but wide areas are still heavily covered and drilling will have to be resorted to if this area is to be explored further.

Very little can be said about the areas lying between those covered by the maps, for they were gone over very hurriedly. Between North and Addie lakes, there is a width of about 1½ miles underlain by iron formation, but the whole area is quite heavily drift covered. The absence of sill outcrops in this area indicates that conditions were probably more favourable for ore concentration than in adjacent parts. The nearest sill outcrop observed occurs near the base, north of the eastern end of North lake. A somewhat similar drift-covered area lies between Iron Range and Sand lakes, but this is considered less favourable because of the presence of a persistent sill near the base and at least one other at about the middle of the formation. Outcrops of beds of Division 3 appear in railway cuts along the south shore of Sand lake and West of Sand Lake station. The outcrops to the north of Iron Range lake and between Little Gull Lake and Silver Mountain areas were not examined.

Pre-Keweenawan concentrations have been reported from Loon Lake district. The writer believes that in the area covered by this report, erosion since the Keweenawan has been so extensive that deposits formed before the intrusion of the sills could scarcely be expected to have been preserved, unless in the case of alteration at considerable depths along a fault-plane.

It has been pointed out in the descriptive part of this report that at certain horizons the beds are more magnetitic than at others and that these characteristics persist over large areas. It is to these horizons that attention must be turned in search of magnetite ores.

No single bed or group of beds has been found which is sufficiently rich in iron to be utilized as an ore without preliminary concentration. The beds of several horizons are locally rich enough in magnetite to produce a concentrate containing 60 per cent Fe with reasonably fine grinding and a concentration ratio of 2 or 3 to 1. No attempt was made to sample the beds systematically, but representative specimens were taken from most of them and many of these were examined microscopically. Geometrical analyses were made of polished specimens from those horizons richest in magnetite, and these form the basis for the figures given in the following paragraphs. They must be regarded as only approximate, but they at least serve to indicate where attention should be turned when exploitation of ores of this type is being considered.

Deposits of considerable thickness and with a magnetite content higher than the average occur in Divisions 1, 3, and 5, which correspond to the "Lower Cherty," "Upper Cherty," and "Upper Slaty" of the Biwabik formation. Though in general these magnetite-rich horizons tend to persist over large areas, there is a gradual change in the proportions of the constituent minerals from place to place and it is only in certain localities that they are of interest commercially. Each of these horizons will be discussed from the standpoint of the magnetite content of the beds in the areas mapped.

Division 1 (Lower Cherty). Broderick[1] has reported from 5 to 15 feet of beds, containing from 50 to 60 per cent of magnetite, near the base of this division in Gunflint district, Minnesota, and magnetite deposits have been reported on the Canadian side, to the north of Gunflint lake, probably at the same horizon.

In North Lake area, only the lowest beds of this division are exposed. In these magnetite is practically absent. The overlying 15 feet may contain local concentrations of magnetite, but no definite information regarding them is available.

In Bishop Lake area, a few thin beds very rich in magnetite are present. One of these, 4 inches thick, contains 75 per cent by weight (54 per cent Fe in magnetite), but most of the associated beds are much leaner. As to the persistence of such concentrations nothing can be said since only one exposure was found.

A local occurrence with an exceptionally high magnetite content is present at the base of the formation in Little Gull Lake area. The

[1]Broderick, T. M.: "Economic Geology of the Gunflint Iron District"; Econ. Geol., vol. 15, p. 428 (1920).

richest part of this deposit carries about 70 per cent magnetite. The maximum thickness observed is 4 feet and this would average somewhat lower in magnetite than the above. The upper boundary of the bed was not exposed, so that the thickness may be considerably in excess of 4 feet. Grinding to 200 mesh would be necessary before any appreciable further concentration could be effected. The extent of this magnetite-rich material along the strike is not more than 300 yards. Its persistence down the dip is unknown.

In an exposure near Hillside station in Silver Mountain area, a 3-inch bed with 70 per cent magnetite occurs immediately above the algal chert and the succeeding 2 feet of beds are quite rich in magnetite.

The above instances serve to show that local concentrations of magnetite exist in the beds of this division. In certain areas they may attain thicknesses and be sufficiently extensive to be of importance commercially.

Division 3 (Upper Cherty). The nodular magnetitic and hematitic chert forming the middle part of this division in North Lake area contains local concentrations (nodules) which run as high as 60 per cent iron oxides and the leaner parts of the beds run from 15 to 20 per cent iron oxides, but though magnetite preponderates locally, hematite is much more abundant in most of the beds. Only that part of the hematite which is intimately intergrown with the magnetite could be saved by magnetic concentration and a large part of it would inevitably be lost.

In Bishop Lake area, only the upper 30 feet of the beds of this division are at all rich in magnetite. These are poorly exposed and nothing like an average can be given, nor can any definite statement be made as to the persistence of the thickness and grade of these beds along the strike. One specimen, which was not exceptional for the few feet of beds exposed, was found to contain 34 per cent magnetite. Fine grinding would be required before any considerable further concentration could be effected. Underground methods would have to be used in mining this material, except for a very narrow bench, which could be quarried.

In Little Gull Lake area, thin beds containing 30 per cent or slightly more magnetite appear about 60 feet above the base of the division, where they alternate with thicker beds of lean greenalite taconite. In open-cut 14, a few beds 4 inches or less in thickness contain up to 70 per cent magnetite, but most of the beds have a very low magnetite content. In open-cut 9, the lower 3 feet of partly decomposed material is quite rich in magnetite, averaging about 50 per cent. The lower limit of these magnetite-rich beds could not be determined. In the vicinity of cut 9, mining would be costly since underground methods would have to be used, but farther to the west these beds should pass out into the flat bottom of Sand River valley, where they could be quarried. The diamond-drill holes put in last spring were commenced in beds just below this horizon and hence missed it entirely.

In Silver Mountain area, the beds immediately below Division 4 in the two exposures observed do not contain any notable amount of magnetite, nor do any of the other beds of this division so far as observed by the writer. However, exposures are so few that no generalization can be made.

Division 5. The persistence of hematite taconite at the base of this division from end to end of the region examined has been emphasized in the descriptions of each of the several areas mapped. Where sills appear in close proximity to these beds, as just south of Shekaka lake in North Lake area and in Strange township, concession II, lots 4 and 5, the hematite has been partly or wholly converted to magnetite. Some of these beds now contain as much as 65 per cent magnetite, and many contain between 30 and 60 per cent. In all the specimens examined microscopically, however, a large part of the magnetite was found to have retained the form and distribution of the original hematite, that is, it is present as microscopic particles dispersed through chalcedony or finely crystallized quartz. Locally a certain amount of aggregation to form larger grains has occurred, but in general, concentration would be extremely difficult and in any case extremely fine grinding would be necessary. The two localities mentioned above contain the richest beds of this type observed.

In Little Gull Lake area, thin magnetitic beds are quite numerous toward the top of the 80 feet of thin-bedded magnetitic and amphibolitic cherty beds. These alternate with leaner cherty and greenalite taconite beds which are also quite thin. The best exposures appear on the outer edge of the prominent bench to the west of Mink mountain.

Magnetitic greenalite taconite containing variable amounts of siderite and other carbonates forms the main mass of the low prominences northeast of Silver mountain and about a mile south of the railway. Specimens taken to represent the average of about 25 feet of beds exposed on the north slope of the hill in R 117, average a little over 30 per cent magnetite by weight. The magnetite content of the 50 feet of beds which overlie these is not known, because they are very poorly exposed. Toward the top of the hill, two outcrops of ferruginous carbonate-rich beds were found. The magnetite content of these is negligible, so that the average of the upper 50 feet is probably considerably lower than that of the 25 feet below. Farther to the west, in R 136 and also on the north slope of Silver mountain, beds also containing about 30 per cent magnetite appear at about the same horizon as those mentioned above, as nearly as can be judged from the lithology. Those exposed in R 115, 116, and 117 are the most readily accessible. In all of these beds the magnetite is coarse enough so that most of it would be freed for concentration by grinding to 100 mesh.

Summary. Of the localities mentioned, R 115, 116, and 117 seem to contain the most accessible and persistent magnetite-rich beds of considerable thickness amenable to concentration with reasonably fine grinding. The altered hematite taconite should be tested to determine whether moderately fine grinding will unlock enough of the magnetite to give a commercial concentrate with a permissible ratio of concentration, and several of the other localities are worthy of further investigation when utilization of ores of this type is being considered. The beds at the top of Division 3, those at the top of the thin-bedded amphibolitic cherty group of Division 5, and the local deposit at the base of the formation in Little Gull Lake area should not be overlooked in this connexion.

MINERAL DEPOSITS OF RUTTER MAP-AREA, SUDBURY DISTRICT, ONTARIO

By T. T. Quirke

CONTENTS

GENERAL INTRODUCTION

The writer was instructed to make a geological map and to report especially on the non-metallic mineral deposits of the area bounded by lines of longitude 80° 30′ and 81° and by lines of latitude 46° and 46° 15′. This area is traversed from north to south by Wanapitei and Murdock rivers, and by the Canadian Pacific and Canadian National railways. French river traverses the southern part of the area from east to west. Opening from main waterways are many subsidiary routes which make nearly all the area fairly accessible. During the summer of 1924 the writer did not finish mapping the area, though he covered all or parts of Waldie, Cox, Allen, Laura, Bigwood,and Delamere townships, and timber berths Nos. 60, 59, and 5.

The general geology of the area is extremely complicated. Although much of the detailed mapping and studies have yet to be made, the general conditions seem to be as follows. The area was at one time occupied by sediments of Huronian age, belonging to the Bruce and Cobalt series, which are readily available for study in the regions along the north shore of lake Huron. These formations are largely quartzites, and conglomerates, with notable beds of argillaceous rocks associated with thin layers of limestone. These series are well known and have been described in detail in other reports of the Geological Survey. These sedimentary rocks were deposited on a granitic basement interrupted by patches of volcanic schists which are the main remnants of the country rock into which the granite was intruded. So long after the sediments had been deposited that they had become indurated into strongly cemented quartzites and rocks of a similar type of metamorphism, they were folded, broken by faults, and intruded by dykes and larger masses of quartz diabase. Still later the region was involved in more intense folding and intruded by batholiths of granite and syenite. Associated with these last intrusions there was advanced contact metamorphism which resulted in the injection of many pegmatite dykes and the alteration of the sedimentary rocks into schists and gneisses.

In this region are sedimentary rocks which have suffered first intense alteration due to movement and folding and later the still more profound alteration which accompanied the intrusion of great masses of igneous rock. In many places it is almost impossible to tell whether the rocks which outcrop are altered igneous rocks or altered sedimentary rocks. It is doubtful whether there are in some regions sedimentary rocks that are merely soaked with the minerals which are brought in by the igneous intrusions, or whether these rocks are really igneous masses that have dissolved so much of the sediments which they have replaced that they are themselves chemically and mineralogically almost the same as though they had been originally clastic rocks. In some places they retain even the bedding forms of the ancient sediments. It is clear that there have been large faults, but fault breccias which are well exposed in some places are found to fade out into streaks of dark schist in the massive gneiss when they are traced a little way. Similarly, there are places where the sedimentary character of the rocks is unmistakable, but when an attempt is made to trace the linear continuation of these rocks it is found that they become gradually less and less definite until they, too, fade out of recognition in the general feldspathic gneisses of the region. Here and there it is possible to trace the transition of a definitely sedimentary rock into a definitely igneous rock. It is true in many places that the definitely sedimentary masses are bordered with zones in which garnets, amphibole, and pegmatite-bearing rocks are well developed, and that many of the areas of very massive granitic gneisses are free of these typical contact metamorphic features. It follows that the original areas of sedimentary remnants may be mapped within these contact metamorphic zones, and the areas of granite batholith are those areas which engulf the others. The general distribution of these sedimentary and igneous rocks is indicated in the following discussion of the deposits of economic minerals in the area and need not be repeated here. The distribution of the deposits of possible economic value is indicated on the index map (Figure 6) accompanying this report.

ECONOMIC GEOLOGY

In consequence of the accessibility of this area any mineral deposits which may be discovered are the more likely to be of economic value.

The mineral resources most likely to be of commercial value are feldspar, garnet, quartzite, building stone, graphite, and mica. Of this group quartzite and feldspar are now being quarried on a profitable scale in the neighbouring districts.

Quartzite is found in the area in many places, but in most of the localities it is not in masses large enough or sufficiently pure to be considered of commercial value. Near Waterfall station on the Canadian National railway there is a great, pure mass of quartzite which runs across Wanapitei river in a generally northeast-southwest direction approaching close to the railway outside the northern boundary of the area of this report, but inasmuch as this mass seems not to have been reported elsewhere it is well to mention it. Farther south along the

Canadian National railway at the great bend east of mileage 81, a streak of pure quartzite about 100 feet wide is exposed and may be traced, with other bands of similar character, to near mileage 74. This series of strips and beds of quartzite is severely contact-metamorphosed by the intrusion of granite streaks and dykes to such an extent that it is not very desirable for quarrying in a region where there are many other purer deposits. These beds, however, are beside the railway tracks, an advantage which they share with those deposits now being quarried at Quartz, Ontario, about 15 miles along the line towards Sudbury. No masses of quartzite have been seen during this season along the tracks of the Canadian Pacific railway. At Rutter, however, beside the road which leads to the settlements

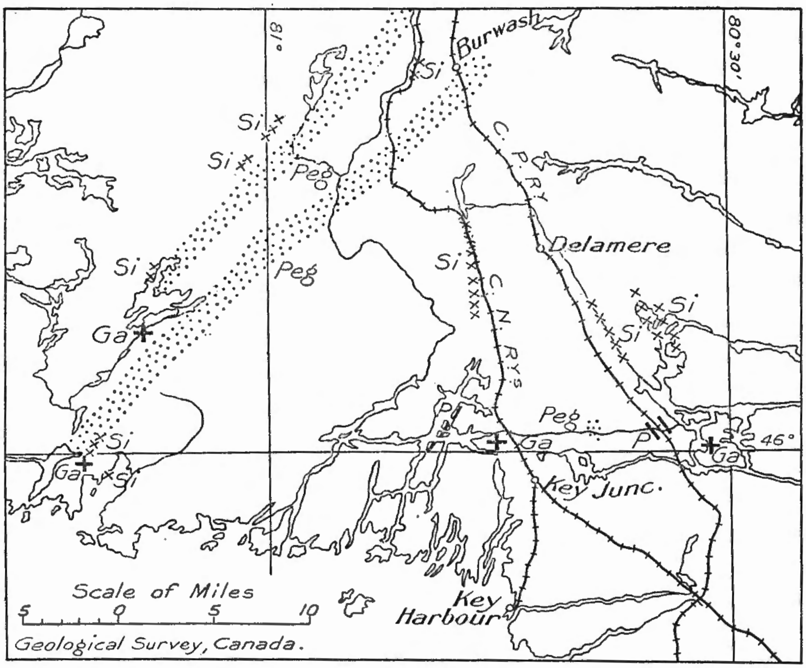

Figure 6. Index map showing location of mineral occurrences. Zones in which feldspar-bearing pegmatite dykes are common are indicated by stipple and the symbol, Peg; areas of quartzite by crosses and symbol, Si; areas in which garnets are abundant by crosses and symbol, Ga; pyrite occurrences by heavy line and symbol, P.

to the east of Murdock river at the bridge, nearly a mile from Rutter station, there are notable deposits of quartzite much of which is very pure. Four miles east of Rutter, on the borderlands of the neighbouring townships of Bigwood and Mason, there is a series of high ridges 4 miles long and 1 mile wide, in places composed of gleaming white quartzite of marvellous beauty and purity—literally crystal hills, uncontaminated by the surrounding igneous intrusions. If this material were used for building purposes, it might result in actual crystal palaces, not of glass like the original Crystal Palace of Hyde Park, but of real quartz crystal. The rock is quite translucent in thin pieces; its colour is glassy white. A rock of such singular beauty lends itself admirably to monumental edifices. Structurally, its strength is very great; its resistance to weathering agencies exceeds that of all other building materials, and it is almost indestructible. Aside from these structural uses, this rock provides enormous quantities of pure silica for refractory and abrasive uses or for flux at the smelters. There are millions of tons of this quartzite in sight above the level of North channel, French river. A thin streak runs northward from Little French River inlet on Pickerel river along the line of Murdock river for 13 miles at least, outcropping generally on the west side of the river, but here and there—as for instance east of Rutter—it appears on the east side. In general, the quartzite runs in bands, with a north and south trend, near the Canadian National railway and near the Canadian Pacific railway. It is found actually beside the Canadian National tracks, but occurs in greatest quantity and best quality a few miles away from the Canadian Pacific railway.

Under the microscope the quartzite is seen to be composed of very coarsely crystallized quartz unaccompanied by any visible impurities. However, the thin section shows only a very small part of the mass, and examination of the specimen shows specks of reddish material, probably hematite, and little silvery specks, probably mica. It is clear that the quartz grains have recrystallized into new crystal units which are generally rounded, but adjusted in shape to the outlines of their neighbours. There appear to be no pore spaces left. Every original opening seems to have been filled by the growth of the quartz grains. The growth is so advanced and the material so pure that the whole mass looks much more like a prodigious quartz vein than a mass of sedimentary rock.

Feldspar is actively worked at a mine on the Canadian National railway at St. Cloud. In that general region, a few miles north of the area being reported upon, there are many pegmatite dykes of considerable size carrying fine feldspar crystals. All these dykes are on the borders of the intruded Huronian sediments and the younger Killarney granite. As a result of the field studies of 1923 and 1924 the following generalization may be made concerning the pegmatite dykes of this type in this locality.

The large, coarsely crystallized pegmatite dykes are found either in the sedimentary schist and gneisses, or near them in gneisses of uncertain origin; the latter have the mineral character of igneous gneisses but may be of sedimentary derivation. In any case, the gneisses are of the banded, well-joined, stratiform, layered type. In regions of uniform, pink gneiss or in coarsely porphyritic gneiss, large pegmatite dykes seem to be entirely absent, except at the borders of these masses where they adjoin the stratiform type of gneisses. Furthermore, the biotite and hornblendic gneisses contain pegmatites more abundantly than the quartzitic schists.

Accepting this generalization as true, the distribution of known pegmatite areas may be outlined as follows: the most northerly area is a streak which runs on the west side of the sediments near Quartz, southwestward through the middle of Secord township towards the centre of timber berth 60. Another streak on the east side of the Quartz masses runs about parallel to that on the west, through Burwash station on the Canadian National railway, past Syer's pulp camp towards Hunter lake—where the pegmatites are very numerous—and continues all the way to Collins inlet on Georgian bay. Another and less important band of pegmatite dykes may be found along the line of lakes and channels which stretches from lake Kakakiwaganda on the north to Canoe channel, French river, on the south. This streak is parallel and near the Canadian National railway almost throughout its length. The great area of quartzites in Bigwood township seems to contain fewer pegmatite dykes than the other areas of sediments noted above. All the pegmatites noted so far are chiefly rich in orthoclase feldspar; very few have any promising contents of mica, or of other feldspars, though on French river southwest from Ham lake an intrusion of nepheline syenite is accompanied by very coarse pegmatites containing nepheline and albite. The albite is so pure that it is almost colourless and transparent, and might be of commercial value. Unfortunately it is in a rather inaccessible locality as compared with the dykes beside the railway track. There are rapids and small falls in French river both above and below these pegmatites, and the deposits are at almost equal distances from the Canadian National railway and the Canadian Pacific railway. Prospecting for feldspar in this region seems unlikely to be profitable outside the areas noted.

Deposits of garnet appear in some places to be almost rich enough to warrant mining. Like the feldspars the most promising regions may be fairly well defined. The garnet zones are usually an accompaniment of pegmatite dyke intrusion, and this is notably the case in the streak which runs through Burwash station, on the Canadian National railway, southwestward to Hunter lake. The continuation of this streak is marked at Collins inlet with so great a concentration of garnets that the sands along the inlet are pink and purple with this mineral concentrated by the waves. As is generally known, garnets are found in sedimentary rocks which have been intruded by igneous rocks, and the streak just described is obviously a contact metamorphic deposit. Garnets may be looked for wherever the granite of the area has intruded the sedimentary rocks, though not all the sedimentary rocks are equally susceptible to this type of alteration. In this area they have given rise to hornblende, and biotite, as well as to garnet, consequently it is generally true that the dark-coloured gneisses and schists are the more likely to contain abundant garnets. In many of the quartzites, and even in some of the granitic gneisses, garnets are numerous, but they are not so abundant in these types of rock as in the dark-coloured gneisses and schists.

There is another type of garnet concentration in the south-central part of this area of greater promise than that associated with the sedimentary schists. It is confined to the zone of contact between diorite masses and the granite which intrudes them. The diorite is a rough-weathering, pale grey rock, with a peculiar chalky whiteness at the surface resembling the effect produced by the dusting of powdered chalk. The rock is so strikingly different from the granites and gneisses of the area that it would be detected as soon as seen if the observer were on the watch for it. It is found in irregular, lens-shaped masses which are curved with the centre towards the north, structurally resembling synclines with a nearly vertical axis, or an axis plunging very steeply towards the south. These outcrops are astride the main line of the Canadian National railway, appearing plainly along the track between Hartley bay and Pickerel river. The masses of diorite and the granite which intrudes them are bordered with marked garnet zones. There are also streaks and lenses of garnet rock within the diorite, emphasizing the distinctly gneissic structure. Upon freshly broken faces the syenite may be seen to be of rather coarse texture, made up of plagioclase feldspar and hornblende.

Almost half-way between the Canadian National and the Canadian Pacific railways, crossing French river, is a band of nepheline syenite. This rock may be known by its pale blue colour and by its pitted surfaces due to the solution of nepheline crystals. Nepheline syenite rocks are not common, and are associated in other places in Ontario with garnets and with corundum—which should be looked for also in this locality. The writer discovered no specimens of corundum during his brief examination.[1]

Graphite has been seen in some of the sedimentary gneisses of the area, but so far not in large quantities in any outcrop. It was noted in the gneisses which outcrop on the east side of Wanapitei river about one mile above the first falls south of Syer's pulp camp. It appears to be another contact metamorphic phase of the intruded sedimentary gneisses already mentioned in connexion with the pegmatites and the garnets. It was seen in larger quantities in the neighbourhood of the coarse nepheline pegmatite dyke on French river, mentioned above in connexion with albite feldspar. This is a locality in which there is a remarkable variety of minerals, due no doubt to the igneous intrusions which gave rise to the nepheline syenite dykes. This group of minerals includes albite, magnetite, amethyst-coloured zircon, graphite, biotite, epidote (?), apatite, nepheline and its alteration products, cancrinite and sodalite.

No pegmatite deposits were found in the area which appeared to give promise of useful deposits of mica, although the general geological relationships would point to the likelihood of their presence. Prospecting of the pegmatite dykes might result in the discovery of this form of mineral deposit.

Most of the bedded and layered gneisses are well jointed parallel to the structure and could be quarried fairly economically for building stone if there were any demand for that material in the district, though the rock has little natural beauty or other advantage over similar deposits nearer the markets. However, the quartzite before mentioned is in quite a different class; although it lacks the convenient jointing of the gneisses it excels all of them in other structural qualities, and is incomparably more beautiful.

Along the route from Little French River outlet to French river there are large masses of hornblende rock south of Fourmile island. Thousands of tons of this rock must run 40 per cent to 60 per cent hornblende and 15 per cent to 30 per cent garnet. This mass of black rock contains a number of coarsely crystallized pegmatite dykes, with crystals up to 12 inches in diameter. The black rock might be used as an abrasive, the hardness of the splintery edges of the fractured garnets offsetting the deficiency of this quality in the hornblende.

[1] Since this report was written corundum has been discovered by the writer in this locality.

Apparently the most promising types of mineral deposits in this area are: (1) abrasives—quartzite, garnets, and, possibly, corundum; (2) materials for fluxes and for pottery materials—quartzite and feldspar; (3) building stones—gneisses and quartzite; and (4) possibly sundry minerals like mica and graphite. Certain streaks of red-weathering gneiss contain a considerable amount of pyrite and might be prospected for gold. Gneiss of this kind may be found on the west shore of Little Wanapitei lake, where it continues for miles across islands and headlands, and another streak of the same type crosses French river one-quarter mile east of the Canadian Pacific railway. Aside from certain pegmatite dykes which contain crystals of magnetite in small quantities there are no other metallic deposits known in the area.

LIMESTONE ON ABITIBI AND MATTAGAMI RIVERS, ONTARIO

By Wyatt Malcolm

Illustration

The occurrence of limestone on Abitibi and Mattagami rivers has been known since the earliest explorations made by the Geological Survey in that part of Canada. Its possible economic value was indicated when, at the suggestion of the writer, some specimens collected by E. M. Kindle in 1923 were analysed in the laboratories of the Mines Branch, Department of Mines, with the following results:

	1	2	3
Calcium carbonate	95·46	95·71	94·55
Magnesium carbonate	1·09	1·11	1·15
Oxide of iron (and alumina)	1·85	2·48	1·10
Insoluble mineral matter	2·42	0·74	2·73
	100·82	100·04	99·53

All analyses made upon material dried at 105° C.
1. Head of Coral rapids, on east side of Abitibi river.
2 and 3. Upper end of island near head of Long rapids, Abitibi river.

The material submitted for analysis consisted of hand specimens only and does not represent in any way a sampling of any possible quarry face. The results are, therefore, to be taken only as pointing to the possibility of finding on careful commercial sampling, a series of beds of high quality limestone that might be quarried on a large scale. Limestones form a continuous cliff along the east shore of Abitibi river between the head and foot of Coral rapids. The following section is found at the head of Coral rapids.[1]

	Feet
Massive, buff limestone splitting easily in layers parallel to the bedding...	25
Thin-bedded limestone weathering buff or grey........................	15
Argillaceous grey limestone...	2

Specimen No. 1, the analysis of which is given above, was taken from the massive limestone comprised in the upper 25 feet of this section.

Limestone of the same geological horizon and probably of similar chemical composition is found in a cliff rising 50 feet above low water-level about 300 yards from the head of Long rapids, Mattagami river. A description, accompanied by a good half-tone illustration, is given by

[1] Kindle, E.M.: Geol. Surv., Canada, Sum. Rept. 1923, pt. C I, p. 32.

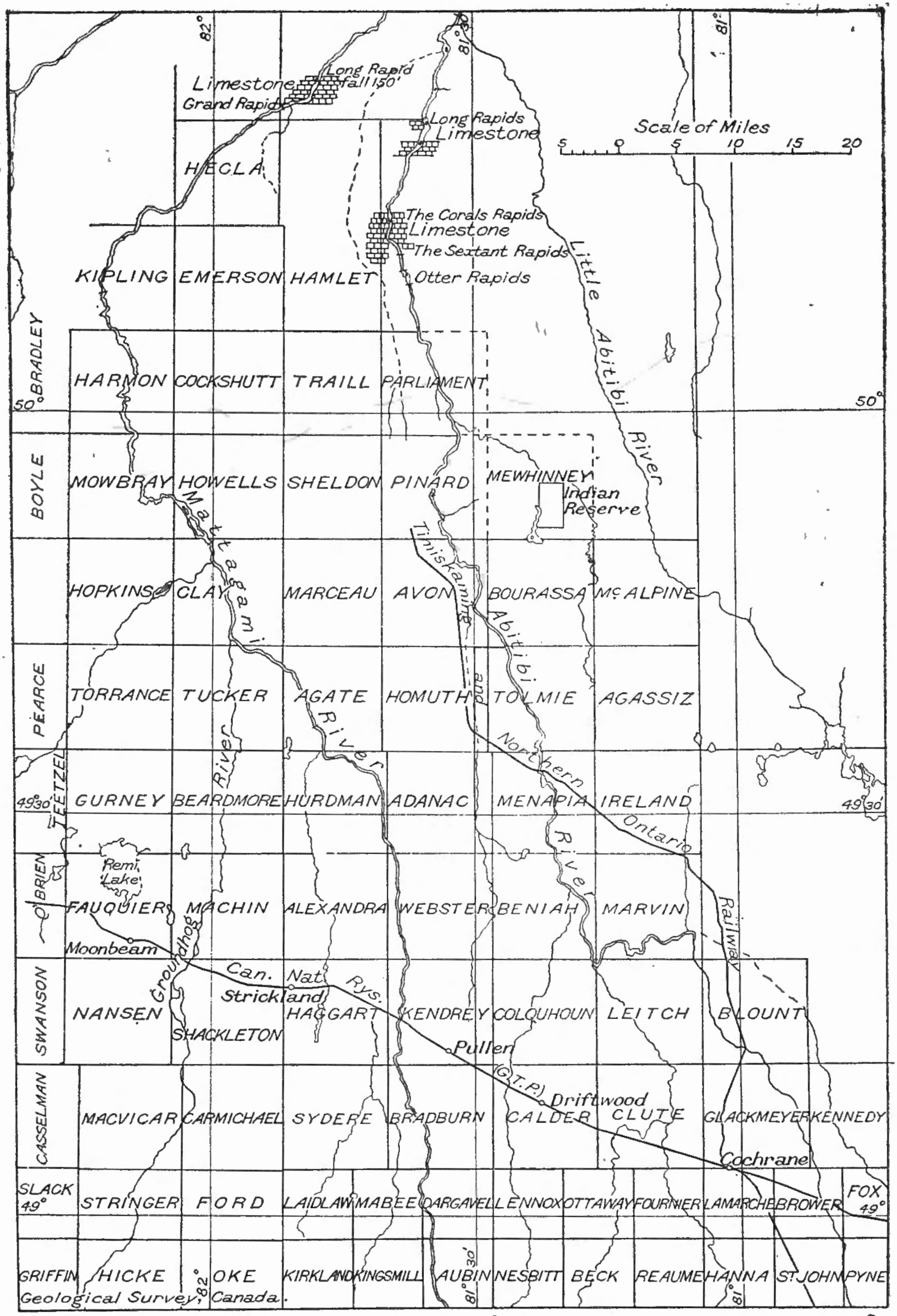

Figure 7. Location of limestone exposures referred to in text.

M. Y. Williams[1] as follows: " Eight feet of thin beds at bottom, containing crinoid columns; 6 feet of massive rock, containing cup and compound corals and stromatoporoids; upper 36 feet in beds 2 to 3 feet thick, more or less crossbedded half-way up, and containing a rich fauna."

The limestones of this part of Ontario may prove of greater economic importance than has been surmised. As the clay belt becomes settled increasing quantities of lime will be required for building purposes; the application of lime to certain soils to correct acidity may also lead to the demand for considerable quantities in northern Ontario and northern Quebec. Limestone is used in the chemical pulp industry and there is likely to be a demand for it in the near future in the metallurgical industry. Other important uses may evolve as the parts of northern Ontario and western Quebec tributary to the Canadian National and the Temiskaming and Northern Ontario railways become settled and industrialized.

Although the limestones are still almost inaccessible, those at Coral rapids lie only about 27 miles, and those on Long rapids about 40 miles, from the end of the Temiskaming and Northern Ontario railway.

[1]Ont. Bureau of Mines, Ann. Rept., vol. XXIX, pt. II, p. 24.

CLÉRICY AND KINOJEVIS MAP-AREAS, TÉMISCAMINGUE AND ABITIBI COUNTIES, QUEBEC

By W. F. James and J. B. Mawdsley

CONTENTS

Illustrations

INTRODUCTION

During the field season of 1924, the writers completed the geological surveying of the two 15-minute by 30-minute map-areas in western Quebec, begun in 1925 by Robert Harvie and W. F. James.[1] The two map-areas are bounded by meridians 78° 30′ and 79°. Clericy map-area extends from parallel 48° 30′ to 48° 15′. Kinojevis map-area lies immediately south and extends to parallel 48°. The total area mapped comprises about 800 square miles. The townships included are Cléricy, Joanne, and Vaudray, and parts of Destor, Dufresnoy, Rouyn, Bellecombe, Aiguebelle, Manneville, La Pause, Bousquet, and Montanier. The areas were previously geologically mapped, but in less detail, by M. E. Wilson[2] of the Geological Survey and in part also by J. A. Bancroft[3] for the Quebec Department of Mines.

Able assistance was rendered in the field by Messrs. B. S. W. Buffam, J. A. H. Paterson, R. A. Pelletier, A. G. Horning, and E. J. Cunningham.

Mr. George Côté, Inspector of Quebec Surveys, and Mr. Savard, Q.L.S., expedited the work by supplying advance data from their field notes of township surveys and arranging their work to provide base-lines in advance of the geological surveying. Messrs. Charles Richmond and John MacCormack and other persons in the district assisted the party at various times.

The district can be entered from three different railways. The eastern section can best be reached from Amos or Villemontel, on the Canadian National railway, the western section from the Temiskaming and Northern Ontario extension to Larder Lake, and the southwestern section from the Mattawa-Angliers branch of the Canadian Pacific railway.

A line of steam and power boats operates between Angliers, the northern terminus of the Canadian Pacific Mattawa branch, and Rouyn lake via Ottawa and Kinojevis rivers. The journey can be made in a day.

[1] Geol. Surv., Canada, Sum. Rept. 1923, pt. C I.
[2] Wilson, M. E.: Geol. Surv., Canada, Mems. 39 and 103.
[3] Bancroft, J. A.: "Mining Operations in the Province of Quebec," 1911.

The easiest canoe route is by way of Villemontel and Kinojevis rivers. Villemontel on the Canadian National railway is within 4 miles of Villemontel river. A good road leads from the village to the river and teams can be had for transportation of freight. The distance down river to Kinojevis river is about 16 miles. From the junction of the rivers to Rouyn lake is an easy route. Three portages are necessary. Kinojevis river is an excellent waterway and runs through most of the townships in the area. A connecting system of streams and lakes provides comparatively easy access to all the townships. The eastern part of the areas may be easily reached from the junction of Kinojevis and Villemontel rivers by way of Kewagama lake. Destor township can be reached from Kinojevis river by way of the small Dufresnoy river, which is quite easily navigable for canoes except in times of very low water. Boundary lines, centre lines, and central range lines have been cut in all townships. These lines and certain trails provide access to points at a distance from the waterways.

A winter road has been cut from Makamik to lake Osisko and provides the shortest land route into the area. It is the proposal of the Quebec government at a later date to improve this road so that it will be suitable for summer travel. Another winter road leads from Larder Lake, a terminus of the Temiskaming and Northern Ontario railway, to lake Osisko. In summer it is suitable for pedestrians, but is not yet fitted for wagon travel. A road from Villemontel village leads to Kinojevis river.

During 1924 a regular air service was operated by the Laurentide Air Service, Limited, from Haileybury and Angliers to various points in western Quebec. In 1925 this service was maintained by another company.

GENERAL CHARACTER OF THE AREA

Topography

Cléricy and Kinojevis map-areas lie within the Canadian Shield and partake of its typical low relief. The areas also are part of the "clay belt" and show the features proper to that physiographic unit. Most of the country is floored with clay from which project isolated, small, rounded, rocky knobs, but there are extensive uplands practically free from the clay.

The higher sections of the country have been referred to by Wilson as the Rocky Uplands. This type of country is best developed in the north in Manneville, Aiguebelle, and Destor townships where the Abijevis hills constitute a comparatively high east-west ridge. The greatest width of this ridge from north to south is 2½ to 3 miles. The maximum height above the level of Kinojevis river is 500 feet. A large part of the ridge is covered by a thin coating of humus. Some glacial drift is present, but no clay is visible except on the lower parts. Where fire has removed the vegetation, large areas of bare rock are exposed on the heights, and on the slopes extensive deposits of morainal and beach material are uncovered. The beach deposits are of well-sorted boulders. The individual beaches are nearly or quite horizontal. They were formed on the shores of a large post-Glacial lake during periods of almost stationary water-level. The upland is crossed from north to south by fairly narrow valleys, in many of which are small streams. There are also valleys trending from east to west which divide the main ridge into a series of minor ridges.

Another section of considerable relief is in southwest Cléricy township and in the adjoining part of Dufresnoy township. The relief is much less pronounced than in the case of the Abijevis hills. In the southern part of Kinojevis map-area there are also areas of fairly pronounced relief. The largest of these is a narrow, steep-sided ridge near the centre of Bellecombe township.

The remaining parts of the map-areas are occupied by two lowland belts, separated from one another by the stretch of higher land already referred to as existing in Cléricy and Dufresnoy townships. These belts are floored, for the most part, by clay, the level surface of which is broken at wide intervals by small, rounded exposures of rock or by low moraines. The lowlands carry the best timber and contain the bulk of the arable land. The northern boundary of the northern of the two lowland belts intersects the east boundary of the map-areas a mile to the north of Kinojevis river and runs almost due west to Dufresnoy lake. Its southern boundary passes about one mile south of Kewagama lake and runs westward to Upper Cléricy lake and from there in a northwesterly direction to the south end of lake Dufresnoy. The south lowland belt is more irregular in shape. It includes the southern part of Dufresnoy township and nearly all of Rouyn township with the exception of a ridge south of Rouyn lake and one north of Kekeko lake; all of Bellecombe township with the exception of an extensive ridge west of Caron lake; all of Joanne township except the northern fifth; all of Vaudray save for two ridges lying, respectively, north and south of Kinojevis river at Gendron portage; and a narrow belt in the northern part of Montanier and adjoining southern part of Bousquet township.

Drainage

The drainage of the region is anomalous. The well-established pre-Pleistocene drainage was disarranged by the deposition of morainic materials and lake clay and by subsequent changes in elevation following the retreat of the Pleistocene ice-sheet and as a result youthful characters have been imposed on it. Kinojevis river is the chief stream and carries to Ottawa river all the drainage of both map-areas. It has a length of about 110 miles, nearly all within the map-areas. Its course is peculiar in that the head of the river is less than 1½ miles from Gendron portage, a point on the main river within 10 miles of its mouth and 150 feet below the level of the small lake at the source of the river.

FARMING

Western Quebec, whatever its mining future may be, will ultimately provide homes for a large number of colonists. Since the map-areas are distant from railways no real attempt at settlement has yet been made, but with the advent of railways and improved highways many parts of this country will be settled. The larger lakes and Kinojevis river provide avenues of transportation that will be of value to the pioneer settlers on the extensive tracts of arable land that border these waters.

The arable land is principally confined to the two clay-covered lowland belts. The largest continuous area of what will likely prove to be good farming land is a wedge-shaped section consisting of La Pause township, the east half and the northwest quarter of Cléricy township, and an area in the vicinity of Dufresnoy lake in Dufresnoy township. North of this lie the rocky Abijevis hills. A second large area of arable land lies in the southern lowland belt and includes most of Joanne and Rouyn townships, the southern part of Dufresnoy and Bousquet townships, and the northern parts of Bellecombe and Vaudray. In the central part of Destor township there are areas of what may prove good farming land, but taken as a whole the southern part of the township is covered by soil that carries a high precentage of sand and the amount of boulder deposit is large. A number of serious bush fires have removed the organic top soil. A conservative estimate is that 60 per cent of the map-areas is suitable for agriculture.

The Dominion Government has an experimental farm at LaFerme, a few miles west of Amos, and since its establishment sufficient time has elapsed to permit of demonstrating the agricultural possibilities of the region. Meteorological records have been kept at this station since the beginning and yield much useful information to the farmer regarding the climate of the district.

FORESTS AND LUMBERING

The timber of the area is one of its most valuable resources. Except where fires have removed the growth, the greater part of the district bears valuable pulpwood, the sale of which provides almost the whole income of many of the pioneer settlers. The pulpwood areas correspond roughly to the areas designated as arable.

The forests of the area are typical of a large section of Abitibi county and the northern part of Timiskaming county. Black spruce is the most common tree. It covers chiefly the low, poorly drained clay areas, but also occurs on more sandy soils and in the higher areas along with jack-pine, balsam, and deciduous trees. Balsam is mostly confined to the areas of heavy soils in the fairly well-drained districts. It has been largely killed off, during the last few years, by the spruce bud-worm. The tree stands for a year or two after being attacked by the worm and is then blown down by storms. The fallen trees and the new growth of shrubs make walking very difficult. Pines are represented by jack-pine, red pine, and to a much lesser extent by white pine. The jack-pine grows chiefly on well-drained rocky land and on the extensive sandy plains. It is by far the most abundant of the pines and some thriving groves on the sandy plains afford railway ties and may also be used for pulpwood. The red and white pine are found on rocky and sandy places and with the larger spruce trees are the chief source of saw logs. The higher ridges support some good growth of birch, but this source of timber will not be available until transportation facilities have been improved. The relative proportion of this type of wood is small. Tamarack was once abundant, but was almost completely destroyed about thirty years ago by the larch saw-fly. Some of the trees then killed are still standing, but the tamarack of the district now consists of young trees springing up on the marshy edges of small lakes.

BUILDING MATERIAL

The surficial deposits of the region will yield building material for local use but not for export. Sand and gravel for construction purposes may be obtained in many places and in considerable quantity. There is no building stone that recommends itself especially through its beauty or ease of quarrying. The lacustrine clays which are found over such a large extent locally vary somewhat in composition. In some places, though tests have not been made, the clay very probably will prove suitable for the manufacture of brick for local consumption, but careful tests of the suitability of the clay in any locality should first be made. Some of the clay is too high in lime to be of use in brickmaking.

PEAT

Numerous extinct lakes occur and many of these old basins are filled with peat. Excavations in one or two places show that the peat deposits extend to a depth of several feet. It is probable that prospecting would reveal large areas of such deposits, but it is improbable that they will be commercially valuable for many years to come, as the supply of wood fuel is so large.

WATERPOWER

The following information as to power derivable from the rapids on Kinojevis river relates to that part of the river between lake Kewagama and the south boundary of Dufresnoy township and has been taken from the "Third Report of the Quebec Streams Commission," 1914, pages 88 to 91. The report contains information regarding various schemes of power development.

	Rapid	Head	Discharge in sec.-feet	Estimated h.p. at 80 per cent
		Feet		
1	(Flat rapid)	3·78	128	43
2	(Cascade rapid)	25·73	128	296
3	(Clayhill rapid, upper part)	17·93	150	243
4	(Clayhill rapid, lower part)	2·20	150	30
5	(Cyclone rapid)	7·38	150	100
6	(Rapid near Sullivan line)	1·60	150	21
	Rapid above Gendron portage	2 to 3	Not measured by the Commission	

GENERAL GEOLOGY

REGIONAL

The bedrock in Cléricy and Duparquet map-areas consists of Precambrian volcanics, sediments, and intrusives very largely covered by Pleistocene deposits, either the direct product of the continental ice-sheet or laid down in lakes formed at the margin of the ice. Without doubt formations such as Palæozoic sediments were once present, but erosion has removed all traces of them, and the gap between Precambrian and Pleistocene is represented by a great unconformity.

The Precambrian formations are eastward extensions of formations previously recognized in Opasatika and Duparquet map-areas. The series of volcanics designated Keewatin is the oldest. Closely associated with them is a sedimentary series found in Cléricy township. Younger than both is a series of rocks chiefly sedimentary in origin. These formations are cut by a number of acid and basic intrusions. West of the map-area there occurs in addition a later Precambrian formation, the Cobalt series, but which does not extend eastward into Cléricy or Kinojevis areas. It either has never been present or, more probably, was present but has been removed by erosion.

Table of Formations

Recent and Pleistocene	....	Lake clays, beach gravels, ground moraine
	Great unconformity	
	Pre-Cobalt (?) intrusive..........	Later olivine gabbro, quartz gabbro
	Intrusive contact	
	Pre-Cobalt intrusives	Granite, diorite, syenite, and syenite porphyry Quartz monzonite Amphibolite Lamprophyre Older gabbro and peridotite
	Intrusive contact	
Timiskaming......	....	Conglomerate, greywacke, arkose, and their altered equivalents
	Unconformity	
	Pre-Timiskaming intrusives......	Granite (?) Lamprophyre
	Intrusive contact	
Keewatin..........	....	Sediments (Cléricy band): conglomerate, arkose, and argillite Volcanics: basalt, andesite, rhyolite, and tuffs

KEEWATIN VOLCANICS

The area underlain by volcanic rocks in Kinojevis and Cléricy map-areas is continuous with that occupied by similar rocks in Opasatika and Duparquet map-areas and which have been correlated with the Keewatin of Ontario. They extend from the northern part of Kinojevis map-area, where they are bounded on the south by Timiskaming strata, to and beyond the northern boundary of Cléricy map-area. West of the northwest corner of this map-area, in the western part of Destor township, they are in contact with sediments lying to the north, which are probably Timiskaming.

The Keewatin volcanics are like the corresponding rocks of Ontario. The great bulk are lavas of varying composition with which are interbanded sediments, some definitely pyroclastic and others of waterlain types. The lava flows, because of their great extent, are thought to have poured out of large fissures, though the presence of pyroclastics indicates that at least some cones were present. The lavas range from rhyolites and rhyolite-porphyries to basalts. In some the original constituents are still recognizable, but others have been so altered that the original composition is only a matter of inference. In some, all minor structural features have been obliterated, but most of them preserve such original features as pillow structures, amygdaloidal and flow textures. The associated bands of pyroclastic material generally show relatively slight alteration.

In the western part of Cléricy map-area, in the vicinity of Dufault and Dufresnoy lakes, acid lavas predominate. Elsewhere lavas of this type form only a small proportion of the volcanic group. The acid lavas include rhyolite, trachyte, and the more acid andesites and their porphyritic equivalents. The porphyritic lavas differ in appearance from the non-porphyritic types only in having phenocrysts of quartz or acid feldspar.

The rhyolites vary in colour from milk-white to pink, brown, pale green, and black. Important characteristics are the conchoidal fracture and fine grain. Most of the acid lavas contain small phenocrysts of quartz or feldspar. These acid rocks are more resistant to weathering than the more basic types. In the vicinity of lake Dufresnoy some of the rhyolites have been replaced by carbonate which in many places produces a rusty weathered surface. Spherulitic and amygdaloidal rhyolites are sparingly present. The spherules are about one-quarter inch in diameter and composed of radiating growths of small crystals. Amygdules are commonly filled with quartz, but in some cases with epidote, zoisite, carbonate, and quartz. They are usually small, though some attain a diameter of 2 inches. Epidote is, perhaps, the most common secondary mineral found in the rhyolites.

Many of the trachytes are fairly coarse in grain, up to more than 1 mm. The normal type is a mat of feldspar with a little quartz and some ferromagnesian minerals. Where phenocrysts of orthoclase are present these are usually more altered than the plagioclases. The andesites grade into dacites with increase of quartz content. A common type in some parts is a dacite porphyrite with well-developed quartz phenocrysts.

The basic lavas include the more basic andesites and basalts. They are generally more altered than the acid lavas and are characterized by a high content of such minerals as chlorite, epidote, and hornblende, from which they derive their predominantly dark green colour. The grain is commonly fine, but there are also coarse-grained and porphyritic varieties. the most striking feature is the pillow structure, which is most prominently developed in the andesites. Amygdaloidal textures are common in the more basic types. Many of the basic flows are of great thickness and commonly the central part is locally coarse grained and has an ophitic texture. This development of ophitic texture is more widespread in Cléricy map-area than in Duparquet map-area to the west. Associated with the coarse diabasic basalts are facies in which very large phenocrysts of feldspar lie in a fairly fine-grained groundmass. These phenocrysts attain a size of 3 inches, but are completely altered. The augite is in many cases quite fresh, though generally some secondary hornblende has developed. The common alteration products in these lavas are epidote, zoisite, and carbonate.

Interbanded with the lavas are numerous beds of tuff and agglomerate mineralogically like the lavas with which they are associated. The tuffs in some cases were deposited under subaerial conditions and in others under water. In hand specimens these rocks, unless they show well-marked bedding planes, may be difficult to distinguish from the lavas, and any slight development of schistosity makes it impossible to distinguish between the two classes of rock.

A very striking phase of the bedded types is the agglomerates and the rare conglomerates. They consist of fragments of volcanic rock in a matrix of finer material. The larger fragments have a diameter of 2 feet or more, but most are less than 2 inches in diameter. In the agglomerates most of the fragments are angular to subangular, but in the conglomeratic phases they are fairly well rounded. The agglomerates probably have been produced in the vicinity of volcanic cones, but the rounded boulders of the conglomerates were undoubtedly transported and correspondingly abraded before deposition. In many instances light-coloured, acid fragments occur in a dark-coloured matrix. A less common rock is the flow agglomerate which resulted from the picking up of loose rock by an advancing lava. Such types are distinguished by the presence of irregular rock fragments enclosed in a lava which may be of quite different composition.

In some places where the rocks are well displayed, a typical volcanic succession is apparent. Flows of varying thickness succeed one another and intercalated with them are beds of fragmental material. Channels through which the lava reached the surface now appear as dykes composed of the same material as the flows, but though dykes are numerous and many may represent such feeders, it is rare that such dykes are seen actually merging into overlying flows. West of Dufault lake where the flows are almost horizontal, a feeder can be seen cutting the older flows and merging into one of the upper flows.[1] This is the only known occurrence within the region where the feeder of a flow has been definitely located.

The relatively small lateral extent of the individual deposits of sedimentary material interbedded with the lavas suggests that they formed in small bodies of water. The rounded fragments in the coarse fragmental deposits are such as could be produced by running water. The general character of the assemblage of flows and sediments suggests that the flows were extruded on a land surface on which existed small bodies of water rather than on a submarine floor, as was formerly thought. The widespread

[1]Cooke, H. C.: Personal communication.

occurrence of pillow lavas is not of itself evidence of submarine origin, since pillow-like forms near modern volcanoes show that pillow lavas may be formed on a land surface.

CLÉRICY BAND OF SEDIMENTS

Within Cléricy map-area is a band of sediments believed to be of pre-Timiskaming age. The meagre data available indicates that the sediments are of the same general age as the Keewatin volcanics by which they are surrounded. The sediments appear to form a continuous band, 22 miles long, from the central part of Destor township to lake Chassignolle in La Pause township. Continuity can not be established definitely because of the lack of outcrops over a large area in La Pause township and the presence, along the strike of the band in the northwest corner of Cléricy and the adjoining southeast corner of Destor township, of a mass of syenite, 2 miles in diameter, northwest of which no outcrops were observed for a farther distance of 3 miles along the strike of the sediments. The greatest observed width of the band of sediments is in the eastern part of Cléricy township and amounts to 2¼ miles.

The sediments are chiefly arkose with some greywacke and slate and minor bands of conglomerate. The nature of the sediments and alterations they have suffered vary somewhat throughout the length of the band. The westernmost observed occurrence is in southeast Destor township and is about one-half mile long with a maximum width of 1,500 feet. Drift-covered country lies northeast and beyond it volcanic rocks are exposed. Along the northern edge of this part of the sedimentary area, the exposures consist of fine-grained greywacke containing lenses of coarser-grained arkose. About 200 feet south there are narrow lenses, 10 to 50 feet wide, of conglomerate in the greywacke. The conglomerate is variable in composition. Boulders of rhyolite porphyry, granite, dark-coloured jasper, quartz, and other rocks are present. The pebbles are well rounded and seldom exceed 3 inches in diameter. South of the conglomerate lenses are fine-grained, distinctly banded sediments which weather to a rather light colour. These have a width across the strike of about 1,000 feet. South of them is a narrow band of conglomerate which has the appearance of a basal conglomerate. It contains boulders of volcanics which resemble the neighbouring Keewatin rocks. Slightly rounded boulders, in some cases 15 inches in diameter, are set in a green matrix which has probably also been derived from the attrition of fairly basic volcanic rocks. One pebble of glassy quartz was seen. The boulders have been considerably squeezed. The strike of the sediments is generally north 60 degrees west and the dip practically vertical. The finer sediments are intruded by small masses of syenite porphyry, some of which are much carbonated. Other porphyry masses occur in the drift-covered country to the southwest along the strike of the sediments.

A mile and a half north of the south boundary of Aiguebelle township and close to the west boundary of the township, is a sedimentary band about 300 feet in width. The sediments are similar in appearance to those just described, but they lie northeast of the main band and are apparently interbanded with Keewatin volcanics. They strike slightly south of east and have an almost vertical dip. On the evidence of cracks resembling mud-cracks, it is considered that the sediments are in ascending order from south to north.

Outcrops of coarse arkose with some argillaceous layers occur along the strike of the main sedimentary band in Cléricy township, northwest of Kinojevis river, but rock exposures are not numerous. The arkose is composed of grains up to 7 mm. in diameter, of quartz, orthoclase, and plagioclase with a little biotite and epidote. The grains are angular to subangular. The feldspar is much altered and some of the quartz fragments are a mosaic of smaller grains and possibly may be chert.

The strata are better exposed just southeast of Kinojevis river, where the sedimentary band is 2¼ miles wide. The sediments are arkose and interbanded slates, like those northwest of the river, with a small band of conglomerate near the northern contact with the volcanics. The strike is generally 30 degrees south of east. The attitude of the volcanics just north of the sediments was determined at one place and there the volcanics face south and dip beneath the sediments. The presence of the conglomerate containing boulders of volcanics at the northern edge of the sedimentary band seems to be further indication that the sediments overlie the volcanics to the north. The dip of the sediments near the contact with the volcanics is either vertical or slightly to the north. The general attitude of the sediments in the neighbourhood of the southern edge of the band could not be determined, but in a few places the strata were seen to dip south.

Southeast of the outcrops near Kinojevis river, no outcrops were seen along the strike for 5 miles until in the vicinity of lake Chassignolle, where there are a few outcrops of somewhat altered, greenish greywacke with some interbedded slaty bands. Much of the rock is a schist and, as seen under the microscope, is composed largely of quartz grains with some of orthoclase and acid plagioclase. Considerable pale brown mica and some white mica have developed parallel to the cleavage. The outcrops in the vicinity of lake Chassignolle do not permit of exactly determining the width of the sedimentary band at this point, but it is thought to be more than a mile.

Ten miles southwest of the Cléricy band of sediments there is in Kinojevis river 3 miles below Routhier lake, a small island underlain by arkose with interbanded slate, exactly like the sediments of the Cléricy. The strike of these beds is about 35 degrees south of east, paralleling that of the main area to the northeast. The dip is steep to the north. This outcrop occurs within the Keewatin area a short distance north of the Timiskaming-Keewatin contact and the strata might be thought to belong with the Timiskaming, but as they are, lithologically, identical with the sediments of the Cléricy band and have about the same general strike it is probable they bear the same relation to the Keewatin volcanics as is held by the strata of the Cléricy band. East and north of the island are some small outcrops of the sediments, but exposures are few and the width of the sedimentary band could not be determined.

The exact relations of the Keewatin to the Cléricy band of sediments were not definitely established owing to the scarcity of outcrops of both the volcanics and sediments, particularly in the critical areas near the contact between the two groups of strata. The sediments are surrounded by the Keewatin volcanics, except possibly to the southeast beyond the limits of the area studied. The attitudes of the lavas, wherever they have been determined as far west as the Ontario boundary, show that there is a general parallelism between the structural axes of the flows and the general strike of the sediments, both having a direction a little south of east. Independent observations by Cooke and the writers indicate that the volcanics just north of the sediments near Clayhill rapid strike parallel to the sediments and face south, and that the strike and attitude of flows 8 miles northeast are the same. Just south of Cyclone rapid on Kinojevis river at the west boundary of Cléricy township, Cooke found that the flows on the south side of the sediments have the usual strike, but face to the north, thus suggesting that the sediments lie along a synclinal axis. Evidence presented on a previous page indicates that the sediments where crossed by Kinojevis river are stratigraphically above the volcanics lying immediately north, but whether the sediments are interbanded with the Keewatin volcanics or whether, as suggested by H. C. Cooke, they lie within a syncline of older volcanics, could not be established. They are provisionally considered as being of the same general age as the Keewatin volcanics. Their lithological dissimilarity to the Timiskaming strata and the structural discordance existing between the two formations, as indicated on a succeeding page, are considered proof that the Cléricy sediments are not of Timiskaming age.

The lack of continuous exposures in the southeastern corner of Destor township precludes the direct statement that the band of sediments in Destor township is continuous with the main body of the Cléricy band of sediments, though this opinion was at first held by the writers. Additional evidence recently obtained indicates that the sediments in Destor township occupy the top of an anticlinal structure which involves the Keewatin volcanics. The axis of this anticline strikes 40 degrees south of east. In the vicinity of Cléricy lake the sediments seem to occupy a position near the centre of a syncline which lies to the northeast of the Destor anticline and has a similar structural trend. The occurrence of such sediments in two parallel and opposite structures may indicate that the sediments near Cléricy lake are later, and even much later, than the sediments in Destor township.

OLDER GABBRO AND PERIDOTITE

A few outcrops of the "older gabbro," which is prominent in Duparquet and Opasatika areas, were seen, but the areas are too small to warrant differentiation on the map. The rock is similar to the later gabbro, but is much more altered and exhibits a greater number of more acid phases. It has a greasy greenish appearance due to the presence of epidote and other alteration products in the feldspars. It is considered by H. C. Cooke to be post-Keewatin, but older than the syenite porphyry. It is confined to areas of the Keewatin.

A very few outcrops of peridotite were observed. It seems to occur as altered dykes cutting Keewatin lavas and to be older than the granite. It is dark green, is usually much altered, and is composed of large individuals of augite, amphibole, chlorite, and serpentine. One small vein of brittle asbestos was observed within one of these bodies of rock, on Kinojevis river below Cascade rapids in Manneville township.

TIMISKAMING SERIES

Timiskaming sediments underlie the greater part of Kinojevis map-area. They are cut off on the south by the great southern batholith and are in contact with the Keewatin volcanics on the north. Their maximum width is over 17 miles and they form a band which extends westward into Opasatika map-area, eastward across the full width of Kinojevis map-area, and onwards towards Bell river.

The strata consist almost entirely of conglomerate and metamorphosed greywacke. At the west border of Kinojevis map-area a band of fine-grained greywacke 1,500 to 2,000 feet wide forms the northern edge of the Timiskaming area and is bordered by Keewatin rocks. From the west boundary of the map-area the band follows a direction a little north of east for a distance of 4 miles, where it turns sharply to the north for a distance of 1 mile, to where it again resumes its easterly course to Kinojevis river. The strata forming this northward projection consist mainly of conglomerate whose dip, as indicated at one place by an included lens of greywacke, is at a high angle to the north. The strike of this mile-wide band is a little north of east. South of the band of fine-grained greywacke is a belt of coarse conglomerate, approximately 4,000 feet wide. This is a continuation of the conglomerate band occurring in Opasatika map-area and it extends, with nearly uniform width, eastward to Kinojevis river. The dip is northward and at a variable angle which averages about 50 degrees. South of the conglomerate band is a broad area of highly metamorphosed greywackes which show progressively increasing metamorphism southward to where the granite batholith cuts them.

East of Kinojevis river the conglomerate phases constitute only a minor proportion of the Timiskaming sediments. At the Keewatin-Timiskaming contact are metamorphosed greywackes so similar in appearance to metamorphosed volcanics that, in places, the boundary between Keewatin and Timiskaming has been arbitrarily drawn. A mile south of the Keewatin contact, a few isolated masses of conglomerate occur within the greywacke near Kinojevis river. One mile farther south, conglomerate forms a definite band of variable width, but in most places amounting to about 600 feet, which outcrops almost continuously for about 7 miles eastward from Kinojevis river. Farther east, there are no exposures for 5½ miles to where the conglomerate again shows on the strike of the band and continues to outcrop eastward for 3 miles to the east border of the map-area. Beyond this point it extends a long distance on the same strike. A minor band parallels it a short distance north at the east boundary of the map-area. The main band strikes a little north of east and dips steeply to the north. South of it, highly metamorphosed greywackes similar to those west of Kinojevis river extend southward to the granite border.

The conglomerate bands are composed mainly of coarse conglomerate with lenses of finer sediments such as greywacke and arkose. Fine conglomerates are also present locally. West of Kinojevis river the most northerly conglomerate band is generally poorly exposed. It extends westward for about 5 miles from the large bend in Kinojevis river and, as previously stated, is in contact with the Keewatin on the north and with fine greywacke on the south. The strata are chiefly fine conglomerate with numerous lenses of greywacke and a smaller number of lenses of arkose. The northernmost exposure at the western end of the band is a fine conglomerate whose pebbles, varying from the size of a man's fist to that of an egg, are embedded in a groundmass of grey to dark green greywacke which exhibits both massive and banded phases. The pebbles form about 80 per cent of the rock and represent many of the rock types of the district, such as red granite, in some instances traversed by quartz veins, syenite porphyry, a carbonated acid schist similar to that found on Rouyn lake, a trachyte porphyry and a porphyritic andesite both similar to rocks found south of Rouyn lake, and numerous examples, the size of an egg, of red, slightly magnetic, ferruginous chert. Minerals forming pebbles are vein quartz and epidote. The latter was probably derived from basic flows. Interbedded with the conglomerate are slaty and quartzitic phases which in many places are much sheared and altered. Elsewhere within this northern conglomerate band, the outcrops are small. Near Kinojevis river the outcrops are mainly of dark green greywacke with, in a few places, conglomerate phases composed of fine pebbles in a matrix of similar greywacke.

The southern conglomerate band which extends from the western boundary of the map-area to Kinojevis river, parallels the northern band. The largest outcrops form ridges west of Vallet (Simpson) lake and extend almost continuously to the western border of the map-area. In the northern part of the band outcrops are fewer and do not form such pronounced ridges. The band is formed of numerous lenticular deposits of conglomerate and of greywacke. The conglomerate lenses are composed of boulders and pebbles of intrusive and volcanic rocks in a matrix of sheared, greenish or greyish greywacke. The boulders are rounded or subangular, vary from a few inches to more than a foot in diameter, and form 40 to 70 per cent of the rock. Of the granitic rocks represented by the pebbles, granite, syenite, and syenite-porphyry are the most common. All the varieties of the volcanics of the area are present as pebbles or boulders. So far as was observed the northern part of the band contains smaller boulders than the southern part. At the southern edge, pebbles of greywacke were also noticed, most of which are only a few inches in diameter, though some attain diameters of more than a foot. The interbedded lenses of greywacke are in many places several feet thick and their composition is similar to that of the matrix of the conglomerate. They are in many places well bedded, the beds as a rule being not more than 4 inches thick. The attitude of the conglomerate member was determined from that of these lenses. The original character of the strata is relatively unchanged over large areas, but locally the rock is much sheared and there the pebbles as a rule are much squeezed and the matrix has a flow structure corresponding to the shape of the harder pebbles.

The most northerly occurrences of conglomerate east of Kinojevis river are small lenses, two of which were observed just south of Davidson creek, which enters the large bend of Kinojevis river. These lenses are poorly exposed, but apparently are local in extent, though faulting may have played some part in their present location and size. The conglomerate is of the finer variety. Pebbles of syenite and vein quartz occur as well as pebbles of volcanics. Some very fine quartzitic material is interbanded. The conglomerate of the main band to the south is of the coarser variety, contains lenses of greywacke, and resembles fairly closely the southern band of coarse conglomerate west of Kinojevis river.

The greywacke, which forms by far the greater part of the Timiskaming rocks in the map-area, is, for the most part, highly metamorphosed and much of it is a typical schist. It is composed of small fragments of quartz and feldspar accompanied by fragments of rock or of ferromagnesian minerals such as mica or hornblende.

The greywacke of the northern band west of Kinojevis river is very soft, easily eroded, and provides on the whole very few outcrops. The strike of the band is conformable to that of the adjoining conglomerate and the dip is to the north. The rocks vary from black-green to grey and in many cases present a glistening appearance. The beds range in thickness from paper thinness to 1 to 2 inches. The rocks as a rule are much sheared and the bedding planes contorted. The grain is very fine. Locally developed are fine conglomerate phases resembling the rocks of the main conglomerate areas, except that the pebbles seldom measure more than 1 or 2 inches in diameter.

The greywackes of the country east of Kinojevis river and which form the 2-mile wide band between the conglomerate zone and the Keewatin border, strike a little north of east and the dip, where determined, is steep to the north. In many places all evidence of bedding has been obliterated by the superimposed schistosity, but in most places bedding can be detected even where the greywacke is sheared, as is the rule. The thickness of the beds varies from a fraction of an inch to more than a foot. Adjacent beds usually show some difference in colour which varies from dark grey or brown to green and is generally determined by the content of the darker minerals. The grain is very fine and seldom exceeds 2 mm. Quartz, orthoclase, plagioclase, and biotite or hornblende are the chief constituents. White mica occurs in small amount in some of the more metamorphosed rocks. Even the least altered greywackes appear to have undergone almost complete recrystallization. The orthoclase, acid plagioclase, and quartz are usually quite fresh and even in much sheared phases of the rock do not show the effects of strain as would be expected if recrystallization had not occurred. The grains of quartz do not show any parallel secondary growth of silica. In the less altered greywacke the mineral grains are irregularly disposed, but in the more altered phases they are parallel to the planes of schistosity and these appear to correspond in direction to the bedding. Some thin sections show irregular grains of quartz, feldspar, and biotite or hornblende set in a groundmass of finer grains of the same minerals. Others consist almost completely of quartz and biotite. Many show carbonate minerals which have developed as alteration products or by infiltration. Epidote, sphene, magnetite, and tourmaline are accessories. Of the feldspars, orthoclase seems to be the most susceptible to weathering. The more highly altered phases of the greywacke approach in general character the highly metamorphosed varieties of the southern band in the vicinity of the granite contact.

The metamorphosed greywackes which on both sides of Kinojevis river lie south of the southern conglomerate bands are in general less altered towards the north and become mica schists in the immediate vicinity of the small granitic masses and toward the edge of the southern batholith. The less altered types correspond to those already described, whereas the more altered are schists and gneisses characterized by mica or hornblende or both minerals. A large amount of feldspar is present in places and occasionally there are intergrowths of quartz and feldspar. Such rocks tend to be coarser in grain than the less altered varieties. Some of the schists near granite contacts contain large quantities of white mica and in one case sillimanite and garnet have been developed, but on the whole garnet schists and gneisses are rare.

One narrow band of magnetic iron formation was observed interbanded with the greywacke south of lake Kewagama. The band is about 125 feet wide and outcrops on the centre line of Bousquet township about a quarter of a mile north of Bousquet (Kiekkiek) river. It causes a very strong deflexion of the compass needle. The rock is banded black and white and the bands range from the thickness of a sheet of paper to over one millimetre. The white bands consist of almost pure quartz, whereas the black are chiefly composed of magnetite. A green fibrous mineral, probably hornblende, forms small spherical bodies. In thin section the rock is seen to be very fine grained and thinly banded. The lighter coloured bands are almost entirely of quartz with a few grains of magnetite, whereas the darker layers are composed of magnetite with very little quartz. Magnetite may form 40 per cent of the whole volume of the rock.

Just north of range post IV-V on the boundary between Duparquet and Destor townships, outside the map-area, occurs a band of conglomerate at least a mile in width. The conglomerate carries well-rounded boulders and pebbles with diameters up to 1 foot. The pebbles seem to be chiefly of acid lava, but pebbles of red chert and of coarse igneous rock are also present. The conglomerate contains numerous lenses of quartzite, arkose, and greywacke. The strike of a silty band within the southern part of the conglomerate indicates a trend of 49 degrees south of east. Towards the north strikes a little north of east were observed, and it is reported that the trend of the band of the conglomerate is in this direction, and that it is a continuation of the area of sediments lying just north of Duparquet lake. Though no detailed work has yet been done, it is considered that this band of sediments is to be correlated with the Timiskaming to the south because of the parallelism of the trend of the two bands and their lithological similarity.

The nature of the structural relations existing between the Keewatin volcanics and the Timiskaming sediments is still a matter of discussion. M. E. Wilson in his report on Kewagama map-area inclines toward the view that the sediments, which appear to dip beneath the volcanics, are the older. J. A. Bancroft, in a report published by the Quebec Department of Mines, recognizes that at least locally the sediments dip beneath the volcanics and expresses the view that the rocks may have been overturned and that the sediments are really the younger. In 1922 H. C. Cooke, in his report on Opasatika map-area, correlated the volcanics of that area with the Keewatin and the sediments with the Timiskaming of Ontario. He submitted evidence that the volcanics were older than the sediments and that an unconformity existed between the two formations.

The evidence collected by the writers in Cléricy and Kinojevis map-areas is in itself not considered conclusive. It may be summed up as follows. Where structural determinations were made in the volcanics, the general strike of these steeply dipping formations was found to be south of east. The Cléricy band of sediments, which is thought to be of the same general age as the Keewatin, also has this trend south of east. The Timiskaming structures, as indicated by the fairly definite and continuous sedimentary bands, notably of the conglomerate phases, have a strike slightly north of east. Their angle of dip ranges from 50 degrees on the west to vertical on the east. Pebbles in the Timiskaming are of rock types such as compose the Keewatin volcanics and in places, as for example in Rouyn township, the pebbles seem to be derived from rocks that occur just to the north of the Timiskaming sediments. Pebbles of granites and syenites resemble the rocks of bodies intrusive within the Keewatin to the north.

The following conclusions are drawn from the above evidence. The structural trends of, respectively, the volcanics and the sediments, point to two successive foldings, the earlier of which did not affect the sediments, and is oblique to the later folding which involved the sediments. If only one period of folding is postulated it is difficult to explain the considerable divergence between the folding in the Keewatin and that in the Timiskaming. If, on the other hand, two foldings are postulated and if the later is considered to be that which developed the southeasterly folds in the Keewatin, it is difficult to explain how the long east-west band of Timiskaming escaped this folding and retained its east-west trend throughout. The pebbles of volcanics within the Timiskaming conglomerate presuppose the existence of an earlier volcanic formation. It seems more logical to think that this formation is the one at hand, the Keewatin, than to postulate a still older volcanic formation, no other evidence of which can be found. The presence in the Timiskaming conglomerate of pebbles of deep-seated rocks mingled with others of the volcanics seems good evidence that a considerable erosive period intervened between the deposition of the volcanics and the sediments.

AMPHIBOLITE

The chief observed occurrences of amphibolite are on the shores of Vallet and Kinojevis lakes. The amphibolite is dark green, of medium to coarse grain, and approximately equigranular. The chief visible constituents are hornblende and chlorite, and, in some places, mica. The cleavage faces of the minerals give the rock a glistening, faceted appearance. Calcite and feldspar are interstitially present in some cases. The rock occurs in dyke or sill-like masses that have the appearance of having been intruded through or along the beds of Timiskaming greywacke. One body was observed to be 12 feet thick, a few are thicker, but more are much thinner. In some places the surface exhibits nodular bodies suggesting the pillows of a poorly developed pillow lava. In such cases carbonate is abundantly distributed between the spheroids. Such a type is well shown near the small rapid on Kinojevis river below Vallet lake.

Thin sections of the rock differ slightly. In some, the only ferromagnesian minerals are actinolite and a blue-green hornblende. Others show considerable biotite, hornblende, and actinolite, with a small amount of interstitial feldspar and a little quartz. Most of the feldspar is untwinned, but some shows the typical cross-hatching of microcline. Accessories are: carbonates, magnetite, apatite, garnet, and sphene.

The origin of the amphibolite is in doubt. Since the chemical composition of the rock is so basic and since the bodies are at all horizons interbanded with the greywacke with no sign of gradational contact, it seems improbable that the amphibolite is of sedimentary origin. On the other hand, there is no decrease in the size of grain near the contact, as would be expected in an intrusive or a flow. Such a condition can be explained as being due to recrystallization of the original rock. The most plausible hypothesis is that the rock is a metamorphosed basic intrusive occurring as sills in the greywacke.

These rocks correspond to some of the phases of the lamprophyre as described by Cooke and to the amphibolite as mentioned by M. E. Wilson in the report on the Kewagama map-area. On Kinojevis lake one body of amphibolite is cut by a small dyke of granite, which indicates that the amphibolite is older than at least some of the granite of the area.

LAMPROPHYRES

A few lamprophyre dykes were seen. They possibly are not all of the same age. A number of greatly sheared lamprophyre dykes are associated with the Keewatin lavas in Cléricy township. They are now almost completely altered to chlorite with groups of rutile crystals in a fine-grained aggregate of feldspar and secondary quartz. Narrow dykes of much less altered mica-lamprophyres cut the Cléricy sediments. These present a distinctly mottled appearance due to the blonze-coloured idiomorphic crystals of mica. A hornblende lamprophyre with phenocrysts of hornblende in a fine-grained groundmass occurs in the Keewatin near its contact with the Timiskaming. It is probably of the same general age as those mapped as post-Timiskaming by Cooke in the Opasatika map-area.

GRANITE AND RELATED INTRUSIVES

Masses of acid intrusive rocks are comparatively numerous in the south of Kinojevis map-area and in the north of Cléricy map-area. Between these two areas of abundant intrusives is a band of sediments and volcanics in which no large acid intrusives have been found. Of the two the southern area contains the greater amount and the largest single masses of acid intrusive. All these masses are possibly part of the embayed northern margin of the great batholith that is known to extend southward towards the lower Ottawa river. The masses in the northern Cléricy map-area are smaller in size and their combined area equals less than half the combined area of the acid intrusives of Kinojevis map-area.

Kinojevis Map-area

The acid intrusive bodies of Kinojevis map-area are variable of outline and irregularly distributed, but going northward there is a progressive decrease in size of the individual bodies and their combined area. They underlie about 50 per cent of the southern half of the southern tier of townships. The strike of the schistosity of the biotite schists intruded by the granites is, in a general way, east and west, and seems to bear no relation either to the directions followed by the boundaries of the large bay-like masses of intrusive that form the northern contact of the southern batholith or to the axial direction of the smaller intrusive masses.

The various outcropping masses of granitic rock are, doubtless, upward extensions of a single, large, underlying batholith. Since the isolated intrusive masses become progressively fewer towards the north, it is reasonable to infer that the batholithic body lies at progressively greater depths northward, and below the mass of steeply dipping Timiskaming strata near the north of Kinojevis area the batholithic intrusives are probably at a great depth.

The acid intrusives cut the Timiskaming schists and are, therefore, post-Timiskaming in age. All the intrusives may not be of the same age, but no evidence of any differences in their age was obtained. Lithologically they may be classed as augite syenite, porphyritic syenite, and granite. The augite syenite forms both masses of considerable size and small bosses such as occur in Bousquet township and in northern Montanier township. The largest body is in the extreme southwest and extends west and south beyond the limits of the map-area, within which, in Bellecombe township, it occupies an area measuring 3 miles both north and south and east and west. Another large mass lies along the eastern boundary of Kinojevis map-area, in Montanier township, and extends some 4 miles from north to south and, within the area, 3 miles from west to east. The porphyritic syenite forms bodies about equal in size to those of the augite syenite. The largest mass lies for the most part west of Kinojevis river within 4 miles of the southern boundary of the map-area. Other masses are distributed throughout Montanier township. Normal granite with its pegmatitic phases forms about 50 per cent of the total area occupied by the granitic intrusives. The largest single mass is about 6 miles long from northwest to southeast and is 5 miles wide. It lies on either side of Caron lake. A large mass occurs in southern Montanier township and numerous small masses are present in Vaudray and Montanier townships.

The augite syenite is generally an equigranular rock with pink feldspar and augite or hornblende that is almost black with a greenish tinge. Locally the rock is slightly porphyritic. Ordinarily the grains have a diameter of about 4 mm. The ferromagnesian minerals make up about 40 per cent of the rock and consist of stumpy crystals, often idiomorphic, of augite or hornblende. Under the microscope, the augite appears almost colourless and shows many stages of alteration to green hornblende. In some cases hornblende is found almost to the exclusion of augite, but always the hornblende appears to be secondary after augite. The ferromagnesian minerals lie in a groundmass of smaller, almost equigranular individuals of microcline, twinned acid plagioclase, and orthoclase which is altered in many cases. Grains of quartz are rather rare. In one locality myrmekitic intergrowths of quartz and albite were observed. The accessory minerals are epidote, sphene, apatite, and a little biotite.

The porphyritic syenite, though it tends to be porphyritic, is not a true syenite porphyry, since it does not consist of well-developed phenocrysts in a groundmass of finer crystals. It is essentially a syenite in which most of the crystals of feldspar are idiomorphic and of considerable size. Many of the pink feldspar crystals attain diameters of half an inch, though generally they are somewhat smaller. The proportion of feldspar to hornblende is about 80:20. Potash feldspars represented by microcline and orthoclase are in about equal proportion to the soda feldspar; albite-oligoclase and perthitic intergrowths of the two are common. In thin section the rock is seen to consist essentially of large crystals of feldspar surrounded by smaller crystals of feldspar and hornblende. The hornblende forms small crystals, in most phases interstitial, but locally reaching a size approaching that of the feldspars. Under the microscope, the hornblende is bluish green. Quartz and orthoclase are interstitial to the other crystals. Biotite is present in small amounts. Apatite and zircon are accessory minerals.

The granite is either pink or grey and shows some degree of variation in texture and composition. The darker varieties are mostly characterized by hornblende and biotite, whereas the lighter contain white mica and some biotite. The rock is made up of from 20 per cent to 40 per cent of quartz, less than 20 per cent of ferromagnesian minerals, and the remainder of feldspars. In most parts of the area, hornblende with lesser amounts of biotite are the ferromagnesian minerals of the granites, but occasional phases contain biotite and some white mica. Albite is almost universally present in large amounts, and orthoclase and microcline are also in evidence. Micrographic intergrowths of quartz and orthoclase are common. Accessories common to all the granites are epidote, sphene, zircon, apatite, and garnet.

Both the sediments and the granites are cut by dykes of pegmatite and aplite, and masses of pegmatite are of common occurrence near the contact of the granite mass around Caron lake and generally throughout the large southern areas of granite. These pegmatites are rich in orthoclase and white mica, the orthoclase in some cases forming crystals up to 8 inches in diameter. The mica crystals attain diameters up to 2 inches. Quartz forms from 10 to 20 per cent of the rock mass and is interstitial to the other crystals and seldom exceeds 1 inch in diameter. Graphic intergrowths of quartz and orthoclase are common and some are on a large scale. Aplites are in the form of small dykes and are of the typical, fine-grained, holocrystalline variety. They are chiefly made up of quartz and feldspar. Albite is the most common feldspar and orthoclase and quartz practically make up the remainder of the rock. Micrographic intergrowths of quartz and albite are common. Hornblende is the principal of the scanty ferromagnesian minerals.

Cléricy Map-area

The acid intrusives in Cléricy map-area are less in total areal extent and the individual masses are smaller than in Kinojevis map-area. They are scattered throughout the area from the north boundary of the Timiskaming sediments to within a short distance of the north boundary of the map-area. Structurally, the acid intrusives in two instances show a regularity totally lacking in the intrusives of Kinojevis map-area. In southwest Cléricy township there is a lineal body of granite with a strike south 30 degrees east, extending in a straight line for 7 miles and having an average width of one mile. In central La Pause township, 12 miles to the east, there is a series of augite-syenite bodies scattered along a line 7 miles long and parallel to the Cléricy granite mass. These augite-syenite bodies are very probably the upper parts of a syenitic mass that is continuous along an axial trend whose direction is indicated by the outcropping, isolated masses. Besides these two areas of acid intrusives, a body, 1½ miles by 2 miles, of syenitic porphyry, occurs in northwest Cléricy township, small bodies of several types occur in the eastern part of Cléricy and in southeast Destor, and in the southwest is the eastern extension of the Dufault batholith, the section of which within Cléricy map-area measures about 5 miles from north to south and about 2 miles from east to west.

Petrographically, the general rock types are like those of Kinojevis map-area, but there seems to be a greater variation and some of the phases of the rock types of Cléricy have no exact equivalent in Kinojevis map-area.

Although none of the acid intrusives of the Cléricy cut Timiskaming sediments, it is, nevertheless, believed that most of them are equivalent in age to the southern intrusives and, therefore, are post-Timiskaming. But it is thought that some may be pre-Timiskaming, the reasons being: the dissimilar petrographic composition of some of the northern intrusives; the indication, in the case of two intrusive masses, of a possible relation between intrusion and supposedly pre-Timiskaming structure; the intrusions adjacent to the Timiskaming beds were nowhere found to extend into these strata; and, lastly, the pebbles of granite and other acid intrusives in the Timiskaming conglomerate closely resemble the acid intrusive masses invading the Keewatin rocks in Cléricy map-area.

Outcrops of augite syenite in Cléricy map-area are relatively few. A small exposure of basic augite syenite occurs south of Clayhill rapid, on ranges V and VI, Cléricy township. A number of outcrops of separate masses of augite syenite occur along a well-defined zone extending from lake Chassignolle to the north boundary of La Pause township, 2 miles from its western boundary.

Porphyritic syenite is the most widely distributed variety of acid intrusives in Cléricy map-area. Small dykes and masses are found in Destor township along a line extending northwestward for a distance of about 5 miles from the southeastern corner of the township. The largest single mass occurs at the northwest corner of Cléricy township, southeast of the previously mentioned intrusions. This mass is oval in shape, about 2 miles long and 1½ miles wide. Within an area 3 miles square in the northeast corner of Cléricy map-area, and extending a short distance into Aiguebelle, Manneville, and La Pause townships, are numerous outcrops of porphyritic syenite belonging chiefly to small masses on the east shores of Matissard (Horsetail) and Caste (Beade) lakes and along the east bank of Kinojevis river. Accurate mapping of these bodies was impossible owing to the drift cover. In Manneville township, just northeast of Cascade rapid, on the MacCormack claims, is a small outcrop of similar rock.

The granites form the largest intrusive bodies within Cléricy map-area. An eastern part of a batholith of granite and more basic rocks is located around lake Dufault. A small body of similar rock lies just north of the Kinojevis-Dufault portage, a mile east of the main body. A linear mass of granite extends from the northwestern part of Joanne township through Cléricy township and into Dufresnoy township, just south of Kinojevis river. Its southern extremity is within 2 miles of the northern contact of the Timiskaming sediments. On the strike of the axis of the intrusive and a mile to the south is a small mass of similar granite that is probably a part of the main body. Another mass of granite about a mile in diameter cuts the greenstones on the centre line of Cléricy in ranges IX and X. The only other mass of granite mapped within the area is one just to the south of the rapid on Cléricy river.

The masses of acid intrusive found in La Pause township have the general appearances of a quartz-augite-syenite, but, owing to the presence of a considerable amount of calcite feldspar with the acid plagioclase and microcline, are an augite-quartz-monzonite. The rock is pink, with a grain up to 4 mm. Ferromagnesian minerals compose 20 per cent to 30 per cent of the rock, the remainder being feldspar and a little quartz. The larger feldspar crystals show a tendency to idiomorphism and have zonal structures. Their centres are reddish brown and are surrounded by a lighter zone and this by one almost white. Under the microscope the central zone is seen to be much altered to calcite. It was probably originally basic plagioclase. Microcline is interstitial to the plagioclase individuals. Stumpy crystals of augite are also interstitial to the feldspar. The augite is partly altered to green hornblende and chlorite. Grains of glassy quartz are sparingly present. Small grains of white mica and calcite have apparently developed as alteration products of the plagioclase. Magnetite and epidote are present as accessories.

The mass of augite syenite south of Clayhill portage is quite porphyritic in habit. It is dark coloured, due to a large amount of ferromagnesian mineral which probably forms about 50 per cent of the rock. Phenocrysts of feldspar are pink and have lengths as great as 1 cm. Both orthoclase and plagioclase are present, the latter in many cases being zoned. A considerable amount of microperthitic intergrowth of the two feldspars is noticeable. Augite forms most of the dark-coloured groundmass and under the microscope the augite is seen to be colourless and in process of altering to green hornblende. Sphene, apatite, zircon, biotite, and, in places, epidote, are accessories.

The large mass of porphyritic syenite in the northwest corner of Cléricy township and the smaller bodies lying northwest of it are mauve or pink rocks, coarsely porphyritic. The zoned, idiomorphic plagioclase and the orthoclase individuals attain a length of 3 cm. Orthoclase makes up about 40 per cent of the rock. Some of it is in perthitic intergrowth with acid plagioclase. Orthoclase crystals also carry small perthitic rods of remarkably fresh plagioclase. The ferromagnesian mineral is pyroxene and forms 10 per cent to 20 per cent of the rock. It occurs in grains 4 mm. in length, is deep green, and is interstitial to the feldspar phenocrysts. The rest of the groundmass is of feldspar grains which do not exceed 6 mm. in diameter. Some quartz is also present and sphene is an accessory. The numerous porphyritic syenite masses in northeast Cléricy township have phenocrysts which seldom exceed 1 cm. in length. The feldspar is pink, in many cases shows zoning, the ferromagnesian mineral is augite, and the rock closely resembles the last-mentioned mass. On the MacCormack claim, in Manneville township, is a small mass of porphyritic syenite similar to those in northeast Cléricy township, but lower in ferromagnesian minerals and containing some quartz phenocrysts.

The large mass of granite on the west border of Cléricy map-area is the eastern part of the Dufault batholith. In the central parts the rock is pink and coarsely crystalline, whereas toward the margins it varies from grey to nearly black and its grain is variable. The pink variety contains from 50 per cent to 65 per cent of quartz, 25 per cent to 35 per cent of albite and orthoclase, and the remainder is chiefly chlorite probably derived from biotite. The dark variety, which is properly a granodiorite, consists largely of hornblende and feldspar, with, as a rule, less than 10 per cent of quartz. The feldspar is mostly highly altered, in some instances is albite and in others oligoclase. The outlier to the north of Kinojevis-Dufault portage consists altogether of the light-coloured variety of granite.

The long intrusive body lying mostly in Cléricy township is a quartz-rich granite which varies in composition from place to place. The commonest phase has a grain of 4 mm. and an allotriomorphic texture. Quartz forms at least 60 per cent of the rock and is in many places opalescent. The feldspar is pinkish to white and is much altered to sericite. Albite oligoclase is the chief feldspar, but some orthoclase may be present and a little microcline was seen. Alteration seems to have attacked all the feldspars in equal degree. The ferromagnesian minerals have been totally altered to cloudy masses of epidote, iron oxide, chlorite, and quartz. Toward the southern end of the body is a porphyritic facies in which the phenocrysts are of quartz and attain a diameter of 1 cm. Little ferromagnesian mineral is present.

Granite, like the above but less quartzose, forms the small mass just south of the rapid on Cléricy river. Another granite, similar in composition but slightly porphyritic, forms the mass on the centre line of Cléricy township, 2 miles west of Caste lake.

East of Kinojevis river in range VII, Cléricy township, are numerous dykes of feldspar and of quartz porphyry. The dykes strike north 45 degrees west and are 30 feet and less in width. The rocks contain numerous phenocrysts of quartz, orthoclase, and oligoclase in about equal proportions and scattered uniformly through a fine, recrystallized groundmass of the same minerals associated with much sericite and chlorite in small, slender flakes. These flakes show parallel orientation which gives the rock in hand specimens a schistose appearance, but the phenocrysts show little or no parallelism. The phenocrysts of quartz vary in size up to 3 mm. in diameter, but those of the feldspar never exceed 1 mm. Calcite is abundantly developed in the groundmass, and apatite, leucoxene, and rutile are accessories.

THE LATER GABBRO

A large number of gabbro dykes were observed throughout the two map-areas and many more probably exist. A large gabbro dyke traced by H. C. Cooke across Opasatika map-area was found to continue across the northwest corner of Rouyn township and on through Cléricy township. This dyke, therefore, has a known length of about 40 miles. It was classified by Cooke as pre-Cobalt, though M. E. Wilson previously mapped it as Keweenawan. A similar dyke in Montanier township was traced about 12 miles in a northeasterly direction into Bousquet township and dykes of lesser length with the same general trend were observed elsewhere. Isolated outcrops, noted at many points in the map-areas, are probably parts of other dykes of considerable lengths. The dykes range in width from a few feet to several hundred feet and the majority trend from north to north 60 degrees east. The smaller dykes generally outcrop in small, rounded knobs, but the larger ones in places form long ridges.

The smaller dykes are much finer in grain than the larger and as a rule exhibit ophitic texture. The larger dykes are in many places coarse grained and hold phenocrysts of feldspar up to 1 cm. across. The rock commonly appears quite fresh. In some places thin veins of aplitic differentiate form seams along the dyke walls.

In thin sections the quartz gabbro is seen to be formed of labradorite feldspar in lath-shaped crystals, which, penetrating the diopside individuals, produce a diabase texture. Some of the diopside is altered to green hornblende. Small quartz-feldspar intergrowths are interstitial to the minerals of earlier crystallization. The olivine gabbro is similar except that it contains olivine and that quartz is lacking. The olivine occurs in large grains generally altered along cleavage cracks to black iron oxide and serpentine.

ECONOMIC GEOLOGY

GENERAL STATEMENT

The developments taking place in connexion with the large body of gold-copper ore on the Horne property in Rouyn township and the discoveries of gold-bearing veins in many places throughout the district are factors tending to sustain public interest in the district. The extensive covering of drift and the dense vegetation have retarded thorough examination and as yet extensive development work has been done on very few properties, so that much remains to be done before the economic possibilities of the district can be properly estimated. The geological conditions of the areas and the discovery of free or combined gold in numerous places support the opinion that there is a good chance that workable deposits of gold and copper may be found within the map-areas.

ASSOCIATION OF MINERALIZATION AND INTRUSIVES

Numerous examples justify the conclusion that most gold-bearing deposits are associated with intrusions of the more acid rocks such as granites, syenites, some diorites, and the corresponding porphyries. In the Precambrian of Quebec and Ontario most of the gold deposits are found in localities where similar acid intrusions cut the Keewatin volcanics and sediments such as the Timiskaming. The nature of the rock, the folding and shearing to which it has been subjected, and other conditions have also an important influence on the formation of gold-bearing deposits. The association of gold with sulphide mineralization is well known.

Within Quebec district prospecting has shown that the mineralized areas are always adjacent to intrusives, though all intrusives do not give rise to mineralization. The association of mineralization with the smaller intrusives is particularly obvious in Cléricy map-area, where practically every prospect worthy of development is located in the vicinity of such intrusives or, as in the case of the long, narrow body of granite in Cléricy township, within the intrusive. The sulphides and free gold so far discovered in Cléricy map-area are carried by quartz veins, but shear zones should not be overlooked as possible loci of gold deposits.

Mineralization of a somewhat different nature characterizes a zone in the northern part of Kinojevis map-area. This zone lies within the Timiskaming sediments and holds mineralized veins of a type known to occur at intervals over a length of more than 30 miles. At one end of this distance are the Bathurst-Gamble and the Bruce-Thibault claims in Rouyn township. Farther east, veins of the same type occur in Joanne and Bousquet townships and still farther east are the O'Brien claims in Cadillac township. The mineralization seems to be of the deep-vein type. The quartz is dark and glassy and carries arsenopyrite, pyrite, and, occasionally, some pyrrhotite and tourmaline—all minerals characteristic of the deep veins. Free gold occurs in the veins and the wall-rock is impregnated with much carbonate, some pyrite, arsenopyrite, and tourmaline. In two instances intrusions of porphyry occur in the vicinity of such veins. The general resemblance existing between the various individual deposits and their distribution along a nearly straight, comparatively narrow, but long, zone suggest a common origin for all the occurrences. The source of the vein-forming solutions may have been the southern batholith, whose northern contact is roughly parallel to this zone, or the zone may mark a line of weakness followed by other intrusives.

As pointed out in the Summary Report for 1923, it is not considered probable that gold deposits of importance will be found at the contact of the southern batholith or in the country for several miles to the north of it.

The recently reported discovery of gold and copper values in the vicinity of the Dufault batholith, and the presence of chalcopyrite in many veins throughout Quebec district, give grounds for the opinion that the discovery of copper-rich ore-bodies may reward the search of the prospector.

DESCRIPTIONS OF MINERAL-BEARING PROSPECTS AND PROPERTIES

The Timmins claims are in the southwest corner of Aiguebelle township about $1\frac{1}{2}$ miles from the southern boundary. Some stripping has disclosed a feldspar porphyry dyke cutting a coarse conglomerate, apparently lying between the volcanics. A little disseminated pyrite occurs in the porphyry and assays have shown very low gold values associated with the pyrite. The stripping consists of a trench about 100 feet long running north and south. Prospecting to the south of the trench has been prevented by a thick clay deposit.

The Richmond claims are situated in ranges VIII and IX, Cléricy township, just east of the centre line of the township. Most of the claims lie along the southern boundary of a mass of granite which has a diameter of about a mile. The granite cuts greenstones, which in many places are much carbonated. The work up to September, 1924, consisted of some minor stripping. The contact of the granite and greenstones could not be accurately established because of the cover of drift and vegetation, but apparently near the southern contact large masses of quartz have been injected. Several outcrops of what appear to be one body of quartz trending east and west were observed over a length of 800 feet with a maximum observed width of 50 feet. The quartz is glassy-white and over long intervals shows no mineralization. Locally, siderite, chalcopyrite, and pyrite are present in minor quantities. Fragments of greenstone within the quartz show silicification and alteration to carbonate, and the wall-rock is altered in similar manner. Grab samples taken soon after the properties were staked gave encouraging results.

The Consolidated Mining and Smelting Company carried out work on claims southeast of the Richmond group. These claims were not visited after development work had been done, but the mineralization and country rock are similar to that found on the Richmond claims. A considerable amount of development work was done late in the season of 1924.

The Dean-McDiarmid claims are near the mouth of Dunne creek which enters Kinojevis river from the east at the boundary between ranges VIII and IX, Cléricy township. Owing to the heavy drift outcrops are few. Country rock consists of Keewatin tuffs intruded by syenite. Along the southern contact the intrusive is fine-grained. Within the tuffs at the contact with the syenite are bands from 1½ to 6 inches wide of fine-grained pyrite with quartz and some feldspar and cut by narrow quartz veins. No carbonate was observed. Stripping had been done along the east-west contact of the syenite for a distance of some 30 feet. Half a mile above the mouth of Dunne creek, on the west bank of Kinojevis river, the same owners have reported a gossan from which gold was panned, but the occurrence was not examined.

The Pelzer claims are between Kinojevis river and La Pause township in range VII, Cléricy township. The principal exposures are on a low ridge running east and west and bounded north and south by thick deposits of drift. The claims are in the Cléricy band of sediments and the volcanics to the north of them. The volcanics consist of andesites, some rhyolites, and minor amounts of tuffs. The tuffs are schistose and some of the flows show pillow and vesicular structures. The volcanics strike north 60 degrees west and dip steeply to the south. The sediments outcrop in the southwestern part of the claims and consist chiefly of greywacke with a minor band of conglomerate close to the northern contact. Quartz and feldspar-porphyry dykes intrude the volcanics along their strike. The largest dyke is 30 feet wide and lies in the centre of a shear zone 200 feet broad. This shear zone has been traced for 600 feet along a strike north 55 degrees west. Parallel this shear zone and 600 feet to the east, is another shear zone with a width of 140 feet and exposed for 300 feet. In the first-mentioned broader shear zone small lenses of quartz associated with siderite and calcite occur south of the dyke. North of the dyke, the shear zone has been silicified and mineralized with thickly disseminated, small octahedra of magnetite, a few crystals of pyrite, and abundant siderite and calcite. The narrower shear zone is mineralized in the same way as the northern part of the broader zone, except that pyrite is more abundant and some chalcopyrite also occurs. Considerable stripping has been done, but the gold values so far discovered are low.

The Tackman-McNeill claims are situated east of the Pelzer claims, just within La Pause township and about 6 miles from the southern boundary of the township. The country rock consists of basic volcanics cut by fine-grained porphyry dykes similar to those on the Pelzer claims. A considerable amount of stripping and trenching has exposed a vein of glassy white quartz, lenticular in shape and in places attaining a width of 3 feet. The vein strikes 40 degrees south of east and lies along the edge of one of the porphyry dykes. Carbonate solutions have produced much alteration in the country rock, but the amount of sulphide is small in both vein and country rock. Assays of samples show low values.

Of the group of Lowry claims in the northern part of Joanne township, just east of lake Marillac, only numbers 1620 and 2130 were visited. Both claims lie within the southern end of the Cléricy granite batholith. The granite is sheared and altered and contains in this vicinity numerous sheared remnants of greenstone. The granite is light pink and contains very little ferromagnesian mineral. Locally it exhibits porphyritic phases with phenocrysts of both quartz and feldspar. The feldspars are much kaolinized and much of the ferromagnesian mineral is chloritized. The batholith is not considered to be deeply truncated in this locality. On claim 1620, 300 feet south of No. 1 post, is a small, irregular quartz vein of varying width, cutting a quartzose granite. The vein where exposed is not more than a foot wide. The quartz is milky white and contains some free gold. On claim 2,130 numerous small lenses of quartz are irregularly disposed in granite. Some of these lenses carry free gold with a small amount of pyrite. The best showing of free gold occurs in a small vein cutting the granite near the edge of one of the inclusions of sheared greenstone which is not itself mineralized. The strike of the small quartz masses is generally a little north of east. The largest observed is about 200 feet south of the cabin near the southeast corner of this claim. It is about 5 feet wide and strikes to the northeast. Some free gold occurs in the vein and the wall-rock is somewhat mineralized with pyrite. The characteristic heavy mineralization usually seen in included fragments of greenstone associated with veins and intrusives is not pronounced in this locality. In October, 1924, when the claims were visited, a substantial cabin had been built and some stripping and trenching had been done. Mr. F. G. McLeod, who had the work under his supervision, reported some good assays from channel samples taken across some of the veins.

Free gold has been reported on a number of claims a short distance to the north, within the granite, but these claims were not examined.

The Brownell Syndicate holds a group of eight claims in the northeast corner of Joanne township. The boundary between the Timiskaming sediments and the Keewatin volcanics passes through the claims, most of which lie within the volcanics, consisting chiefly of andesites and basalts. Some outcrops of sheared quartz porphyry were observed. On a ridge in the centre of the group of claims, a shear zone 6 to 10 feet wide has been stripped for a length of 1,000 feet. Other shear zones were seen in the vicinity. They strike about east-west. The main shear zone carries stringers of milky white quartz and is mineralized with pyrite, chalcopyrite, and some tourmaline. Gold has been panned from the weathered outcrop of these shear zones.

BARRAUTE AREA, ABITIBI COUNTY, QUEBEC

The increasing interest that is being displayed in the mineral possibilities of western Quebec has resulted in an increased demand for geological maps of the various districts. The accompanying map of Barraute area (No. 2057), representing the results of work in this district in 1924 by G. W. Bain, and by other geologists in earlier years, should prove of service pending a more detailed geological investigation of the map-area.

SHICKSHOCK MOUNTAINS, CENTRAL GASPE, QUEBEC

By F. J. Alcock

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Illustrations

INTRODUCTION

During the field season of 1924 the writer mapped an area of about 55 square miles around mount Logan, Gaspe. Geological sections were also studied along Matane and Little Matane rivers and on the shore of lake Matapedia. This work was undertaken to determine, if possible, the age of the belt of rocks which forms the high country of the Shickshocks. These rocks are altered volcanics with, in places, some associated beds of clastic sediments. Their age, since exploration of the peninsula began, has been one of the major geological problems of Gaspe. Sir William Logan, the first worker in the field, placed them provisionally with his Quebec group of early Palæozoic age. Later workers concluded that they were older than this group, and on the geological map of Gaspe they are shown as Precambrian. Work by the writer in Mount Albert area in 1923 furnished evidence that the series is probably Palæozoic, and suggested the desirability of further investigation. Areas likely to furnish the most fruitful results were accordingly selected. Near Port Daniel, on Chaleur bay, another belt of rocks is shown on the geological map of Gaspe as Precambrian. Several days were, therefore, spent in studying the relationships of this belt to the surrounding rocks of known Palæozoic age, to determine whether there are undoubted Precambrian rocks anywhere in the peninsula.

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The writer is indebted to Mr. E. S. Halloway for the use of maps of Matane Lakes region, and for other courtesies; and to Professors M. L. Fernald and F. C. Collins for photographs and a map of Mount Logan region. Assistance in the field was rendered by A. N. MacIntosh.

TOPOGRAPHY

The Shickshock mountains of Gaspe are a continuation of the Notre Dame range of southern Quebec. Both belong to a much larger belt of mountainous country extending from the gulf of Mexico to Newfoundland. The Shickshocks form the highest land in southeastern Canada, Tabletop mountain at one point reaching an elevation of 4,200 feet.

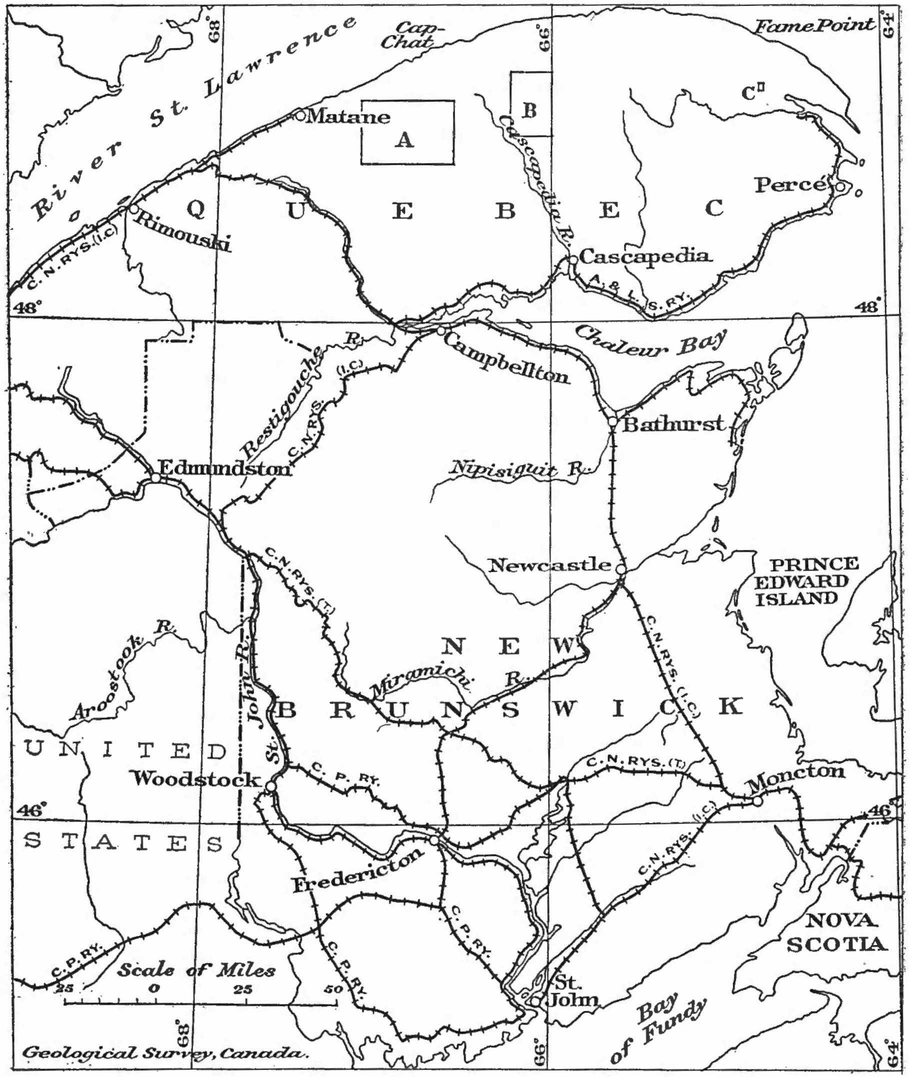

Figure 8. Index map showing position of: (A) Matane Lakes-Cap-Chat River area; (B) Mount Albert area; and (C) Mount Serpentine area, Gaspe peninsula, Quebec.

The most striking feature of the range is the flat-topped character of the mountains composing it (*See* Plates I and II). The region is in reality a plateau dissected by deep valleys. Mount Albert, Tabletop, mount Logan, Matawees, Bayfield, LeClercq, and many others, all have broad, flat summits. In places on this high upland are lakes and ponds, and in many cases the streams commence with a gentle gradient before plunging into the deep-cut valleys. The high plateau is developed on hard volcanic and intrusive rocks, and varies in elevation from about 3,500 feet to 4,200 feet.

North of the high upland is a second plateau developed on shales. In this belt the interfluvial areas are also remarkably flat-topped, standing at elevations from about 1,000 to 1,600 feet. The descent from the higher to the lower plateau is abrupt. On the south side of the Shickshocks is a similar, though less striking, descent to a lower plateau developed on limestone. The lower plateau country on either side of the range is cut by deep valleys marked by steep slopes. In the lower parts of the main valleys are terraces cut in the gravel and clay deposits that border the streams.

Evidence that Pleistocene local glaciers occupied the flanks of the Shickshocks is shown in Mount Logan region. The trail to the summit from Camp Nector follows up a well-defined cirque; another, equally striking, lies to the northeast of mount Logan (*See* Plate II B), and others are also to be observed.

GENERAL GEOLOGY

The rock succession in the part of the Shickshock range covered by the accompanying map (No. 2074), and also along the northeast side of lake Matapedia, is as follows:

Silurian	Limestone and shales
Unconformity	
Ordovician (?)	Volcanics and arkose Shales

SHALES

The lower plateau country north of the Shickshocks is developed on shales. These were observed on the northeast shore of lake Matapedia, on Matane and Little Matane rivers, and on Cap-Chat river and its numerous tributaries. The rocks are grey and black, in places showing fine colour-banding. Locally, they contain sandy and limy layers. They stand at high angles, are locally much drag-folded, and are traversed by numerous small quartz and calcite stringers. The general strike is northeast, and the dips vary from 30 to 80 degrees to the southeast. The only fossils found by the writer in this series were from some sandy layers on a small island in lake Matapedia. They were very indistinct remains, probably graptolites.

VOLCANICS AND ARKOSE

The best section of the volcanics and arkose is exposed on the northeast shore of lake Matapedia. The arkose is reddish, grey, or greenish grey. Bedding planes for the most part are well marked, so there is little difficulty in determining the structure. Locally, the rock contains thin fragments of reddish shales. In one outcrop it is conglomeratic. The strike of the beds is a little north of east, and the dips are all to the southeast at angles varying from 25 degrees to 50 degrees.

The rock consists of quartz and feldspar. Orthoclase and plagioclase grains, all subangular and many broken or bent, are present. In all the sections studied, there is calcareous cement.

Interbedded with the clastic sediments are horizons of basic lavas. These are dense, hard, massive rocks. Their surface origin is shown by the presence in places of amygdaloidal and ellipsoidal structure. These structures also afford evidence as to the top and bottom of the flows. The top of one flow was ascertained by the presence of amygdaloidal structure grading down into massive rock; that of another by ellipsoidal structure; and the bottom of a third by the presence in it of sand grains which it evidently had picked up by flowing over the sandy layer beneath. In each case the structure of the volcanic rocks bore out the evidence of the sediments that the dips are to the south, thus ruling out the possibility of an overturned structure.

In the Lake Matapedia section the arkose is more abundant than the volcanics, but it thins out eastward and the volcanic rocks become proportionately more important. In the region of Matane lakes the volcanics are dominant, but towards the base of the series arkose is interbedded with them. As at lake Matapedia, the dips of the sediments are uniformly to the south. In the region of Cap-Chat river, arkose is present only in subordinate amounts. It is found on the north flank of mount Nicolalbert, and a thin bed occurs on the steep change of slope near the base of the volcanics west of mount Logan.

The exact contact of the volcanic rocks with the underlying black shales was observed at a number of places along this change of slope. In each place the contact had a steep dip to the south, and there was an absence of any sign of faulting, such as gouge, breccia, slickensiding, or shearing.

The most abundant volcanic type is a massive greenstone variety. In places it contains irregular masses and stringers of epidote. Locally, it is sheared into chlorite schist. In thin section all the specimens proved to be much altered. All the ferromagnesian minerals have been largely altered to chlorite, uralite, and epidote, but small amounts of augite remain. Some of the plagioclase is fairly fresh and in some sections it occurs as lath-shaped crystals that give the rock an ophitic texture. A little quartz is present in some sections and iron oxides occur in varying amounts.

Locally associated with the massive greenstone rocks are well-banded types which are evidently tuffs. Examples were found on one of the islands in the middle of lake Matapedia, near the southern end of Matane lake, and in several localities near mount Logan.

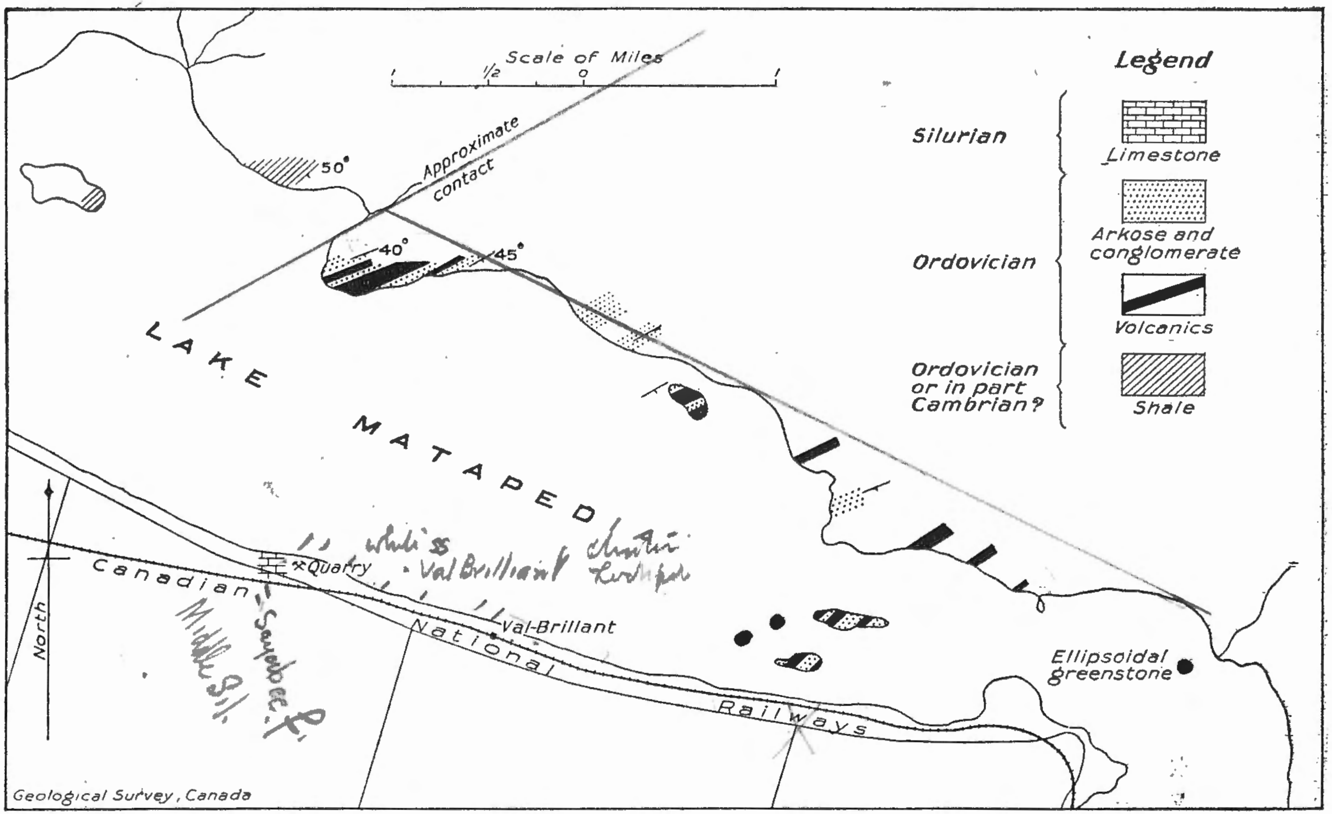

Figure 9. Location of rock outcrops along the shores of part of lake Matapedia.

The evidence that this series of rocks which was mapped as Precambrian is really younger than the early Palæozoic shales to the north may be summarized as follows:

(1) It lies stratigraphically above the shales. The evidence of the strikes and dips is clear and the structure of the interbedded flow rocks shows that the structure is not overturned. There is, moreover, no evidence that there is a fault along the contact of the two series.

(2) The arkose contains fragments of reddish shales similar to those occurring in parts of the shale series.

(3) The arkose-volcanic series is overlain to the south by Silurian rocks. If the series were older than the shales a belt of the latter would probably be exposed between the volcanics and the Silurian limestones.

(4) The only argument advanced in favour of the Precambrian age of the series is the degree of metamorphism which it shows. It is, however, on the whole no more highly metamorphosed than the rocks to the north, which are sheared and dragged and pass into slates. The volcanics and arkose are locally sheared, but on the whole are massive. Moreover, a period of deformation suffered by both series would naturally have a greater effect on hard volcanics than on soft shales, and the fact that the volcanics have occasionally been rendered schistose is only what might be expected, and does not affect the conclusions reached from a study of the stratigraphic relationships.

SILURIAN LIMESTONES AND SHALES

Silurian limestones and shales were observed on lake Matapedia and on Matane river. On the lake, one mile west of Val Brillant, are quarries in which bluish grey limestone in thin to thick beds dips at angles of from 5 to 10 degrees to the south. East of Val Brillant, almost opposite the largest of the islands in the middle of the lake, a railway cutting exposes a section of highly tilted limestone and shales. No outcrops were observed on the east side of the lake, but from the sudden drop in the topography and the presence of large blocks of limestone on the shore, the boundary between the hard volcanic-clastic series and the softer overlying limestones can be inferred. It is probable that a fault passes along the south side of lake Matapedia, throwing the south side down relative to the north.

Good exposures of limestone occur at a number of places along Matane river. Subsequent valleys like that of the Bonjour are developed along their contact with the underlying volcanics.

ECONOMIC GEOLOGY

The volcanic rocks of the Shickshocks are locally traversed by quartz veins, which, wherever observed, are small and lacking in mineralization. Much of the region is concealed by a heavy overburden that renders prospecting difficult except along the mountain summits and the steep changes of slope.

THE ROCKS AT CAPE MAQUEREAU

The only belt of rocks in Gaspe which has been mapped as Precambrian (other than the one forming the higher Shickshocks), is at cape Maquereau on Chaleur bay. The belt is shown on the geological map of Gaspe as a band about 2 miles wide extending in a northwest direction for 18 miles from the coast. On either side it is shown on the map as being flanked by strata which are called Ordovician, except for a short distance at the coast where on its southwestern margin it is bordered by Silurian rocks. It would appear from the map that there is here an anticlinal structure with the older rocks in the middle, and progressively younger rocks on either side.

An examination of these rocks was made from east of Newport westward to Port Daniel. Near Newport the rocks are reddish, firmly cemented arkoses. Throughout the rock are small, rounded, vitreous quartz veins. In places, the series contains thin slabs of red shale showing that it is younger than some formations composed of that type of rock. The strike and dip of the series vary considerably. In a general way the strike parallels the coast-line. Near Newport it is northeast. The dips are steep and in many places vertical. In places the arkose is so massive that no stratification lines can be distinguished.

Approaching cape Maquereau the rocks are hard arkoses and quartzites, traversed locally by numerous quartz stringers. Associated with the clastic sediments are dark, massive, greenstone rocks. The whole series is lithologically and structurally similar to the arkose-volcanic series on the northeast shore of lake Matapedia. The writer is of the opinion that Logan's interpretation of these rocks as one series of early Palæozoic age is correct. That they were folded and metamorphosed in pre-Silurian time is shown by the presence of their pebbles in the Silurian sandstones near Port Daniel.

GEOLOGY OF MOUNT SERPENTINE, GASPE, QUEBEC

By F. J. Alcock

CONTENTS

Illustration

INTRODUCTION

In connexion with the geological mapping of Mount Albert area, central Gaspe, begun in 1921 and completed during the past field season, one of the problems encountered was the geological age of the mass of serpentinized peridotite which forms mount Albert. This intrusive was not found in contact with any Silurian or younger rocks and, consequently, its age, whether pre- or post-Silurian, could not be satisfactorily determined in the area. Near Dartmouth river, at the eastern end of the peninsula (*See* Figure 9, page 131), another smaller mass of serpentine was known to occur. On the geological map (No. 2060) it was shown to be flanked on one side by Silurian rocks and on the other by Devonian. It was thought that a detailed study of the relationships of the intrusive to these two formations might throw some light on the date of the intrusion. Since it is highly probable that the various exposures of serpentine throughout Gaspe are to be related to the same period of igneous activity, the age of all the serpentine rocks of the peninsula might thus be settled.

The Mount Serpentine area on the Dartmouth has also attracted attention from an economic point of view. The serpentine contains a certain amount of asbestos and a number of prospect pits have been opened up to investigate the quality and quantity of fibre available. Though nothing of importance was discovered there was a demand for a geological investigation to see what were the probabilities of deposits of commercial importance being discovered.

FIELD WORK

A week was spent in the area in June and a map covering approximately 7 square miles was prepared. Chain, compass, and barometer traverses were made up the streams, along the ridge tops, and in the neighbourhood of geological contacts. Mapping was done on a scale of 2,000 feet to the inch and the topography shown by contours with 100-foot intervals. The elevations shown are all from unchecked barometer readings.

LOCATION AND ACCESS

Serpentine mountain lies in Blanchet township, Gaspe county, between Ladystep and Hole brooks, streams which flow into Dartmouth river from the west. From Gaspe basin an automobile can be driven along the northeast side of the river to what is known as the Dartmouth fork, a distance of about 12 miles. From this point, the road which follows up the river is passable only by wagons. About half-way between the mouths of Hole and Ladystep brooks, the river is crossed at what is known as Millers crossing, and from this point a trail can be followed to an old lumber camp on Ladystep brook, a distance of less than 3 miles. The camp is situated near the foot of mount Serpentine and is a convenient location from which the geology and principal prospect pits can be studied. An alternative route may be taken up the Dartmouth by canoe as far as Millers crossing. The river is, however, swift in places and loaded canoes can be taken up only when the water is suitable.

PREVIOUS WORK

The region was visited by James Richardson in 1857 and his description of it is given in the Report of Progress for that year. After surveying Madeleine river as far as it could be ascended by canoe, Richardson made an overland traverse eastward to Dartmouth river and then a section northward, reaching the St. Lawrence at Grand Etang. In the first of these traverses he visited and named mount Serpentine. The serpentine belt was followed for a distance of about 1½ miles, but its actual relationship to the adjacent Silurian and Devonian rocks was not described. The presence of chrome and nickel is mentioned as a result of analyses of the serpentine rock, but no statement is given of the occurrence of asbestos.

TOPOGRAPHY

The region in which mount Serpentine lies is a plateau dissected by youthful valleys. The higher parts reach elevations around 1,600 feet. The summits of the interfluvial areas are flat and present a very even sky-line. Here and there on these flat tops are small lakes and ponds, and in early June when the work described in the present report was carried out, big banks of snow occupied the depressions and more sheltered parts. The region is wooded with spruce, balsam, and birch.

The streams are deeply entrenched in the plateau. The valley of Ladystep brook lies over 1,000 feet below the flat plateau country. The character of the valleys depends to some extent on the type of bedrock. The Gaspe sandstone weathers the most readily of any of the rocks exposed in the area and produces the broadest valleys. Above the lumber camp on Ladystep brook the valley is broad with gentle slopes and is known locally as the "Plains," to distinguish it from the steep valley slopes which are the common feature of the area. The sandstone country east of the schist and serpentine belt is also of low gradient in contrast with the steep change of slope where these rocks are exposed. The limestone

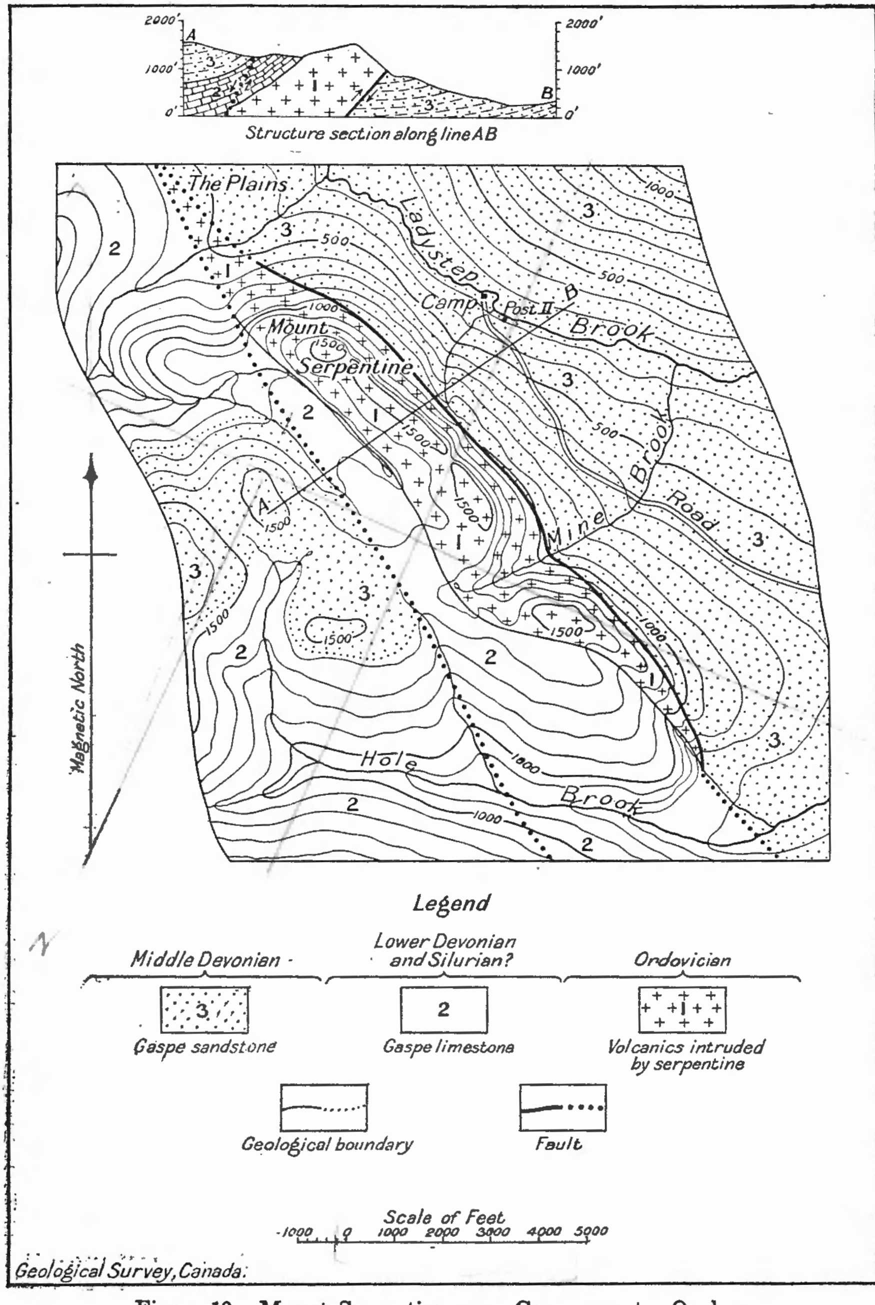

Figure 10. Mount Serpentine area, Gaspe county, Quebec.

country shows gorges and cascades. On Hole brook is a series of cascades and at one place between the 600 and 700-foot contours the whole stream plunges down behind a narrow arch. This was evidently once a large pot-hole of which only a rim of the upper part has been left. The whole region is evidently one of mature topography rejuvenated by uplift with subsequent rapid down-cutting.

GENERAL GEOLOGY

The rock succession in the region may be tabulated as follows:

Middle Devonian	....	Gaspe sandstone
	Unconformity	
Lower Devonian	....	Gaspe limestone
	Unconformity	
Ordovician	....	Serpentinized peridotite
	Intrusive contact	
		Altered volcanic rocks

ALTERED VOLCANICS

Mount Serpentine consists largely of metamorphosed rocks which occupy a belt having a maximum width of about 2,000 feet and extending for a distance of about 3 miles. For most of this distance the boundary of the belt on either side can be sharply delimited. To the northeast the boundary is a fault-plane whose topographic expression is a cliff. To the southwest the contact with the overlying limestone lies along two depressions, the southern one occupied by a stream flowing to Hole brook and the northern by a branch of one of the tributaries of Ladystep brook.

The rocks are of the kind commonly known as greenstone and greenstone schist. They are dark in colour and vary from massive varieties to fissile schists. The massive varieties contain irregular masses of epidote and are traversed by quartz stringers. The rocks are apparently all of volcanic origin. Many of them are flows. The study of thin sections of a number, however, shows that some are of tuffaceous origin.

The rocks of flow origin and their schistose derivatives occupy the northeast side of the greenstone belt, whereas the volcanics of tuffaceous origin lie to the southwest, apparently above them. The massive rocks are dark in colour and dense in texture. At one place appeared to be what were squeezed amygdules. Irregular masses of greenish epidote occur throughout the rock and small stringers of quartz are locally abundant. One dark green variety in thin section was found to consist chiefly of epidote with minor amounts of chlorite and quartz, all three of secondary origin. The chlorite is associated with the epidote and the quartz occurs chiefly as seams throughout the mass. Magnetite is present in only very small amounts. A section of another dark green, massive rock showed a less degree of alteration. In this, there is considerable feldspar, all more or less altered. One crystal of labradorite was observed, but most had apparently been converted into secondary albite. A great deal of secondary quartz and chlorite were also found to be present. The original composition of the rock is difficult to state, but it was probably an andesite.

Many of the rocks along the eastern margin are schists in which the platy mineral is chlorite. The rocks are dark in colour, some black, and many have a ribbed effect normal to the plane of schistosity; this suggests a movement after the flow cleavage of the rock had been developed, producing a secondary incipient fracture cleavage. In some sections the rock is seen to consist almost entirely of chlorite and quartz, with the chlorite crystals in parallel alignment. In others, there is considerable feldspar, much of it unstriated secondary albite. Zoisite is also found as an alteration product of the feldspar. Magnetite occurs in varying amounts and zircon is present as an accessory mineral in most of the sections.

The tuffaceous rocks which lie along the southwest side of the belt are dark grey to green, and are massive with no well-defined bedding planes. In thin section they are clearly seen to be clastic, consisting of definite fragments in a matrix of finer particles. The larger fragments consist of feldspar, many of which are broken and all of which are more or less altered. Quartz is present in varying amounts. The tuffs have suffered the same type of alteration as the rocks of flow origin, showing the development of chlorite, epidote, secondary albite, sericite, and quartz. It is also very probable that many of the schistose rocks are altered tuffs rather than altered flow rocks.

These rocks are identical with the volcanic series which extends down the middle of Gaspe peninsula from Tabletop mountain to lake Matapedia. This series, on account of its greater resistance to erosion, stands up above the belt of Ordovician shales to the north and the Gaspe limestones to the south, forming the belt of country known as Shickshock mountains. In the western part of this belt there are, interbanded with the volcanics, sandstone horizons from which the structure can more readily be worked out than from the volcanics themselves. On the geological map of Gaspe this belt of volcanics and clastic sediments was shown as Precambrian. During the past two seasons, however, the writer collected evidence that this series overlies the early Palæozoic shales to the north, and hence is younger. It is very clear, also, that they were deformed before the deposition of the overlying Silurian limestone. Their age is, therefore, probably Ordovician.

SERPENTINIZED PERIDOTITE

The main exposure of serpentine is on the steep, northwest slope of mount Serpentine. A narrow band is also found on Mine brook which is probably the continuation of the same intrusion. The rock is dense and dark green, weathering on the exposed surface to a grey or brownish buff. In places, it is broken and sheared. It contains locally a little chromite and in other places asbestos. Only one thin section was studied. It consisted of serpentine traversed by small veins of chrysotile.

Near one of the prospect pits in the serpentine the writer collected a fragment of a rock which, according to Mr. William Johnstone, the prospector who has carried out most of the exploratory work in the area, forms one or two small outcrops on the plains. The rock is dark grey to black, showing in hand specimens black, glistening crystals of augite and hornblende. In thin section it is seen to consist of pyroxene, hornblende, plagioclase, and secondary chlorite. The pyroxene is much the most abundant mineral, and is in places altered to chlorite. The feldspar is labradorite and is for the most part fresh. The hornblende is of the green variety and occurs in subordinate amounts. The rock forms rather a typical gabbro and is apparently a differentiate of the basic rock magma from which the peridotite was formed.

These basic rocks were quite evidently intruded into the volcanic complex in pre-Silurian times. In no place was there found any dyke or offshoot of them into the Silurian or Devonian rocks. This is the same relationship as was found in Mount Albert area, central Gaspe. The age of the Gaspe serpentine rocks can, therefore, be placed as pre-Silurian. This is in agreement with what was found by Harvie in the serpentine region of Thedford and Black Lakes area of the Eastern Townships of Quebec.

GASPE LIMESTONE

The Gaspe limestone lies along the southwest side of the schistose belt of rocks and dips off it at angles around 30 degrees. Good outcrops are found in the steep valley sides, and along Hole brook almost continuous exposures are met with. Here, there is a considerable variation in both dip and strike. The series consists dominantly of limestone, dense and dark blue to grey in colour, weathering to a light grey on the exposed surface. The beds vary greatly in thickness. No fossils were found, but the lithological character and the place in the section correlate it with the Gaspe limestone series in which fossils have been found in other localities. This series has a total thickness of about 2,000 feet. The age of most of it is Lower Devonian. In places, however, the basal beds contain Silurian fossils and the series may, therefore, be considered as having begun to be deposited in Upper Silurian time and as continuing to accumulate through much of the Lower Devonian. The most detailed work on this series of rocks has been carried out by J. M. Clarke, of the Geological Survey of New York state, on the rocks at the eastern end of Gaspe peninsula. His results are included in Memoir No. 9 of the New York State Survey, under the title of "Early Devonian History of New York and Eastern North America."

GASPE SANDSTONE

About half the area mapped is covered with Gaspe sandstone. Outcrops occur along Ladystep and Mine brooks and loose blocks on the gentler slopes. Outcrops occur also to the west of mount Serpentine, but the boundaries of this area were put in largely from the occurrence of float.

In Mount Serpentine area, the rock is a well-bedded, buff-coloured sandstone. It is for the most part loosely cemented. In places, it is conglomeratic. The individual grains consist of quartz, pink feldspar, and small fragments of volcanic rock, for the most part fairly well rounded.

The Gaspe sandstone series covers wide areas in Gaspe. The basal part contains beds carrying marine fossils of Middle Devonian age. The series is especially noted for the remains of Devonian plants which have been found in it. The plants represent the *Psilophyton-Arthrostigma* flora, of which many species have been described by Sir William Dawson. About a mile east of the railway station on the south side of Gaspe harbour is an exposure of coarse-grained sandstone in which are numerous plant remains, and associated with them are curved impressions up to about 5 inches long of what were apparently teeth of Devonian fish.

In the interior of the peninsula flows of basic volcanic rocks and dykes of the same composition are associated with the series which, therefore, was apparently formed during a time of great volcanic activity.

STRUCTURE

As already mentioned the rocks of the schist belt are highly altered and the changes produced in them are of the type which result from heat and pressure. The Gaspe limestones and Gaspe sandstones have been folded and faulted, but otherwise have suffered little deformation. There have been, therefore, two periods of movement, one in pre-Silurian time, probably at the close of the Ordovician—in which the rocks were folded and altered—and a second, in Middle Devonian time, in which all the rocks of the region were involved. The first of these revolutions was accompanied by the intrusion of peridotite and the second by that of a granite batholith with syenitic and porphyritic differentiates.

The limestone along the southwest border of the schist complex dips off that series at an angle of about 30 degrees. This contact represents an unconformity. For the distance over which there is data the limestone was deposited on an area of low relief and the unconformity, therefore, represents a long erosion period, occupying probably most of the Silurian.

On the northeast side of the schist complex, the Gaspe sandstone ends abruptly against the steep face of mount Serpentine. The beds are little deformed, with low dips to the southwest. The contact is quite evidently a fault and its topographic expression indicates its character. On Mine brook the line of contact is V-shaped with the angle of the V upstream, which shows that the dip of the contact must be upstream, and at either end of the schistose belt the direction the contact takes also shows that the dip of the fault-plane is to the southwest. The fault, therefore, has been a thrust in which the schist on the hanging-wall has gone up relative to the sandstone on the foot-wall. The throw of the fault is large. There is no indication where the sandstone which now lies against the schist belt comes in the Gaspe sandstone section, which has a thickness of about 5,000 feet. Below the sandstone, however, is a thickness of 2,000 feet of Gaspe limestone, so that even if the sandstone now exposed at the schist cliff represents the base of the Gaspe sandstone, the fault must still have a throw of over 2,000 feet in order to cut out all the Gaspe limestone.

West of the schist belt a second fault follows two depressions occupied by streams flowing to Ladystep and Hole brooks, respectively. This fault is less clearly defined than the one along the northeast contact of the schist belt. The chief evidence for it is the thickness of the limestone along the line of section between mount Serpentine and the Gaspe sandstone on the hill between the headwaters of Hole and Ladystep brooks in the western part of the map-area. Between the outcrops of sandstone and volcanics, allowing for the strike and dip, there is room only for 1,000 feet of Gaspe limestone, whereas, as has already been stated, that series has actually a thickness of at least 2,000 feet. There must, therefore, have been a fault as indicated on the map and section that has cut out part of the limestone at this point. Mount Serpentine is, therefore, of the nature of a horst thrust up between younger strata.

Still other faults are present in the surrounding region. Richardson found evidence of a large fault just east of the area. Along Dartmouth river at and below Millers crossing the Gaspe sandstone lies flat on the south side of the stream and is highly tilted on the north side, suggesting that here is another fault along which the river has eroded its course.

ECONOMIC GEOLOGY

A certain amount of prospecting has been carried out in the area in the hope of finding asbestos deposits of importance. Several pits were opened up in the serpentine on the side of mount Serpentine below the steep face on the northwest side of the mountain. Narrow stringers of asbestos were locally found to be abundant in the rock and at one place, over a width of from 6 to 8 feet, veins with fibre up to seven-eighths of an inch in length were uncovered. The amount of rock with this grade was, however, small, and there would seem to be little hope of finding, in this comparatively narrow belt of serpentine, asbestos fibre in sufficient quantity to be of commercial importance.

CARBONIFEROUS FORMATIONS OF NORTHUMBERLAND STRAIT, NOVA SCOTIA

By W. A. Bell

CONTENTS

Illustrations

INTRODUCTION

The writer was engaged during the field season of 1924 in the study of the Carboniferous formations in Nova Scotia to the south of Northumberland strait. The work was begun at McAras brook near the Pictou-Antigonish county-line and was concluded 65 miles westward at river Wallace in Cumberland county. Inland the rocks were studied across the width of the Carboniferous area, the boundary of which lies 5 to 15 miles south of the strait.

The Carboniferous formations of the Maritime Provinces, since they contain all the coal, salt, gypsum, and oil-shale of eastern Canada, are pre-eminently of economic importance. The district studied includes the Pictou coal field—which was the subject of a previous investigation, of which the results will be published at a later date—and is bordered 25 miles to the west by the Springhill coal field, which was under study by F. A. Kerr. Reference may be made to the index map, Figure 11, and to the published geological map-sheets of Nova Scotia, Nos. 34, 43, 44, 45, 46, 47, 58, 59, 60, 61, 62.

The special purpose of the present investigation was twofold. Primarily, it was desirable to determine the possible occurrence of workable coal in the country between Pictou and Springhill. Secondarily, there was need for the interpretation of the geological structure and stratigraphy with special reference to data relating to the probable extension of the Malagash salt deposits. Furthermore, the Pictou coal field, and to a lesser extent the

Springhill coal field, presented many geological facts so difficult to interpretation that it was hoped that a study of the intervening terrain would aid materially in the solution of some of the outstanding problems. Most of the latter are directly concerned with the sequence of deposition and geological history of the various Carboniferous rock formations, knowledge of which has in many cases to be gathered from outlying districts or from regional studies as a whole.

In the following report a summary of the general structural and stratigraphical features will be followed by a more detailed discussion of the individual formations. As the district is quite uniformly drift covered, exposures of bedrock are limited mainly to the stream and coast sections.

Mr. J. C. Macgillivray ably assisted the writer in the field, and special acknowledgments and thanks are due to the officials of the Nova Scotia Steel and Coal Company, particularly to Mr. A. J. McCall, mining engineer, as well as to Mr. J. W. MacLeod of the Greenwood Coal Company and Mr. A. W. Chambers of the Malagash Salt Company.

GENERAL STRUCTURE

The Carboniferous rocks of the area range in age from Upper Mississippian to Upper Westphalian, inclusive. In the western part of the district they are bounded on the south by the igneous and metamorphic complex of the Cobequid massif (Figure 11, and Plate III A), in the eastern, by the McLellan-Browns Mountain massif, which may be considered an eastern extension of the Cobequids, and in the central part by rolling country underlain by disturbed Carboniferous rocks. Igneous rocks north of the Cobequids are a very minor element and are confined to Upper Mississippian and Lower Westphalian basic lava flows and intrusive sheets. With the exception of one marine series of Upper Mississippian age, the sediments were all deposited by fresh waters, and in general their outstanding physical feature is the dominance of dark red or chocolate colours. The most satisfactory explanation of their mode of origin, aside from that of the marine beds, is deposition by a conjunction of river waters, alluvial wash from ancient mountains, and flood-plain lakes, in progressively downsinking intermontane basins. The most persistent climatic conditions were probably those of semi-aridity and associated heavy seasonal concentration of rainfall, with periodical stages, more humid and equable. Temperature conditions are more difficult of interpretation. Despite the presence of heavy boulder conglomerates (Plates III B, V B) none of these suggests glacial formation but rather local fanglomerates.

The total thickness of Carboniferous sediment is many thousands of feet, not short of 20,000, but in no single locality was any such thickness known to be deposited. Local alluvial fans of conglomerate add greatly to the total thickness, as will be seen hereafter. Conglomerates, sandstones, and shales make up the bulk of the rock, with chocolate-red colours predominant. Originally these sediments were laid down on nearly horizontal river flats, except some of the thick, coarse boulder conglomerate members which doubtless may have had steep depositional slopes. At present, however, the rocks lie at various angles to the horizontal, from 5 degrees

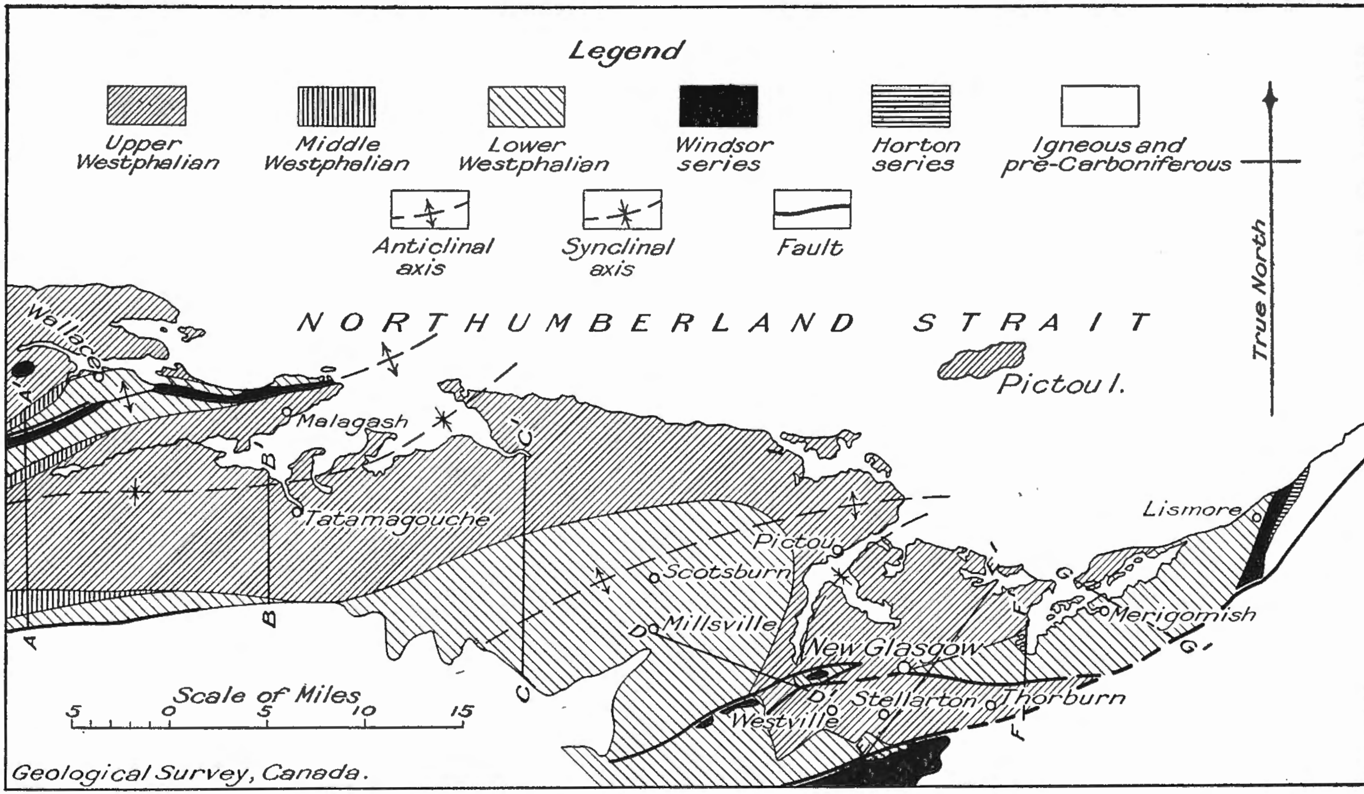

Figure 11. Index map showing distribution of Carboniferous formations in Nova Scotia in the vicinity of Northumberland strait. For structural sections along lines A-A′, B-B′, etc.

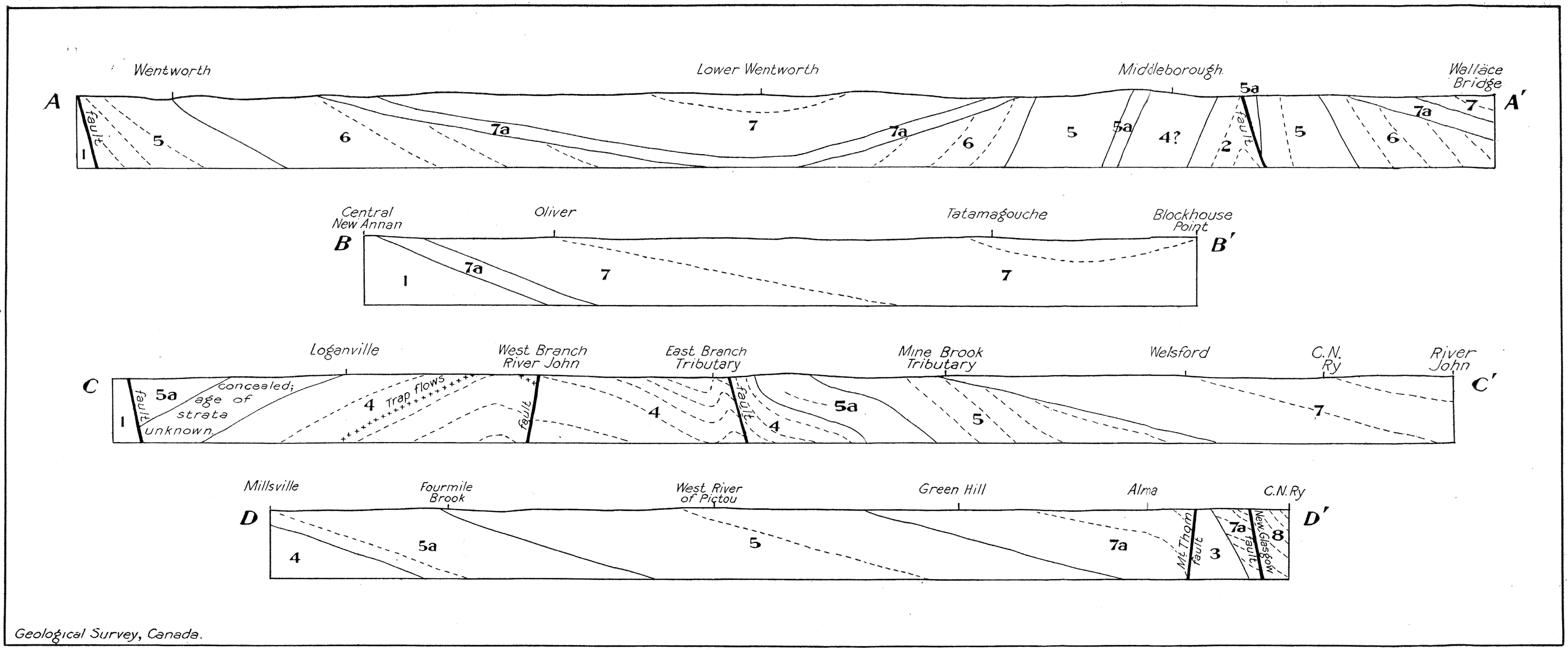

Figure 12. Structural sections based on published geological map-sheets. Vertical and horizontal scales: 1 mile to 1 inch. For further explanations of Figure, *See* page 145.

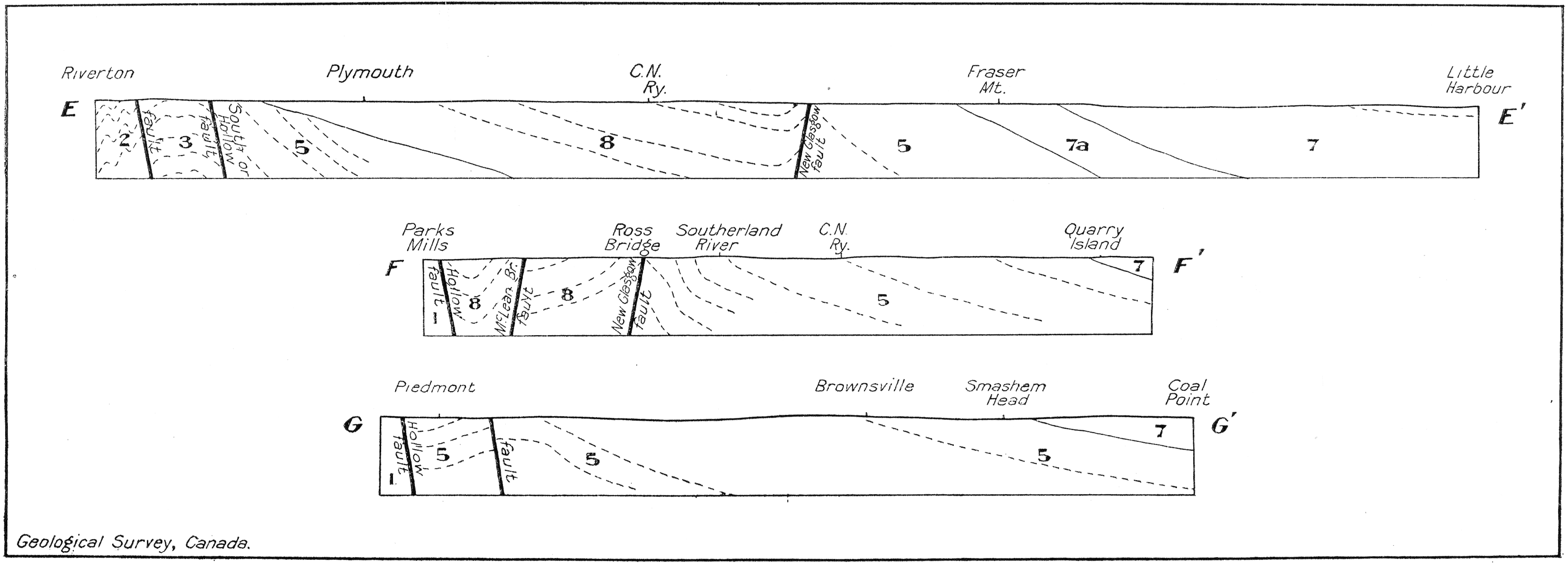

Figure 13. Structural sections based on published geological map-sheets. Vertical and horizontal scales: 1 mile to 1 inch. For further explanations of Figure, *See* page 145.

to vertical, and with various strikes. These attitudes are quite evidently the resultant of earth forces that acted on them since their deposition and which folded them in arches and troughs or uptilted them along great fracture planes or faults.

Explanation of Figure 12

The structural sections have been constructed from geological map-sheets surveyed by Hugh Fletcher. The sections indicate the geology as now revised and they may be used in conjunction with the map-sheets to interpret the geology of the areas under discussion.

Section A–A′ is along river Wallace, serial map-sheets Nos. 61 and 62.
Section B-B′ is along French river, Tatamagouche, serial map-sheet No. 59.
Section C–C′ is along West branch river John, serial map-sheet No. 46.
Section D–D′ is from Millsville to Alma, serial map-sheets Nos. 46 and 47.

Legend

		Symbol on map
Upper Westphalian	Stellarton series	8
	Pictou series	7
	New Glasgow conglomerate member	7a
Middle Westphalian	Joggins formation (?)	6
Lower Westphalian	Lismore formation	5
	Millsville conglomerate member	5a
	River John series	4
	Alma formation	3
Upper Mississippian	Windsor series	2
Igneous and pre-Carboniferous		1

Explanation of Figure 13

The structural sections have been constructed from geological map-sheets surveyed by Hugh Fletcher. The sections indicate the geology as now revised, and they may be used in conjunction with the map-sheets to interpret the geology of the areas under discussion.

Section E–E′ is from Riverton to Little Harbour, serial map-sheets Nos. 43 and 44.
Section F–F′ is along Sutherland river, serial map-sheets Nos. 43 and 44.
Section G–G′ is from Piedmont to Coal point, Big island, serial map-sheet No. 44.

Legend

		Symbol on map
Upper Westphalian	Stellarton series	8
	Pictou series	7
	New Glasgow conglomerate member	7a
Middle Westphalian	Joggins formation (?)	6
Lower Westphalian	Lismore formation	5
	Millsville conglomerate member	5a
	River John series	4
	Alma formation	3
Upper Mississippian	Windsor series	2
Igneous and pre-Carboniferous		1

Folding

There are four major structural axes of folding, all of which pitch at low angles northeasterly beneath Northumberland strait. From northwest to southeast these may be defined as: (1) the Clairmont or Malagash anticline; (2) the Tatamagouche syncline; (3) the Scotsburn anticline; (4) the Pictou syncline. In general the folds are broad and open, but the Malagash anticline is closely compressed, with resultant high angles of dip. Faulting has materially modified all the folds.

Minor folds are practically confined to the downfaulted inlier of the Pictou coal field, where two systems are definable, one with northerly pitching axes and a second with easterly pitching axes. Of the first type, there are five, these being from west to east: (1) the Plymouth anticline, (2) the Vale syncline, (3) the Whitburn anticline, (4) the Sutherland syncline, (5) the Telford anticline. The second type, with easterly pitching axes, comprises the Lourdes syncline, the Marsh Brook anticline, and the McLellan Brook syncline.

Faulting

Some of the major faults may be briefly noted. The Malagash anticline is narrowed by a downthrow of its northern limb of at least 2,500 feet where cut by river Wallace. The northern limb of the Scotsburn anticline is cut by several faults of which the vertical displacements are unknown, although the net result appears to be a downthrow on the north against a rectangular uplifted block that embraces the greater part of the East branch river John. These faults have the general easterly axial trend of the folding axes. There are also a few cross-faults trending from north by east to northeast and from north by west to northwest. In the upper River John area the zigzag contacts of the Carboniferous rocks with igneous or Silurian rocks of the Cobequids are in part at least the resultant of faults with such trends.

The southern part of the Pictou syncline is even more intricately faulted by a major system of faults trending from due east to 50 degrees north of east. The Pictou or Stellarton coal field is delimited by them and is a downfaulted triangular block bounded on the north and south by two great fractures. The south fault that limits the field is continuous with the Hollow fault of Arisaig district, estimated by Williams[1] to have there a throw of 3,000 to 4,000 feet. The northern downthrow of the coal-bearing beds was likewise probably several thousand feet in extent. The effect of this dislocation may be traced from East river to Malignant cove, a distance of nearly 35 miles. Beyond East river its course is not proved as it enters a series of complexly folded and faulted rocks of early Pennsylvanian age. The main fault that bounds the Pictou coal field on the north has a course nearly due east for 17 miles from Middle river to an intersection with the Hollow fault near the junction of the latter with the east branch of French river, Merigomish. West of Middle river this fault has not been clearly deciphered. A narrow, faulted horse there separates it from Mount Thom fault which runs from lower mount Thom to Alma and beyond, a distance of 10 miles, and which has resulted in a downthrow on the north. It is possible that the Pictou coal field is also bounded on the west by a fault running about 15 degrees west of north, as defined by Fletcher, but the paucity of outcrops in this latter area forbids any positive statements. There would appear to be also an east fault that has downthrown the coal-bearing beds of the Thorburn formation against older red beds of the Sutherland River and Ross Bridge members of the Stellarton series.

[1] Geol. Surv., Canada, Mem. 60, p. 95.

Breaks of Sequence

It was previously stated that the sum total of all the Carboniferous formations occurring in the district is much greater than the thickness now recognizable at any given locality. The present land surfaces underlain by Carboniferous strata rise from sea-level to a maximum elevation of 950 feet on Fitzpatrick mountain. The greater part of the country is a rolling lowland beneath an elevation of 300 feet; but, regardless of elevation, the rocks are truncated by the present surfaces, which show no sympathy save in a broad way with their tilted attitudes. Hence many thousands of feet of strata have been removed by erosion at every locality since the close of Carboniferous time. But a detailed study of the rocks reveals important losses that can only be attributed to events during Carboniferous time itself. These losses may be attributed to local lapses in sedimentation on the one hand and on the other to local erosion of sediments previously deposited. The recognition of such sedimentary breaks is of major importance in the interpretation of the geological structure and in the reconstruction of past historical events.

Stratigraphic breaks of this order are termed either disconformities or unconformities. The former denote sedimentary gaps due either to local or regional non-deposition of sediments throughout long intervals of time, or to subsequent removal by erosion of appreciable thicknesses of previously deposited beds without resulting in any apparent discrepancies of dips or strikes, or without the production of any important erosional channels. Unconformities, on the contrary, are gaps in the sequence rendered conspicuous by decisive erosional channels or by a marked discordance of the younger strata upon the older. A discordance of the latter type indicates for the locality where it occurs important tectonic disturbances during some stage of the time interval represented by the unconformity. Some of the major breaks in the sequence may now be considered.

One of the most important and conspicuous sedimentary gaps in the area examined preceded the deposition of the Upper Westphalian series of strata (Plate IV B). It is economically significant because it records the absence of the formation that carries the workable coals at Joggins and Springhill. This lapse is represented by a marked unconformity with angular discordance at Malagash and on river John, and by a disconformity in Merigomish district. The base of the formation that overlies this sedimentary break is the New Glasgow conglomerate (Plate V B). The presence of this unfortunate hiatus, established in the greater part of the district east of river Wallace, discounts the probability of any important extension of the Springhill coal seams in this area. The 25 miles of country between river Wallace and Springhill was not examined, but as the hiatus is filled to some extent on the River Wallace section it is possible that sediments equivalent to the productive coal-bearing strata of Springhill may underlie some part of the country to the west and east of the river.

A second major break in the sedimentary sequence occurs within the Lower Westphalian series in New Glasgow district. This is evident not on account of any visibly exposed contacts but by the disturbance to which older Lower Westphalian rocks were subjected locally prior to the deposition of later rocks, as well as by the local formation of massive conglomerate (the *Millsville*) at the base of the latter rocks (Plate III B). This disturbance was particularly localized at the present eastern terminus of the Cobequid hills, as well as south of that upland, but it is not apparent at Lismore, only 32 miles distant eastward. The basal beds of the Lower Westphalian formation that succeeds the disturbance are cut by basic lava flows and seemingly by some acidic volcanics, and it is pertinent to inquire whether the Cobequid granitic and basic intrusions may not have taken place wholly, or in part, in association with this disturbance. The main batholithic intrusions were certainly pre-Middle Westphalian, because their debris entered into conglomerates of late Lower Westphalian age.[1]

A third Westphalian break, Upper Westphalian in age, is indicated by an unconformity exposed at East river in front of the asylum where the Plymouth member of the Stellarton coal-bearing series (Upper Westphalian) rests with angular discordance upon rocks of Lower Westphalian (Lismore) age. Only 1½ miles to the west of this contact coal-bearing beds of the Westville formation (Upper Westphalian) fill part of the interval represented by the unconformity, and 2 miles farther west in the Middle River area more than 3,000 feet of post-Lismore strata are present. In the Westville area there is an anticlinal fold in the Stellarton beds that does not affect Westville coal beds actually mined below them, but the precise nature of the contact of the two formations is not known. Formerly it was inferred that the Stellarton beds were upfaulted along an assumed McCulloch Brook fault against the Westville. But mining operations on the Drummond coal seams have since penetrated, at an angle little exceeding 20 degrees, well beyond the supposed locus of this fault and well beneath the Plymouth member of the Stellarton, so that if a fault be present it would have to be in the nature of a very flat-lying thrust-plane initiated prior to the regional block faulting, and it is difficult to define any such thrust in conformity with other structural and stratigraphical relations.

Unfaulted contacts between Mississippian and Pennsylvanian formations are actually exposed in only one locality. Here, on the Merigomish shore, near Lismore, marine strata of Upper Windsor age (Upper Mississippian) that rest directly upon freshwater strata of Upper Horton age are disconformably overlain by Lismore Lower Westphalian strata. In MacLean brook, south of Thorburn, a narrow area of gypsum and associated shale and limestone beds of Lower Windsor age is present, and these beds seem to be overlapped unconformably by adjacent strata of Upper Westphalian age. Elsewhere faulted contacts of Windsor rocks occur, such as in the Malagash anticlinal area. At river Wallace the southern Windsor contact is concealed; it does not appear to be a faulted one against Westphalian rocks as is the northern contact, but rather one of disconformity to Lower Westphalian beds exposed nearby. The supposed unconformity existing between the Mississippian and Millstone Grit at Malagash, and

[1] The writer has since discovered, within the Cobequid complex north of Five Islands, argillites carrying a Windsor fauna and hence of Upper Mississippian age, which are intruded by plutonic igneous rocks. This definitely establishes the Carboniferous age of a part at least of the Cobequid intrusives.

described by A. O. Hayes,[1] is actually an unconformity between the Pictou Upper Westphalian series and the Lismore Lower Westphalian formation, and is an excellent exposure of the break between these two Westphalian stages.

The Lower Mississippian contact is exposed at only one locality, near the mouth of McAras brook, where the McAras Upper Horton formation rests with marked angular discordance upon the Lower Devonian (or Upper Silurian) Knoydart formation. This is a great major break, as the whole, or nearly the whole, of the Devonian system is missing.

[1] Geol. Surv., Canada, Mem. 121, p. 12.

Chronological Table of Formations

	—	Northern facies	Southern facies	Former usage
Pennsylvanian (Coal Measures)	Upper Westphalian	Pictou series New Glasgow Conglomerate member	Stellarton series: Thorburn formation Ross Bridge member[1] Sutherland River member[2] Albion formation Plymouth member *Unconformity* Westville formation Middle River formation	Coal Measures (pars) Permian or Permo-Carboniferous (pars) Millstone Grit (pars) Millstone Grit conglomerate (pars)
	Middle Westphalian	*Unconformity* or *Disconformity* Joggins formation ?	*Unconformity or Disconformity*	Millstone Grit (pars)
	Lower Westphalian	*?Disconformity* Lismore formation Millsville conglomerate member	Lismore formation	Millstone Grit (pars) Permian or Permo-Carboniferous (pars) New Glasgow conglomerate (pars) Millstone Grit conglomerate (pars)
		?Disconformity	*Unconformity*	
		River John series[3] Middleborough member	Alma formation	Devonian (pars) Permian or Permo-Carboniferous (pars) Carboniferous limestone (pars)
Mississippian	Upper Mississippian	*Disconformity*	*Disconformity*	
		Windsor series	Windsor series	Carboniferous limestone
		Disconformity		
		McAras Brook formation		Carboniferous conglomerate
		Unconformity		
	Pre-Carboniferous...	Knoydart formation		

[1]Position doubtful: may be as low as Middle River.
[2]Position doubtful: may be as low as base of Middle River.
[3]Upper part may be equivalent to Millsville conglomerate.

In the table of formations no more new terms are added than were deemed essential for the purpose of brevity and clearness of discussion. To ensure precision in description and reference new terms are unavoidable, but place names only are used in order that the type localities for the formations may be automatically recorded. The confusion resulting from a loose nomenclature is too well exemplified in the usage formerly employed to necessitate further discussion here (*See* page 169 and Table of Formations).

The term Westphalian, adopted from the coal basin of Westphalia, Germany, has been in use in current European geological literature for so long a time that its usage here as a general name for an epoch of time or series of strata seemed more desirable than the coinage of a new term, as it is not thought that the degree of error in the intercontinental correlation of its various stages forbids the use of the threefold division advanced. The adoption of the terminology in use in the United States would present even greater difficulties. In general the Lower and Middle Westphalian divisions are together roughly equivalent to the Pottsville, and the Upper Westphalian to the Alleghany, but it is not improbable that a part of the Upper Westphalian as here used is equivalent to the Transition Coal Measures of England rather than to the Upper Coal Measures and hence might be in part uppermost Pottsville in age.

Precise correlations between subdivisions of the freshwater Carboniferous strata of Nova Scotia are commonly made with extreme difficulty even in localities quite near one another, and a balance has to be struck between the use of a multiplicity of local names and the widespread use of a few terms based on unjustifiable assumptions or inferences of correlation. The Lismore formation may suffice for an illustration. The type locality for this formation is the section on the Merigomish shore opposite Lismore village. The author of the formational name,[1] M. Y. Williams, did not define its limits otherwise than by an acceptance of the limits assigned to the Millstone Grit of that particular locality by Fletcher. Now the Mississippian and Pennsylvanian strata present no apparent discordance of strikes or dips in Lismore district, nor any sharp lithological distinctions; hence an arbitrary lower limit of the Lismore has to be chosen. The base chosen by the writer lies about 550 feet stratigraphically below that chosen by Fletcher on a mistaken assumption of unconformity. Fletcher evidently regarded the upper boundary as the base of the New Glasgow conglomerate or its equivalent horizon. Proceeding westward to the district west of New Glasgow, the most typical sections of the formation regarded in this report as in large part equivalent to the Lismore are those exposed by Fourmile and Sawmill brooks, tributaries of West river, Pictou. Here the upper boundary is the base of the New Glasgow conglomerate as at Merigomish, but the lower boundary is well defined lithologically by the summit of a thick mass of coarse conglomerate that has no lithological counterpart at Lismore. But this coarse conglomerate member is yet several thousands of feet stratigraphically above the Mississippian, as is evident from sections farther west. It was necessary, therefore, either to employ a new formational term for the unit that lies between the two bounding conglomerates,

[1]In the memoir by Williams, written *Listmore* in error.

or to extend the use of the name Lismore to cover this unit. The latter alternative is adopted, for, although the western unit is not entirely definable lithologically in terms of the original Lismore, its fossil evidence indicates a deposition largely synchronous.

An explanation remains to be given in justification of the division into a northern and southern facies. Briefly it may be stated that insufficient evidence has hitherto been gathered to fix the precise correlations of certain Carboniferous formations north of the Cobequid massif with those south of it. Yet in New Glasgow district the two groups are brought into juxtaposition by faulting, and their treatment necessitates a reference to a single chronological table. This table as presented is an outline of the chronological facts so far as are at present known and excludes any inferences based on theoretical considerations of structure or palæogeography. Discussion of an hypothesis in explanation of the two facies will be reserved to a later section of this report.

DESCRIPTION OF FORMATIONS

McAras Brook Formation

The name "McAras Brook" for this formation was introduced by Williams[1] to supersede locally the term "Carboniferous conglomerate" used by Fletcher.[2] The type section extends westward along the shore from McAras brook for nearly a mile. The total thickness of strata was computed by Fletcher to be 1,145 feet. Rather rough hand measurements by the writer, unchecked by an instrumental survey, gave only 863 feet, and this includes about 220 feet of diabasic extrusive flows or sills, leaving only 640 feet as the thickness of sediment. The basal limit of the formation is an unconformable, sharply angular contact with the Knoydart formation of Upper Silurian (or Basal Devonian) age. The upper limit is sharply defined by disconformably overlying, calcareous, fossiliferous shales belonging to the Upper Windsor series.

At the lower contact the older Knoydart beds strike south 132 degrees west, dip 28 degrees south, whereas the McAras beds strike south 18 degrees west, dip 40 degrees north. The lithological characters of the McAras are best indicated by the following measured section.

Section 1. McAras Brook Formation. Shore of Northumberland Strait West of McAras Brook. (Descending section)

Shales, dark grey, argillo-calcareous. Small pelecypods, ostracoda, *Spirorbis*, worm trails. Windsor series. Ardness formation (Upper Windsor). Strike south 25 degrees west, dip 25 degrees west.

Disconformity

	Feet
(s) Shale, green-grey, argillo-arenaceous, thinly fissile	1
(r) Shale, purple-red to chocolate-red, occasional green layers, argillaceous and argillo-arenaceous	13
(q) Sandstone, argillaceous, and shale, arenaceous. Chocolate, with a few beds mottled chocolate and grey	74

[1]Geol. Surv., Canada, Mem. 60, pp. 30–32, 52, 53, 75–77, 95.
[2]Geol. Surv., Canada, Rept. of Prog. 1886, pt. P, p. 89.

Disconformity—Con.	Feet
(p) Sandstone, massive, weathering irregularly platy, chocolate-grey, grey, and chocolate red, mottled in places. Rare fragments of *Aneimites acadica* and rare *Estheria dawsoni*	95
Strike south 27 degrees west, dip 24 degrees north	
(o) Shale, chocolate, argillaceous, with several bands of green shale at base	16
(n) Sandstone, massive, argillaceous, weathering in irregular plates, "scalloped rippled" or smooth surfaces	23
(m) Sandstone and shale, alternating; sandstone is soft, argillaceous, chocolate colour; shale is chocolate-red, argillaceous, and argillo-arenaceous. Small slip strikes south 50 degrees west, pitching 75 degrees north with 5 feet downthrow on north. Strike south 32 degrees west, dip 26 degrees west	14
(l) Sandstone, argillaceous, chocolate-grey	26
(k) Sandstone and shale, alternating; sandstone is chocolate-red or mottled with green, lenticular beds, shale pellets, ripples common; shale is chocolate-red, argillaceous, and argillo-arenaceous. Strike south 28 degrees west, dip 24 degrees west	46
(j) Sandstone; and shale, argillo-arenaceous, chocolate-red, with hard sandstone nodules	2
(i) Conglomerate, chocolate-red to grey, pebbles up to 5 inches of fossiliferous Silurian and of green and chocolate sandstone	2
(h) Shale, chocolate, areno-argillaceous, with two lenticular beds of conglomerate of 5 feet and 11 feet respectively, carrying pebbles of quartz, pink volcanics, and green sandstone. Strike south 25 degrees west, dip 25 degrees west	19
(g) Conglomerate, chocolate, weathering friable	14
Trap, amygdaloidal 0–13, average	7
(f) Sandstone, chocolate, argillaceous; and shale, chocolate, argillo-arenaceous; and conglomerate. Thin bands of nodular, drab, concretionary limestone. Strike south 18 degrees west, dip 22 degrees west	28
Trap, amygdaloidal; top 3 feet to 5 feet is fissured, with fissures filled with argillaceous, chocolate sandstone or shale carrying concretionary grey limestone nodules	24
(e) Conglomerate, chocolate-red, weathers friable; lenticular beds of shale and sandstone; pebbles of brown and green sandstone, quartz concretionary, dove-coloured limestone, dark, crystalline limestone. Strike south 23 degrees west, dip 24 degrees west	121
(d) Shale, chocolate, areno-argillaceous; concretionary nodules of limestone, scattered or in thin seams	9
(c) Shale, chocolate, argillo-arenaceous, and conglomerate, chocolate, with argillo-arenaceous matrix; pebbles up to 5 inches, mainly of purplish brown and chocolate sandstones; top 7 feet has concretionary nodules of limestone	21
Trap, amygdaloidal; top 25 feet is much brecciated and carries some fragments of red shale. Possibly a fault breccia rather than a flow breccia, as trap again overlies the breccia at the headland to east of brook	124±
(b) Sandstone, chocolate, and shale, argillaceous, with one thin band of conglomerate. Strike south 22 degrees west, dip 38 degrees west	103
Trap, amygdaloidal	65±
(a) Conglomerate, chocolate-red, with thin sandstone lenses	16
Unconformity	863

Knoydart (Upper Silurian or Lower Devonian) chocolate to brick-red shales and sandstones. Shales commonly characterized by small nodules of concretionary lime.

It will be seen from the above section that conglomerate beds make up about half the basal 330 feet of the section, and that a chocolate-red colour greatly predominates. The pebbles have fracture faces but well-rounded corners; bedding, in particular crossbedding, is quite apparent, and lenticular intercalations of sandstone and shale are common. The dominant red colour, great thickness of some individual conglomerate beds, common occurrence of nodular concretions of lime, absence of any marine fossils, presence of plant remains, and of the freshwater *Estheria dawsoni*, suggest terrestrial deposition under conditions of semi-aridity, and are in conformity with the environmental conditions of deposition postulated for the Cheverie formation of Upper Horton age in the Horton-Windsor district.[1] The McAras Brook formation is assigned an Upper Horton age on account of the presence of *Aneimites acadica* and *Estheria dawsoni*.

[1] Am. Jour. Sci., vol. 1, p. 164 (1921).

Windsor Series

Although the Windsor series undoubtedly underlies at depth much of the area, outcrops are rare and small in extent and too poor, except in one locality, to yield more than fragmentary information. The localities where Windsor rocks may be seen are: (1) on the Merigomish shore in continuation of Section I, and in a narrow belt of country north and south of Ardness; (2) in MacLean brook, and in the eastern tributary of Sutherland river, that parallels the Antigonish post road; (3) near Limerock; and (4) in a narrow axial belt of the Malagash anticline.

At the first locality the rocks have already been fully described by Fletcher and Williams, and have been named the Ardness formation by the latter. This name, however, must be restricted to the formation at the type locality and not extended to cover the Windsor rocks in the vicinity of Antigonish. The fossils in the Ardness formation denote an Upper Windsor age, and hence there is an important local sedimentary break at the base of the formation that was undetected by Williams. The whole of the Lower Windsor salt-bearing strata are absent, and the Ardness represents an overlap of the Upper Windsor sea in Lismore area. The section of the Ardness formation as exposed on the Merigomish shore and as measured by the writer follows:

Section II. Ardness Formation of the Windsor Series. Shore of Northumberland Strait North of Ardness. (Descending order)

"Bastard limestone" intraformational conglomerate (pellets of shale and of concretionary grey or reddish limestone in an arenaceous matrix) occurring as lenticular patches in a shaly-weathering grey sandstone. Arbitrary base of the Lismore formation (Lower Westphalian).

Disconformity

		Ft.	In.
(w)	Shale, chocolate, arenaceous, and chocolate-red, argillaceous; and thin beds of sandstone, chocolate, chocolate-grey, or mottled chocolate and green	164	
(v)	Sandstone, massive, green-grey at base with obscure broken plants, chocolate-grey above. Very crossbedded. Weathers soft and irregularly platy	28	
(u)	Sandstone, chocolate, argillaceous, interbedded with shale, chocolate, argillo-arenaceous, and with a 22-foot member of chocolate-red, argillaceous shale on top. Not all exposed. Cut by a fault which runs about parallel to the strike or approximately south 28 degrees west. Downthrow probably on east side. Dip locally steepened by the fault to 37 degrees. Average strike about south 20 degrees west and dip 28 degrees west	293	
(t)	Shale, chocolate-red, argillaceous and arenaceous, alternating with sandstone, chocolate, argillaceous; several bands of green, arenaceous shale or sandstone, but none exceeding 1 foot. Top is a hard grey sandstone band, 0 feet 5 inches, which weathers with minute cavities. Partly concealed	144	
(s)	Limestone in four thin bands, oolitic and argillaceous, alternating with chocolate-red shale. *Schizodus* rather common, *Bucanopsis* rare, crinoid stem fragments rare. Top of undoubted marine beds	3	
(r)	Shale, chocolate, arenaceous, with a few green bands. Crossbedding common. Broken obscure plant debris in the green beds. Many rippled surfaces, some of current type and running south 32 degrees west, amplitude about 4 inches, steep sides to southeast. Average strike of beds about south 24 degrees west, dip 23 degrees west	180	
(q)	Shale, chocolate, argillaceous, with top 2 feet grey in colour	50	
(p)	Sandstone, massive, irregularly bedded, weathering shaly or platy, chocolate-red to grey or mottled. Obscure plant debris in places. Strike south 24 degrees west, dip 16 degrees west	82	
(o)	Sandstone, chocolate, argillaceous, and shale, chocolate, argillo-arenaceous	23	
(n)	Nodular band. Nodules of sandstone as rolled "ball-like" masses up to 1 foot or more in length, in an argillaceous matrix. Green at base, red at top. Lenticular form 0 feet-3 feet	2	
(m)	Sandstone, chocolate, argillaceous, and shale, chocolate, argillo-arenaceous	34	

Disconformity—Con.

	Ft.	In.
(l) Sandstone, chocolate-grey and green-grey, irregularly bedded; and shale, chocolate-red, argillo-arenaceous	17	
(k) Shale, chocolate-red, arenaceous and argillo-arenaceous, with thin beds chocolate sandstone. Strike south 30 degrees west, dip 19 degrees west	22	
(j) Sandstone, chocolate-grey to green-grey, more or less regular beds. Rare broken plant debris. Strike south 21 degrees west, dip 18 degrees west	52	
(i) Sandstone, chocolate, argillaceous, in irregular beds; and shale, chocolate, argillo-arenaceous. Strike south 9 degrees west, dip 18 degrees west	29	
(h) Shale, chocolate-red, argillo-arenaceous, and sandstone, chocolate-red, argillaceous	60	
(g) Sandstone, chocolate, argillaceous, irregular beds	5	
(f) Shale, chocolate, areno-argillaceous, and sandstone, chocolate, argillaceous	29	
(e) Sandstone, chocolate-red to chocolate-grey. Weathers shaly	11	
(d) Sandstone, grey, uneven in thickness owing to lenses of chocolate-red, argillaceous shale. Intraformational fragments of shale abundant. Strike south 8 degrees west, dip 25 degrees west	3	
(c) Shale, calcareo-argillaceous, chocolate-red, fossiliferous, *Streptorhynchus* common, *Dielasma* and *Productus* rare	0	4
Shale, chocolate-red, argillaceous, obscure *Productus*	2	
(b) Limestone, dense, compact, grey, partly oolitic. Oolite of top bed weathers rusty. *Schizodus* and a few other fossils. Two pronounced rippled surfaces near summit, oscillatory type, amplitude 8 inches to 16 inches, height 0 inches to 5, direction south 142 degrees west	1	8
Limestone, crystalline, grey, oolitic, more dense at top		5
Limestone, massive, oolitic	9	5
Limestone, grey, finely crystalline, abundantly fossiliferous with *Camarotoechia*, *Productus*, *Composita*, *Martinia*, etc	0	9
(a) Shale, calcareous, dark grey, ostracoda, small pelecypoda, worm trails, *Spirorbis*	4	
Total	1,254	

Disconformity

Shale, green, argillo-arenaceous, thinly fissile; and shale, purple-red with a few green layers. McAras Brook formation (Upper Horton series).

The 17 feet of solid limestone at the base of this section has been actively quarried for lime for fertilization purposes. It is offset by a fault that strikes about south 74 degrees west, the west block having been upthrown and offset about 100 feet along the fault-line. The thickness of the Ardness given by Fletcher is 2,110 feet which is reduced by Williams to 2,045 feet, as Fletcher obviously made no allowance for the duplication caused by the fault. From this 2,045 feet must be further subtracted the 550 feet belonging to Fletcher's division 18 to 20 that are arbitrarily assigned in the present report to the overlying Lismore formation. This leaves a net total of 1,495 feet as compared with the 1,254 feet above.

As regards the boundary chosen between the Ardness and Lismore formations it may be noted that the uppermost definitely recognizable marine horizon is stratum (s), which lies only 625 feet above the well-defined base of the formation. It might be considered fully as justifiable to include the remaining 629 feet of strata comprised in (t) to (w) with the Lismore as with the Ardness, or to assign them rather to a separate formation of Lower Westphalian age. There is little to guide one in the choice of these alternatives. They are provisionally referred to the Windsor series merely on account of the strong physical resemblance they bear to the strata (d) to (r) of the Ardness, although in full cognizance of the dangers of any such correlation based on lithology alone.

The Ardness beds border the pre-Carboniferous rocks, as a narrow belt running from their shore outcrops to Bailey brook where they are cut off by the Hollow fault. The Mississippian and Pennsylvanian rocks are affected by this fault and the assignment by Williams of the age of this fault as pre-Mississippian is based on an error.[1]

Elsewhere within the area rocks belonging to the Windsor series cannot be assigned to the Ardness formation and are simply referable to the Windsor series. In the tributary of Sutherland river, that parallels the Antigonish road, there is a meagre outcrop of much shattered chocolate and grey sandstones, conglomerates, and shales, including a bed of reddish limestone 4 feet thick. An old pit was formerly present here on a bed of calcareous ferruginous ore closely related to a fault-plane. The beds emerge from beneath heavy red conglomerates of the Coal Measures and strike about south 58 degrees west, dip 62 degrees north, at the southern part of their outcrop, and south 79 degrees west, dip 42 degrees south, at the northern part. They are seemingly brought up in the axis of the Telford anticline. No fossils were found, and their reference to the Windsor series is based only on the presence of the limestone bed. The latter is very dense in texture, oolitic, and grades above into a green and purplish conglomerate. The lowermost bed of the section is a 2-foot bed of grey conglomerate with boulders up to 6 inches, chiefly of green quartzites.

In the MacLean Brook tributary of Sutherland river there are obscure outcrops of shattered gypsum, grey limestone, and red sandstones. The limestone is in part fossiliferous; among the fossils, *Productus* and *Parallelidon hardingi?* were recognizable. Another bed of limestone, at least 8 feet thick, stands vertically, is massive and dense, blue-grey in colour, unfossiliferous, and cut by many stringers of calcite. Limestone in the same general line of strike outcrops in the fields north of the brook, where the strike is south 75 degrees west, dip 76 degrees north. In the creek section the uppermost beds are hard chocolate sandstones that are overturned to the south with a general strike of about south 40 degrees west and dip 63 degrees. The presence of *Parallelidon hardingi?* in the fossiliferous beds suggests a Lower Windsor age for these rocks. They emerge like those on the Telford tributary from a position beneath red conglomerates of the Coal Measures, seemingly in a second anticlinal axis, and in both cases the northern contact appears to be a faulted one. A fault is met with, also, on Sutherland river at the mouth of MacLean brook, with downthrow on the north, and it is probable that a single fault, with a course about north 65 degrees east from MacLean brook, has exposed the core of the two anticlines.

Gypsum has been reported to be present at mount William, which lies in the horst that separates the Pictou coal field from the Westphalian strata of the lower part of West river. Moreover, at the most northerly bend of McCullough brook there are, in close association with Alma beds, hard chocolate sandstones striking from south 75 degrees west to south 115 degrees west and dipping at high angles to north or south, and also in the upper part of Waters brook similar beds occur with high angles of dip. These red beds may be either Windsor or Alma in age, but if gypsum is present to the north at mount William the probability would be that they are Windsor. The limestone on Waters hill, a half mile farther to the west, is probably of Alma age as it resembles limestone present elsewhere in that formation and is wholly unlike any known Windsor limestones.

[1]Geol. Surv., Canada, Mem. 60, p. 63.

Near Limerock there are outcrops of limestone with fossils that establish their Windsor age. They occupy a small area bounded on the south by Alma beds and on the north by a faulted contact with Coal Measures. Two miles eastward a second small area near Salem or Green Hill is inferred to be underlain by Windsor rocks on account of the presence of several sinkholes. This is perhaps only an eastward extension of the Limerock area. A mile to the southeast of Salem, on the road running from the Truro road to Union Centre and near its junction with Brown brook, surface salt efflorescences are common in dry weather and it would seem as if salt beds might be associated with the gypsum of the Green Hill area. On account of the close proximity to faults and to disturbed Alma beds it would not be a promising locality in which to search for salt with a drill.

No further outcrops of the Windsor series are to be met between West river, Pictou, and the Malagash anticline. The latter contains the only existing salt mine in eastern Canada.[1]

Bands of clear white and reddish salt are there associated with bands of grey anhydrite, the beds dipping at a high angle and of unknown thickness. Several bands contain appreciable percentages of potassium salts, which leads to the hope that richer salt strata may be ultimately discovered within the Windsor series. The Malagash salt deposits are seemingly in disconformable relation with Coal Measures strata of Early Westphalian age, which in turn are overlain unconformably by the Pictou series. Parallel cross-faults running about north and south magnetic affect the rocks in this area, producing corresponding offsets of strata. Limestone and gypsum of Windsor age are poorly exposed on the shore north of the salt mine in close proximity to one of these faults. *Pseudamusium simplex* is common in calcareous shales associated with the gypsum, and poor specimens of *Productus lyelli* are present in the associated brecciated limestone exposed at low water. The probable age of the beds is, therefore, Lower Windsor. In the section of the anticline cut by river Wallace there is a narrow axial belt of poorly exposed, calcareous, sparingly fossiliferous shales of Windsor age. A fault limits these beds on the north against top beds of the River John series, but the southern contact is seemingly a disconformable one with the Middleborough member of the River John series.

Alma Formation

The type locality for this formation is at Alma on Middle river, Pictou, near the mouth of the Brown Brook tributary. The rocks here are brecciated, fine, grey sandstones and dark grey, arenaceous shales. Fossils occur very rarely and include *Leaia, Anthracomya, Estheria,* and ostracoda.

Similar beds are exposed in scattered outcrops in the channel of McCullough brook for 4,000 feet upstream from the railway bridge, and Alma rocks underlie a large area of country drained by the headwaters of Middle and West rivers, Pictou, and may be studied there in many stream exposures, particularly in the neighbourhood of Lovat, Millbrook, Burnside, Rocklin, and Concord Mills. At all these localities, however, the strata are closely folded and commonly fractured, and as they were not closely examined, no estimates of thicknesses were made.

[1] Geol. Surv., Canada, Mem. 121.

The upper contact of the formation at Alma and in McCulloch brook, where unfaulted, is an unconformable overlap by the New Glasgow conglomerate member of the Pictou series. The lower contact is with the Windsor series and may be a disconformable one as both series have been subjected to like stresses.

As the species of *Leaia* and *Anthracomya* are those held in common with the Harrington River formation of Colchester county it is inferred that the two formations are in part synchronous.

In the Lovat-Concord Mills area there are, in addition to the light and dark grey beds, interstratified beds of red or purplish shales and sandstones. Some of the shales are blackish grey and where slickensided have in some places been mistaken for impure coal.

As the Alma rocks outcrop in such a small area within the territory covered by this report they are important mainly on account of the light they shed on the geological history of the Coal Measures rocks. They were formerly, on the authority of Sir William Dawson, assigned a Devonian age. Now that their Pennsylvanian age is proved, the strong structural disturbance to which they have been subjected is of great significance. This disturbance, recorded by them, of early Pennsylvanian time in the region of the eastern termination of the Cobequids, is now linked up with a similar disturbance witnessed in areas to the south of the Cobequids, such as that which affected Lower Pennsylvanian rocks on the Bay of Fundy shore south of Parrsboro. The disturbance was associated with, or followed by, igneous activity, because the Alma rocks are cut by basic sills, extrusive flows, and dykes. The Cobequid massif itself is a complex of altered sediments and igneous rocks both basic and acidic. Up to date no satisfactory evidence has been advanced sufficient to prove that Cobequid batholithic intrusions may not have been affected in late Mississippian, or early in Pennsylvanian, time. The igneous geology was not a subject of the present study and the precise ages of the Cobequid igneous rocks still await solution.

In the region north of the Cobequids there is no formation that has been definitely correlated with the Alma. As the River John series, however, occupies a corresponding stratigraphic position between the Windsor Upper Mississippian below and beds of late Lower Westphalian age above, it is probable that a part at least of the River John series is synchronous with the Alma. Definite correlation between the two must await fossil evidence from the River John series.

River John Series

This series comprises an unknown thickness of chocolate-red sandstones and shales, chocolate shales with nodular concretions of limestone, grey sandstone, and massive grey conglomerates with pebbles of green quartzites. It is partly exposed on the East branch river John, West branch river John from near Loganville to 1,700 feet north of the junction of the East and West branches, on the Diamond tributary of river John, and on river Wallace in the vicinity of Middleborough. Its upper limit is the Millsville conglomerate member, but in River John district there is no sharp demarcation between this series and the Millsville.

On river Wallace the thickness of the River John series, as defined by the above stratigraphic limits, is about 2,785 feet. In River John district it is probably much greater, but the strata belonging to the series are there cut by faults and no reliable estimates of thicknesses could be made. There are, moreover, in the southern part of this latter district, an additional 5,750 feet of grey conglomerate at the summit of the River John series, which are here included with it, but which might just as logically be included with the Millsville member.

The *Middleborough member* of the River John series is the only one well exposed in the River Wallace section. It lies in the southern limb of the Malagash anticline, and comprises 650 feet+ of alternating chocolate, argillaceous, and argillo-arenaceous shales and sandstones. A marked feature of the shale beds is the number of rain-pitted surfaces, of which fourteen distinct horizons were noted. Ripples of the current type are fairly common and several sun-cracked surfaces were observed. These rocks are seemingly underlain disconformably by strata of Windsor age. Above, a stratigraphic interval of nearly 1,400 feet, with rocks concealed, separates them from 735 feet of chocolate-red sandstone and shale. In the latter beds nodules of concretionary limestone are not uncommon. They are overlain with seeming conformity by 350 feet of red conglomerate, here assigned to the Millsville.

In the northern limb of the Malagash anticline on river Wallace a fault abruptly terminates the Windsor rocks and brings them against the extreme top beds of the River John series. The latter are chocolate, argillaceous sandstones and chocolate-red, argillaceous shales, some beds of which abound in concretions of limestone, and there are several beds up to 3 feet thick of nodular argillaceous limestone. Conglomerate beds, lithologically like the Millsville, are first interstratified with these beds and later surmount them. The total thickness here exposed including the conglomerate is 600 feet. This section too would seem to show a gradation or conformity between the River John series and the Millsville.

In River John area the stratigraphic definition of the River John series is still more difficult. About 10,000 feet north of the West Branch River John settlement and in the river section, Millsville conglomerate with an estimated thickness of 900 feet rests upon alternating chocolate sandstones and chocolate red shales of the River John series. Concretionary limestone nodules are common in many of the beds of the latter and indeed are present in the conglomerate as pebbles. In the eastern high bank of the river the conglomerate, striking about south 56 degrees, dipping 17 degrees north, is resting directly upon 30 feet or more of the shale and sandstone. The conglomerate channels into the soft shales, but there is no apparent discordance. The sandstone and shale member continues to outcrop with rapidly increasing dips southward to near the junction of the East branch river John where the dip is vertical against an inferred fault. Beds south of the fault are fairly well exposed in the East branch and are evidently lower beds of the River John series. In addition to red sandstone and red shales with or without concretionary nodules of limestone, there are beds of grey to olive-green sandstone, and of grey conglomerate, the pebbles of which consist dominantly of green quartzites. Occasional lenticular beds of bastard limestone accompany sandstone beds.

In the main or West branch river John there are scattered outcrops of chocolate sandstone and shale for a half mile upstream above the East branch junction. The general strike of about south 71 degrees west persists, but the northward dips are very variable from 10 degrees to vertical. These sudden changes in dip are seemingly due to the presence of several faults. The river valley then becomes broad and open upstream, and the rocks are concealed for the distance of a mile or nearly to the bridge at West Branch River John settlement. At the bridge chocolate sandstone and shale with a strike of south 18 degrees west, dip 32 degrees north, are underlain by grey conglomerate striking south 60 degrees west, 12 degrees north. The pebbles in the conglomerate are dominantly of green quartzites with minor amounts of red quartzites and of concretionary limestone. The conglomerate is similar to that noted in the East branch. There are interbedded some chocolate-red sandstone and shale carrying lime concretions. These rocks are seemingly upfaulted against a massive, chocolate-grey sandstone at the dam which strikes south 120 degrees west and dips 74 degrees north, and south of the dam there again appear chocolate sandstones, chocolate-red shales, and grey conglomerates with quartzite pebbles, which roll over in an anticline that pitches westerly. Associated with these sediments are two or three beds of coarsely amygdaloidal trap. Beds in the south limb of the anticline are well exposed in the tributary from Diamond, and south of Diamond are overlain by about 5,750 feet of grey conglomerate with quartzite pebbles and boulders up to 12 inches diameter. These conglomerates are overlain in turn conformably by conglomerates perhaps several thousand feet in thickness, in which granitic and igneous boulders become more and more prominent, and these upper conglomerates are undoubtedly of Millsville facies. Accordingly, in view of this conformable gradation, it is doubtful whether the great mass of grey, quartzite conglomerate should be assigned to the River John series rather than to the Millsville. It is provisionally included with the former solely because similar beds of conglomerate are interstratified with the finer sediments of the series. It would seem probable that there was little or no depositional break in the upper River John district between the River John series and the Millsville, and that the earlier conglomerates with dominant quartzite boulders were followed, as erosion of the Cobequid massif progressed, by conglomerates derived from the igneous rocks from which the quartzite cover had been stripped.

Lismore Formation

MILLSVILLE MEMBER

The Millsville member is a basal conglomeratic local phase of the Lismore formation. The type section is that afforded by the upper part of Sawmill brook, a tributary of West river, Pictou, but the conglomerate is exposed in many places in the vicinity of Millsville. The estimated thickness of the Millsville conglomerate in Sawmill brook is

934 feet, to which must be added a computed thickness of 1,816 feet to the assumed base of the member at the northern foot of Fitzpatrick mountain, giving a total of 2,750 feet. In Diamond brook, south of Diamond settlement, about 5,750 feet of grey conglomerate assigned to the River John series is overlain by massive conglomerate of Millsville facies. Assuming that Fletcher correctly mapped the approximate contact of these upper conglomerates with the igneous rocks of the Cobequids their distance across their strike would be one mile, and assuming a dip of 35 degrees, the average dip of the rocks in the brook, the computed thickness would be about 3,000 feet. Moreover, the dip is towards, and not away from, the igneous mass, so that the section is incomplete. The nature of the igneous contact whether intrusive, or faulted, was not established.

The Millsville conglomerate, as defined in the type area, underlies conformably the sandstone and shale facies of the Lismore formation and consists dominantly of coarse boulder conglomerates of which the boulders and pebbles are largely granitic and basic igneous rocks (Plate III B). They commonly exceed one foot in diameter. Fossiliferous Silurian calcareous pebbles are present in minor amounts, as well as pebbles of concretionary limestone. On Diamond brook the member is underlain conformably, as already noted, by conglomerate of the River John series.

In the West branch river John, the Millsville conglomerate is estimated to be approximately 900 feet in thickness. It is overlain conformably by Lismore beds and underlain by sandstone and shale strata of the River John series. The Lismore beds that directly overlie the Millsville member both here and in Sawmill brook are chocolate sandstones and shales that are commonly marked by the presence in them of small, nodular, concretionary masses of lime. The beds of the River John series that immediately underlie the Millsville on river John are likewise chocolate sandstones and shales with lime concretions much resembling the Lismore beds above the conglomerate. The lithology of the Millsville conglomerate on river John is much like that at Millsville, but there is a lesser amount of coarse conglomerate. Pebbles and boulders are still dominantly igneous and comprise pink granite, acidic volcanics, and basic rocks (*See* Figure 2). Intercalations of chocolate-red shale with concretionary limestone nodules occur. The finer beds of conglomerate are quite noticeably stratified (Plate IV A), but the coarser beds may show little sorting, and the boulders are angular in shape, although with rounded corners. The colour is most commonly chocolate-red.

In Waugh river at The Falls there is a deep gorge cut through chocolate conglomerate of Millsville age (Plate IV A). Igneous pebbles and boulders are present, but no longer predominant. Boulders of trap, however, up to 18 inches diameter, occur scattered in some beds, but granitic boulders are rare. Fossiliferous pebbles and boulders of Silurian age have increased greatly in amount and include boulders up to 8 inches or more in diameter and boulders of fine-grained green quartzite occur up to 2 feet. Similar conglomerate underlies the rolling land to the east of the river. The number of trap boulders increases noticeably to the south.

The conglomerate of The Falls is overlain by Pictou strata, seemingly in an unconformable contact. An unconformable overlap of the Pictou beds directly upon pre-Carboniferous rocks at Central New Annan, only 4 miles to the west, likewise suggests an unfaulted over-lap below The Falls. The Millsville beds strike about south 90 degrees west, dip 45 degrees north; the overlying Pictou beds with approximately the same strike dip only 15 degrees north.

On river Wallace there is a very poor representative of the Millsville conglomerate in both limbs of the Malagash anticline. In the southern limb the computed thickness is about 390 feet, in the northern limb 375 to 450 feet, giving an average of about 400 feet. The conglomerate carries pebbles of acidic volcanics and red granitic rocks and, in addition, minor amounts of greenish-grey quartzites. These pebbles range in size up to several inches diameter, with fracture faces, and corners not markedly rounded. The Millsville conglomerate here bears a close lithological resemblance to the younger New Glasgow conglomerate of the north shore of Malagash.

The great thickness (3,000 feet+) of the Millsville conglomerate in the Millsville area, in contrast with its rapid thinning to 400 feet only 30 miles northwestward on river Wallace, and with its total disappearance 25 miles eastward in the Lismore area, strongly points to its formation as a local alluvial fan against an ancient Cobequid mountain ridge. Such an origin is supported by the local mountain-making disturbance to which the previously deposited Alma strata were subjected. To what extent the coarse boulder beds of the fan gave place to finer deposits (perhaps now by error included in the River John series) in the forelying alluvial plain in the region north of the Cobequid massif will only be evaluated when the age limits of the River John series are more accurately determined. Were the whole of the River John series, together with the overlying Millsville conglomerate, of river Wallace, to be considered as a lateral equivalent to the River John series and the Millsville of the type localities there would still be a thickness of only 3,200 feet in River Wallace area in contrast with a thickness of more than 8,000 feet in upper River John district.

LISMORE FORMATION

The total maximum thickness of the Lismore, exclusive of the Millsville basal conglomeratic facies, is computed to be about 8,000 feet. But this thickness holds good only for the type Merigomish district, and there is a possibility that several thousand feet of basal strata there may be only a lateral equivalent of the Millsville member.

The Lismore strata are grey sandstones of "grindstone" facies, chocolate-red sandstones, and argillaceous shales, and a very minor amount of grey argillaceous shale. The majority of the sandstones are of medium grain, consist dominantly of angular quartz grains in an argillo-arenaceous matrix, are commonly crossbedded, are characterized in places by hard, spherical, concretionary "balls" or "kettles," and commonly have associated with them lenticular patches or beds of "bastard limestone." The latter is an intraformational conglomeratic rock consisting of pellets or pebble-like masses of concretionary limestone in an arenaceous matrix. Broken carbonized plant material is common in many of the grey beds, although *Calamites* alone is commonly recognizable. *Cordaites* leaves are absent or very rarely seen, but Cordaitean silicified or calcified drift stems are fairly common in some beds. Some of the thin grey shale members carry small *Anthracomya, Spirorbis,* and, rarely, *Leaia.* As the Lismore underlies a large part of the country examined it will be treated by districts.

Merigomish District

The name Lismore was given by Williams[1], and the type locality must be considered as the Merigomish shore north of Lismore settlement, although only the lower beds of the formation are there exposed. The strata outcrop on the shore with several concealed intervals from near Ponds to the chosen basal contact of the formation 2,180 feet east of Knoydart brook. The writer estimated the thickness of strata in this section to be 2,817 feet. The basal contact is arbitrarily chosen as the lowest bed of intraformational, concretionary, limestone conglomerate (" bastard limestone " of Logan) and this would fall seemingly about 550 feet stratigraphically below the base of Fletcher's Millstone Grit. Adding this 550 feet to the measurements of Fletcher, the latter would allow only 1,532 feet for the thickness of the same section as was measured by the writer. This great discrepancy is explicable only by the low dips of 10 degrees to 15 degrees cited by Fletcher, whereas dips taken by the writer varied from 21 degrees to 28 degrees. The section is given below in detail.

Section III, Lismore Formation, from Summit of Outcrops North of Ponds Eastward to Assumed Contact 2,180 Feet East of Knoydart Brook. (Descending section)

	Feet
(t) Sandstone, grey, massive, with several beds "bastard limestone," rare, hard, concretionary balls; a middle member of chocolate-red, argillaceous shale and sandstone and minor green or mottled, areno-argillaceous shale. Strike south 37 degrees west, dip 21 degrees north. Base is 230 feet west of wharf at a lobster factory	304
(s) Sandstone, greenish grey, crossbedded, several beds "bastard limestone", rare pyritized drift logs, alternating with chocolate, argillaceous and arenaceous shale and sandstone. Partly concealed. Base is at wharf of Bailey brook. Strike south 36 degrees west, dip 21 degrees north	394
(r) Concealed	423
(q) Sandstone, chocolate, argillaceous, and shale, arenaceous. Much crossbedded. Strike south 38 degrees west, dip 21 degrees north	18
(p) Concealed, with exception of one outcrop of chocolate sandstone and arenaceous shale, strike south 34 degrees west, dip 21 degrees north	202
(o) Shale, chocolate, argillaceous and arenaceous, with a middle member of green-grey, platy weathering sandstone marked by hard spherical balls. Strike south 32 degrees west, dip 21 degrees north	22
(n) Shale, green and chocolate, argillaceous. One grey band at base with *Spirorbis*, fish scales, ostracods, rare *Leaia*	88
(m) Shale, chocolate, arenaceous, with a few spherical concretions at base, and alternating chocolate, argillo-arenaceous shale and sandstone. Strike south 36 degrees west, dip 21 degrees north	80
(l) Concealed, at small brook	38
(k) Sandstone, green-grey to chocolate-grey, rippled, and arenaceous shale both grey and chocolate. Strike south 6 degrees west, dip 19 degrees to 24 degrees west	75
(j) Shale, chocolate, argillaceous and argillo-arenaceous	53

[1] Geol. Surv., Canada, Mem. 60, pp. 33, 52, 54, 79, 98.

	Feet
(i) Sandstone, and shale, arenaceous, chocolate and grey, strike south 8 degrees west, dip 27 degrees west	50
(h) Shale, chocolate, arenaceous and argillaceous	28
(g) Sandstone, massive, grey, with patches and beds of "bastard limestone." Shaly at top. Strike south 23 degrees west, dip 28 degrees north	19
(f) Sandstone, chocolate, crossbedded, and shale, chocolate, arenaceous, with minor chocolate, argillaceous shale and grey sandstone with associated "bastard limestone"	216
(e) Concealed, with exception of scattered outcrops of green-grey sandstone. *Calamites* present. These beds cut by Knoydart brook	197
(d) Sandstone, massive, grey, carrying large, hard, spherical balls; 2-foot bed of grey bastard limestone at base. Strike south 9 degrees west, dip 23 degrees west	64
(c) Scattered outcrops of chocolate, argillaceous shale and sandstone with one band of chocolate "bastard limestone"	453
(b) Sandstone, massive, platy weathering, green-grey to brownish-grey on top. Strike south 8 degrees west, dip 23 degrees west	27
(a) Sandstone, chocolate, and shale, chocolate, arenaceous, and argillaceous. Below is a green-grey, shaly weathering sandstone with bed of "bastard limestone" at base. Strike south 10 degrees west, dip 23 degrees west	66
Total	2,817

In Huggan brook, 7 miles to the westward of Ponds, there are excellent exposures of the upper two-thirds of the formation. The formation is there downfaulted near Piedmont against green slates or argillites of Ordovician age, which outcrop at the dam 1,600 feet south of the Piedmont road. The first Lismore exposures in the brook are about 2,600 feet north of the pre-Carboniferous rock, where greyish-chocolate sandstone and chocolate, arenaceous shales strike about south 101 degrees west and dip 17 degrees south. Grey or greyish-chocolate sandstones are exposed downstream for 1,600 feet with strikes swinging from northerly to south 163 degrees west and dips from 17 degrees to 11 degrees westward. The rocks are then concealed for 2,100 feet to an outcrop of platy weathering, finely jointed sandstone striking south 114 degrees west, dip 23 degrees east, near the bridge on the road which runs east of the brook. There is apparently a fault in this vicinity with a general east-westerly course and with a downthrow on the north. The remainder of the brook section is unbroken to the mouth of the brook. The exposed southern limit of this unbroken section is about 400 feet downstream from the said bridge, where grey and chocolate-grey sandstones strike south 54 degrees west, dip 23 degrees north. It is inferred that the lower 793 feet of these beds repeat horizons already observed in the upper part of the Ponds section. They occupy the brook for 2,350 feet. On this assumption it is computed that the overlying strata younger in age than those of section III are 3,920 feet in thickness up to a 3-inch band of limestone that outcrops on the Merigomish shore about 1,000 feet in a direction north 12 degrees east from the Brownsville bridge over Ballamona brook. The computed section above this limestone band in Merigomish harbour to the upper limit of the Lismore is 1,290 feet. The total computed thickness of the Lismore is thus arrived at, viz., 2,817 feet in section III+3,920 feet in Huggan brook+1,290 feet under Merigomish harbour, or 8,025 feet.

The Lismore strata revealed by Huggan brook are alternating grey and chocolate sandstones and chocolate-red, argillaceous shales. There are numerous lenses of " bastard limestone " associated with the sandstones. Worthy of mention are several thin beds of hematite that outcrop in the western bank of the valley about 4,200 feet in a direction south 12 degrees east from the road bridge at the old grist mill. The hematite beds are interstratified with chocolate shale and are overlain by ferruginous bastard limestone and grey sandstone. They were largely obscured by talus, but their total thickness may not exceed a few feet. Upstream about 1,600 feet a small rivulet from the west precipitates a good deal of flocculent iron hydroxides. Limestone deposition was confined to the concretionary bastard beds, which are seemingly in part the intraformational product of eroded shale beds carrying lime concretions, and to several thin bands of freshwater limestone. In addition to the 3-inch band already mentioned there is a second, about 125 feet, stratigraphically, below, which is a grey oolite.

From the mouth of French river Merigomish, to a point at the former site of an old dam, nearly 2 miles upstream above the shore road bridge, the Lismore strata are unbroken by folds or faults, and in general dip about 20 degrees northwest. The computed thickness of this part of the French River section is 3,900 feet, but undoubtedly these strata are in general equivalent to those exposed in the lower part of Huggan brook. Massive grey sandstones alternate with chocolate, argillaceous shales and sandstones. One thin band of grey, argillaceous shale carrying small *Anthracomya* occurs in the west bank of the stream a half mile above the shore road. Upstream from the old site of the dam the strata are disturbed by several faults and folds. There is probably a downthrow on the north in the vicinity of the dam site, and a second east-west fault with upthrow on the north occurs about 800 feet upstream from the second road bridge. But the most important fault is situated about 4,500 feet southwards of this latter bridge, where the Lismore strata are brought abruptly against a downfaulted heavy conglomerate belonging to the Sutherland River member of the Stellarton series. This broken section of the Lismore is noteworthy for the decided dominance within it of chocolate-coloured beds, for the presence of a second thin band of *Anthracomya*-bearing shale at its summit, and for the occurrence of abundant tracks of *Belinurus* or some similar merostomatan crustacean in platy sandstone beside the second road bridge.

The Lismore strata in Sutherland river are confined to the area north of Ross bridge, as 600 feet north of this bridge they are concealed by a downfault (New Glasgow fault) of the younger Ross Bridge member of the Stellarton series. At the summit of the Sutherland River section extensive quarrying operations for grindstones have been carried on in the southern part of Quarry island and on the mainland shore opposite. The formation is overlain disconformably north of Blackhall gut and on Quarry island by the New Glasgow conglomerate, here greatly attenuated in thickness. About 1,000 feet north of the New Glasgow fault thin bands of grey shale and of chocolate, argillaceous shale carry *Estheria*, *Leaia*, and *Spirorbis*. Otherwise the Lismore strata of Sutherland river are essentially like those already described.

Lismore exposures may be seen in Pinetree brook and in its tributaries that drain a triangular wedge of Lismore rocks north of the New Glasgow fault. The Pinetree beds occupying the thicker end of the wedge are disconformably overlain by the New Glasgow conglomerate of Fraser mountain. However, just west of East river and in Blackhall brook, the thin edge of the wedge is overlapped unconformably by the conglomerate. Here, Lismore grey sandstone strikes about south 148 degrees west and dips 30 degrees east, whereas overlying New Glasgow conglomerate strikes about south 80 degrees west and dips 55 degrees north (Plate IV B).

East and Middle Rivers, South of the Pictou Coal Field

On East river, in the vicinity of the asylum near Riverton, there are exposed highly tilted, chocolate sandstones and shales that are unconformably overlain by the Plymouth member of the Stellarton series. These beds are assigned to the Lismore, provisionally. The basal conglomerate of the Plymouth member strikes about south 155 degrees west, dips 27 degrees east at the contact; and strikes south 136 degrees west, dips 18 degrees east close by. The Lismore beds at the contact strike south 137 degrees west and dip 57 degrees east. The red beds of the Lismore are again exposed in MacKay brook dipping generally at variable angles, 25 degrees to 85 degrees northwesterly. Two thin bands of grey shale carrying rare *Leaia* were noted here and another horizon with poorly preserved *Calamites* and *Sphenopteris*. The formation on East river is underlain, perhaps by faulted contact, by a dominantly red shale formation. The colour of the latter varies from chocolate-red to brick, or purplish reds. On the whole the red colours are lighter than those of the formation above and the strata are more disturbed. Some of the argillaceous beds carry concretions of limestone. There are present also several beds of brecciated grey sandstone not unlike some beds of the Alma formation. This formation, formerly mapped as Devonian, is provisionally assigned to the Alma. The general structure is an anticline with strikes of south 65 degrees west, dip 48 degrees north at the north end of the outcrop, and south 45 degrees west, dip 45 degrees south at the south end.

On Middle river at the bridge at Union Centre and in the river channel above, there are green-grey sandstones, with abundant casts of *Calamites*, that are referable to the Lismore. They are associated with chocolate and grey arenaceous shales. The nearest exposures of younger strata outcrop 1,500 feet north of the bridge and belong to the Middle River formation. The uppermost Lismore rocks strike south 145 degrees west, and dip 22 degrees west, whereas the Middle River beds, which are chocolate, argillo-arenaceous shales and platy grey and chocolate sandstones, strike about south 110 degrees west and dip 35 degrees north, although locally the lowermost beds exposed have a dip of 70 degrees north. The contact between the two formations is either an unconformable or a faulted one.

Lower West River Valley of Pictou

The best exposures of Lismore strata within this area are afforded by Sawmill, Fourmile, and Eightmile brooks, tributaries of West river. The top limit of the Lismore is here the base of the New Glasgow conglomerate mass of Green hill, which overlies the Lismore disconformably (Plate V A).

The basal boundary of the sandstone facies is the summit of the Millsville conglomerate member. The total thickness of the Lismore as defined within these limits was computed to be 5,540 feet in Sawmill brook and 5,490 in Fourmile brook, or in round numbers about 5,500 feet. Lithologically, the Lismore is like that of Merigomish district, but the total amount of massive grey sandstone is increased and locally pronouncedly dominant over the beds of chocolate shale. However, it is quite evident from a comparison of equivalent geological horizons in Sawmill and Fourmile brooks that grey sandstone in one brook may be represented in the other by chocolate shale or sandstone beds. In general, however, the increased percentage of arenaceous beds in West River district denotes a source of supply of sediment from the westward.

The sandstones in general are too crossbedded, too soft, or too closely jointed for good building stone, but there are exceptions and several horizons have been quarried in the past.

The Lismore strata in this district, as well as those in River John district, were included by Fletcher in his Permian series. Seemingly this error arose from the fact that Fletcher confused the Millsville with the New Glasgow conglomerate. The recognition of two distinct conglomerates and the separation of the Lismore in this and in the succeeding district is of great importance because it demonstrates the absence of the Joggins-Springhill coal-bearing formation in this part of the country.

West Branch River John

The Lismore strata exposed by West river, Pictou, are on the southern limb of the Scotsburn anticline, whereas those now to be considered are on the northern limb. The upper limit of the formation in the latter locality is, as before the New Glasgow conglomerate, greatly attenuated. The contact between the two formations is an unconformable one; the New Glasgow conglomerate bed strikes about south 73 degrees west and dips 9 degrees north, whereas the underlying Lismore beds strike south 84 degrees west and dip 41 degrees north. The lower limit of the Lismore is again definable as the summit of the Millsville conglomerate member. Between these two limits the Lismore strata on river John are estimated as 3,250 feet. The upper half of the formation is dominantly chocolate in colour; in the lower half massive grey sandstone members alternate with chocolate-red shales. Immediately over the Millsville conglomerate member are chocolate shales with limestone concretions similar to beds that overlie the Millsville in Sawmill brook.

It is evident that the unconformity between the New Glasgow conglomerate and the Lismore on river John may represent a loss of as much as 2,250 feet, the difference between the thicknesses of the strata there (3,250 feet) and in West River valley (5,500 feet). The loss becomes rapidly greater west of river John; for in Waugh river near The Falls the sandstone shale facies of the Lismore is entirely overlapped by the Pictou series, which rests directly on the Millsville. The most southerly Pictou strata in the latter locality strike about south 88 degrees west and dip 15 degrees north, whereas the chocolate-red conglomerate of the Millsville member with approximately the same strike dips 55 degrees north. There is a short, concealed interval between the loci of these dips, but it would seem improbable that a fault is present here. Indeed only 4 miles farther to the west in French river, Tatamagouche, the Pictou series is seen to overlap directly upon older rocks of the Cobequids.

River Wallace

But farther to the west in River Wallace district near Wentworth a narrow band of strata again intervenes between the Pictou series and Cobequid igneous and pre-Carboniferous rocks. These strata are believed to be partly upper Lismore in age and partly younger or of Joggins age. The Lismore beds are partly exposed by Higgins, Giles, Caldwell, and Whetstone brooks. Their contact with the Cobequid rocks is a faulted one, as is evident from the section on Caldwell brook where grey sandstones, carrying *Calamites,* striking south 89 degrees west, dip 46 degrees north, are brought abruptly in the tunnel beneath the railway against much jointed, blue-grey, massive, quartzitic sandstone of probable Silurian age. At Wentworth in Higgins brook grey sandstone with thin lenses of bastard limestone strike south 84 degrees west and dip 30 degrees north.

Overlying these sandstones, either conformably or disconformably, are conglomerate beds with boulders up to 18 inches diameter. The conglomerate is commonly chocolate in colour, and the pebbles and boulders are thinly coated with iron oxide. In composition these latter are predominantly arenaceous, hard purplish, and chocolate micaceous, and green quartzitic sandstones, subangular to well rounded. The age of these conglomerates is considered to be Joggins and not Pictou on account of their stratigraphic relations farther west, as revealed in Fletcher's Map-sheet 63.

On river Wallace there are good sections through the Lismore strata that are brought up in both limbs of the Malagash anticline. In the southern limb their estimated thickness is 3,360 feet, in the northern limb 2,935 feet. The upper contacts in both cases are conformable or disconformable ones with grey conglomerates and sandstone assigned provisionally to the Joggins formation. The latter are about 1,540 feet thick in the southern limb and are overlain unconformably by typical Pictou sediments. The Lismore beds are alternations of grey sandstone, commonly carrying some associated bastard limestone, and chocolate-red, argillaceous shales.

As the present correlation of the geological formations exposed by river Wallace differs markedly from that hitherto in use and presented in Map-sheets 62 and 63, a table of equivalents is here presented, and reference may be made to the diagram of the geological sections.

Present usage	*Former terms*
Pictou series	G_4^b—Upper and Middle Permian
New Glasgow conglomerate member	G_4^a—New Glasgow conglomerate
Joggins formation?	G_2^a Wentworth G_2^b (pars), Malagash anticline
Lismore formation	G_1 Wentworth G_2^b (pars), Malagash anticline
Millsville member..........................	G_2^a Malagash anticline
River John series..............................	G_1 (pars), Malagash anticline
Windsor series.................................	G_1 (pars), Malagash anticline

Malagash

Lismore strata are exposed on the north shore of Malagash in the vicinity of longitude 63° 20′, where they lie with decided unconformity beneath the New Glasgow member of the Pictou series. This unconformity is exceptionally well exposed on the beach at low water. The conglomerate strikes about south 94 degrees west and dips about 15 degrees north, whereas the Lismore beds strike about south 73 degrees west and are overturned to the south at an angle of about 50 degrees. Descriptions of these strata are given by Hayes[1], but Hayes in conformity with the former usage of Fletcher included the Lismore mistakenly with the Windsor series and assigned the overlying Pictou series to the Millstone Grit. The overturned attitude of the Lismore beds was first discovered by Hayes and was confirmed by the writer for the shore exposures after a close study of the ripple-marks. The red beds of Ross brook, also considered by Hayes to be overturned, were not examined by the writer. Hayes compares these Ross Brook beds and similar strata in Wade brook with the Middleborough member of river Wallace, and if his conclusions regarding their overturned nature are correct, Middleborough strata would be looked for in those localities. Accordingly, the writer agrees with Hayes in his inference that the Malagash salt deposit should underlie the axial area of Wade and Ross brooks.

At Treen bluff there are strata that likewise form a part of the northern limb of the Malagash anticline. These beds, which were only cursorily examined, dip northerly and include massive grey sandstones with petrified drift logs, as well as chocolate-red sandstones and shales in which imprints of both *Calamites* and *Cordaites* are rather common. Lithologically, the sandstones more closely resemble Lismore than they do the more arkosic beds of the Pictou series. The presence of *Cordaites* leaves alone, seemingly rare in the Lismore, would scarcely be sufficient to assign to them a Pictou age, and provisionally the Treen Bluff strata are regarded as of Lismore age. The so-called Permian strata of Fletcher and Hayes on the

[1] Geol. Surv., Canada, Mem. 121.

north shore of Malagash at Cantwell point belong to the Pictou series, and the strata in the southern limb of the Malagash anticline, exposed at Malagash point, are likewise of Pictou age and not of Lismore (or Millstone Grit) age. This latter correlation is based on the presence of *Neuropteris scheuchzeri, Sphenophyllum emarginatum,* and *Pecopteris miltoni,* characteristic Upper Westphalian species.

The present correlation of the formations, although differing radically from that formerly held, does not affect appreciably Hayes' conclusions regarding the effects of the post-Pictou normal faults that run in a direction about magnetic north and south. The most important of these is that separating the outcrop of Windsor strata on the shore from Lismore sandstone. Although the Lismore strata on the west are brought into direct contact with older Windsor strata on the east the upthrow must be on the western side because the Lismore beds were overturned to the south before the faulting took place. The relation of the salt beds in the mine to the gypsum and limestone of the shore is unknown, but as the upthrow of the fault is on the western side it would imply a northern offset of the salt beds on the east side of the fault, and hence the salt beds probably lie in close association with the shore gypsum—though whether to the north or south would depend on the amount of throw resulting from the fault. The block of salt in the mine has, therefore, been shifted southwards as a whole.

No fossil evidence sufficiently diagnostic to fix the age of the Lismore formation has been gathered. The common occurrence of *Calamites* and the absence or rarity of *Cordaites* may be convenient guides to local correlation, but have little or no chronological significance. The lithological characteristics and stratigraphic position of the Lismore are, however, sufficiently marked to indicate that it is in part synchronous with the Boss Point formation of the Joggins section[1], but until their age relations are more definitely determined, the retention of the two formational terms is desirable. The Lismore formation being pre-Joggins, and the latter carrying a flora equivalent to that of the lower part of the Middle Coal Measures of England, it would follow that the Lismore is most probably of Lower Coal Measures age and hence Lower Westphalian.

Joggins Formation ?

Outcrops of the Joggins ? formation are first met on river Wallace. Moreover, this formation can only underlie a narrow belt of country to the east of the river. For over the great part of the area comprised in the present report, the Pictou series overlies unconformably or disconformably formations of pre-Joggins age. West of river Wallace the Joggins formation probably has a fuller representation.

On river Wallace, in the area of the Malagash anticline, the maximum thickness of the strata doubtfully assigned a Joggins age is 1,530 feet, whereas the formation in the type locality at Joggins is 6,886 feet. The loss of strata in River Wallace district is readily explainable by unconformity beneath the Pictou series. The River Wallace beds consist of

[1]Geol. Surv., Canada, Sum. Rept. 1912, p. 366.

grey and chocolate conglomerates and grey and chocolate-grey sandstones. The pebbles in the conglomerate are chiefly hard, green, and purple, micaceous sandstones, and grey quartzites, all well rounded and in sizes up to 6 inches diameter. *Calamites* and *Cordaites* are not rare. At the summit igneous pebbles appear and later become abundant.

At Wentworth, on the upper part of river Wallace, conglomerate, mostly chocolate in colour, lies between the Pictou series and beds that are assigned to the Lismore. There are boulders up to 18 inches of hard, purplish sandstone in addition to pebbles and boulders of green, quartzitic sandstone and micaceous, chocolate sandstone. Fletcher, in Map-sheet 63, shows a much greater development of this conglomerate westward, where it is overlain at Atkinson by finer beds containing a small, coaly seam. It is chiefly these stratigraphical relations that has led to the assignment of these conglomerates to a Joggins age rather than to their inclusion within the Pictou series. But there is need of work farther to the west to fully establish the validity of such a reference.

The flora of the Joggins formation in the type locality at Joggins Mines is a meagre one, but is sufficient to indicate an age corresponding to that of the Middle Coal Measures of England and hence Middle Westphalian.

Pictou Series

In the Pictou series are included all the strata of which the base is the New Glasgow conglomerate or equivalent horizon. The type section is taken as that in the West branch river John, where the thickness is computed to be 7,350 feet; of this amount 4,940 feet is the estimated thickness of the strata in the river section above the highway bridge at river John, and the remaining 2,410 feet that of the strata underlying John bay to the assumed axis of the syncline. Similar calculations of the thickness of strata in French river, Tatamagouche, gave 7,435 feet, so that 7,400 feet in round numbers may be taken as the approximate maximum thickness of the Pictou series in the Tatamagouche syncline.

The *New Glasgow conglomerate member* is a basal member of the Pictou series. The name was first conferred by Sir William Dawson on the conglomerate that outcrops at East river beside the New Glasgow highway bridge, and this must be taken as the type locality. The conglomerate here strikes about south 85 degrees west and dips 58 degrees north, and is faulted on the south against the Albion formation of the Stellarton series. In Blackwood brook, however, only 1,500 feet west, the base of the conglomerate is seen to rest unconformably upon sandstone of Lismore age (Plate IV B), the conglomerate striking about south 80 degrees west and dipping 55 degrees north, and the underlying Lismore about south 148 degrees west, dip 30 degrees east. The local steep dip of the conglomerate is due to its proximity to the New Glasgow fault, as the dip flattens northward to 8 degrees near Trenton. Sir William Logan estimated the total thickness of the conglomerate on East river to be about 1,600 feet. That this is a conservative estimate is shown by two sections with partial exposures across Fraser mountain east of New Glasgow. The more westerly of these, approximately 6,500 feet east of New Glasgow, presents a dip of 25 degrees at the top of the conglomerate and 45 degrees or more at the base. Assuming an average dip of 37 degrees the computed thickness is about 1,865 feet. About 4,500 feet farther east the conglomerate dips uniformly about 45 degrees and underlies a belt of country 2,750 feet across the strike, which would give a thickness of 1,940 feet. The average thickness of the member in the neighbourhood of New Glasgow may, therefore, be taken as approximately 1,900 feet. Eastward this thickness must diminish rapidly, as on Quarry island in Merigomish harbour, only 7½ miles east of New Glasgow, the maximum possible thickness is 325 feet and the true thickness may be much less. In Green hill, about the same distance to the west of New Glasgow, the conglomerate is still very thick, perhaps even exceeding 2,000 feet. But westward and northward it again thins rapidly, so that on river John, 25 miles to the northwest, the thickness does not exceed 5 feet. It is evident, therefore, that the New Glasgow conglomerate at the type locality is a thick alluvial fan and that it rapidly thins to the north, east, and west.

The materials composing the conglomerate likewise bear witness to its local fan origin. At Green hill, well-rounded boulders within the conglomerate commonly have diameters of 1 to 2 feet (Plate V B). They consist almost entirely of chocolate or reddish sandstones and bastard limestone conglomerate that have undoubtedly been derived from the Lismore formation. Imperfect shingling, and crossbedding in sandstone lenses, suggest currents from the south or southeast. Several beds on Middle river are notable for the common occurrence of boulders and pebbles of hematite similar to those present at some horizons in the Sutherland River member of the Stellarton series. One such hematite boulder noted was 9 inches diameter.

In the lower part of McCulloch (Bear) brook, a tributary of Middle river, the conglomerate rests directly upon rocks of Alma age, and subangular fragments of the underlying rocks make up the bulk of the material in the basal beds.

The conglomerate beds in East river at New Glasgow and in Fraser mountain likewise carry well-rounded boulders, up to 18 inches diameter, of chocolate sandstone and bastard limestone conglomerate. Pebbles of hematite occur sparingly. In Quarry Island district the conglomerate that outcrops is finer, with boulders rarely exceeding 6 inches. In addition to chocolate and green sandstone pebbles there are a few of green argillite like that in the Ordovician series of McLellan mountain to the south. The strike there is about south 48 degrees west, dip 17 degrees north, of both the Lismore and conglomerate strata.

In River John area the conglomerate has lost its boulder character and the pebbles rarely exceed 3 inches. Grey and red quartzites, green arenaceous shale or argillite, chocolate sandstone, and vein quartz, make up the majority. The strike of the conglomerate, which scarcely exceeds 5 feet in thickness, is south 71 degrees west, dip 9 degrees north, whereas underlying Lismore chocolate shales and sandstones strike south 82 degrees west and dip 47 degrees north. This locality showing the unconformable contact is on river John directly south of Mine brook, a small tributary from the east.

In French river, Tatamagouche, and westward to the border of the district, the New Glasgow conglomerate again thickens, but has a different facies due to the prominence of igneous pebbles within it. In French river, near Central New Annan, pre-Carboniferous green argillite intruded by trap-sheets is unconformably overlain by about 10 feet of chocolate conglomerate that is practically a compost of the underlying rocks, and thereafter by grey conglomerate containing many pebbles of the underlying argillite formation in addition to pebbles of porphyritic and felsitic, acidic volcanic rocks. There follows an alternation of grey sandstones and chocolate or grey conglomerate, with predominant pink or red igneous pebbles as before and with diameters of several inches—in places reaching one foot. The total thickness of these basal beds is about 500 feet. They are overlain by feldspathic grits, sandstones, and chocolate shales of the Pictou series. The strike of these rocks is south 83 degrees west, dip 20 degrees north.

In the upper part of river Wallace there are exposures only of the conglomerates of the Joggins (?) formation, the New Glasgow beds being concealed. Where the river cuts through the Malagash anticline in the lower part of its course the exposures of conglomerates deserve further notice. Quartzite conglomerates and interbedded sandstones of Joggins (?) age are overlain without any angular discordance by purple-red, feldspathic grits and chocolate conglomerate containing besides quartzite pebbles an abundance of acidic igneous pebbles up to 6 inches diameter. On lithological grounds alone these latter conglomerates would suggest the New Glasgow member, but the nearest overlying beds of undoubted Pictou age lie at much flatter angles, and similar relations occur in the northern limb of the anticline. So that it is probable that the conglomerates with igneous pebbles are likewise of Joggins (?) age, and that the contact with the Pictou series is one of decided unconformity there as at Malagash. The New Glasgow conglomerate on the north shore of Malagash is constituted for the most part of acidic igneous debris. Reference has already been made to the unconformable contact of this conglomerate upon underlying Lismore strata. The conglomerate strikes about south 101 degrees west and dips 20 degrees north and the underlying Lismore south 84 degrees west, overturned 51 degrees south.

The *undifferentiated strata of the Pictou series* include all beds above the horizon of the New Glasgow conglomerate. Formerly they were in large part mapped as Permian rocks. The section of these so-called Permian rocks in river John given by Fletcher[1] includes Lismore strata and the basal Millsville. Fletcher's section in French river[2] gives 4,925 feet as the thickness of strata from the vicinity of the highway bridge on the shore road to the contact on the upper part of the river, but to this must be added the thickness of higher strata that underlie the country towards Waldegrave. Lithologically, the strata may be defined as an alternation of chocolate-red and grey sandstone and arkosic grits with chocolate arenaceous and argillaceous shales. Chocolate colours are greatly predominant. Both sandstone and grits commonly carry angular fragments of pink feldspar. Many sandstones, particularly those near the base of

[1]Geol. Surv., Canada, Ann. Rept., vol. V (pt. II), pt. P, p. 114 (1893).
[2]Geol. Surv., Canada, Ann. Rept., vol. V (pt. II), pt. P, p. 129 (1893).

the series, contain fine debris of green argillite or slate and abundant coarse flakes of mica. In these characters they differ from the more normal quartz sandstones of the Lismore formation. The grits are commonly conglomeratic with pebbles of vein quartz, quartzites, sandstones, feldspars, and acidic volcanic rocks. Petrified drift logs and carbonized or coalized drift of plants are common. Grey argillaceous shales are extremely rare, and rarely too there are thin seams of coal and thin beds of freshwater limestones either unfossiliferous or *Spirorbis*-bearing (Plate VI A). Both thin coals and limestone occur on Malagash point, where the roof shales of a 5-inch coaly seam yielded abundant *Pecopteris miltoni* and *Sphenophyllum emarginatum*. Elsewhere in the same section *Neuropteris scheuchzeri, Alethopteris serli, Mariopteris muricata,* and *Annularia sphenophylloides* were gathered from chocolate shale that lay 12 feet below a second coaly seam 2 inches thick. Chocolate shales with small nodules of concretionary lime are common in the series and bastard limestone conglomerates are not uncommonly associated with the sandstones. Beds showing casts of rootlets in situ are not rare and casts of *Stigmaria* occur at the base of two freshwater limestone beds at Malagash point (Plate VI A). Small coal seams occur elsewhere in the basal third of the series. At Coalmine point, Big island, Merigomish, a coal seam 1 foot to 1 foot 6 inches thick has an undershale with rootlets and a roof of heavy, coarse, feldspathic sandstone or grit. Another coal seam is present in Fraser mountain, about 200 feet stratigraphically above the top of the New Glasgow conglomerate and overlying a band of botryoidal freshwater limestone. Several, thin, coaly seams occur on East river near Trenton within the basal several hundred feet of strata that overlie the conglomerate. But in spite of the rather widespread occurrence of thin, coaly laminæ, no coal of workable thickness has hitherto been found in the series, nor does the stratigraphy hold out any encouragement that such occur. Associated with the thin, coaly strata of Trenton there are thin, unimportant bands of oil-shale and it may be the presence of these that has led to fruitless search for oil. The utter hopelessness of striking oil in this series cannot be too strongly emphasized.

The most marketable product of the rocks of this series is building stone. Barytes occurs sparingly in veins, e.g. near Hodson and on river John, some of which have been worked in the past. Certain of the grits and sandstones carry masses of chalcocite and malachite closely associated with carbonized drift of plants, but the quantities are quite insufficient or of too sporadic occurrence for development.

The age of the Pictou series, denoted by the plant remains gathered at Malagash point, is Upper Westphalian. But the flora gathered to date is too meagre to clearly differentiate, on the basis of age, the Pictou series from the Stellarton series, which belongs likewise to the Upper Westphalian epoch. The two series represent two distinct lithological facies. The arenaceous beds of the Pictou series are characteristically arkosic and the coarser materials composing them were clearly derived in large part from the Cobequid massif. Finer material may have been river wash from the New Brunswick highlands. The coarser sediments of the Stellarton series have been derived wholly or in large part from the massif of McLellan mountain, which is mainly composed of slates, argillites, and quartzites, and in which acidic igneous rocks occupy a very minor place. The New Glasgow conglomerate combines the two facies in itself; for in the west it is dominantly derived from igneous rocks and in the east consists almost wholly of debris from the Alma, Lismore, and McLellan rocks that outcrop to the south and southeast. Here it is regarded as an alluvial fan built out into an alluvial plain that was a basin of deposition of sediments derived dominantly from the west.

On account of the indecisive value of the present fossil evidence the age relations of the two Upper Westphalian series must be inferred from the structural relations. The New Glasgow fault is the plane of separation between them, and it effectively cuts off all traces of the Stellarton series to the north of it. Neither is there any debris present in the New Glasgow conglomerate that is traceable to the Stellarton series, nor are there any contacts of the New Glasgow conglomerate with rocks younger in age than the Joggins. Moreover, the New Glasgow conglomerate is clearly affected itself by the New Glasgow fault. But this fault brings the Stellarton series on the south in direct contact not only with the New Glasgow conglomerate and overlying beds of the Pictou series on the north, but also in places with Lismore strata. As the Lismore is definitely of pre-Stellarton age the only possible inference is that the fault at one time was a locus of movement resulting in a pronounced upthrow on the north. If this movement along the New Glasgow fault were the sole one, the New Glasgow conglomerate overlying the Lismore must have been similarly upfaulted, and the structural argument is sufficient to fix the age of the conglomerate as older than the Stellarton formations in contact with it. But there remains to be considered the remote possibility of two movements at different times along the same fault-plane, one of pre-New Glasgow conglomerate age, the other of post-New Glasgow age. Such an hypothesis, and such only, would permit of a post-Stellarton age of the conglomerate.

This hypothesis would demand: (1) a post-Stellarton movement whereby Lismore and overlying Stellarton strata were up-thrown on the north; (2) an interval of erosion whereby the upraised Stellarton strata lying north of the fault were eroded off, at least in the vicinity of the fault; (3) deposition of New Glasgow conglomerate and a part at least of the overlying Pictou strata; (4) a post-New Glasgow movement along the New Glasgow fault in a reversed direction to the earlier one, whereby New Glasgow and Pictou beds were downfaulted on the north; and finally (5) removal by erosion of all conglomerate and other Pictou strata lying south of the fault.

At first glance there would appear to be some facts in favour of such an hypothesis, such as the unconformability of the New Glasgow conglomerate upon Lismore or Alma strata in close proximity to the fault-plane, as contrasted with a disconformability in some areas away from the fault-plane. For unconformability of the conglomerate close to the fault-plane would be a logical deduction from the hypothesis by reason of greater tilting of strata near the plane of movement. Moreover, to the west of Middle river, the Mount Thom fault approximately lies in the direction of the New Glasgow fault and it clearly records a downthrow on the north as Lismore strata are brought in contact with Alma strata. The critical area for the interpretation of the structure is evidently that in the vicinity of Middle river where these two faults approach juxtaposition.

The New Glasgow fault can be clearly traced to Middle river where Westville strata of the Stellarton series on the south are brought into contact with New Glasgow conglomerate on the north near the junction of Middle river with its tributary McCulloch brook. Is there any possible record here of the Mount Thom fault? About 2,500 feet downstream from McCulloch brook and near the mouth of Brown brook another fault occurs in Middle river and this brings New Glasgow conglomerate on the north against Alma strata on the south, certainly testifying to a downthrow on the north. The block of strata between the two faults does not reveal any other important breaks, but is made up of New Glasgow conglomerate resting unconformably upon fractured Alma strata. The more northerly fault with its established northern downthrow is more nearly in direct line with the Mount Thom fault than is the New Glasgow fault. Accordingly, it is held to be the actual continuation of the Mount Thom fault, and its recorded northern downthrow sheds no light on the movement along the nearby New Glasgow fault. But direct evidence in support of the conclusion that the New Glasgow fault was the locus of a single movement resulting in a northern upthrow is furnished by the section exposed in McCulloch brook at the locus of the New Glasgow fault. The latter crosses the brook about 800 feet northwest of the Drummond Colliery railway bridge. At the bridge, strata of the Westville formation strike about south 46 degrees west, dip 25 degrees south. In close proximity to the fault the dip increases to 70 degrees southwards. Shales, sandstones, and arkosic grits of the Pictou series occur on the north side of the fault. In close proximity to the fault they are bent in a sharply closed anticline, but to the north lie in a flat syncline with dips around 10 degrees. The anticline is interpreted as a drag-fold due to upward movement of the Pictou strata. The Mount Thom fault projected would lie north of Waters hill and is the probable explanation for the gypsum of the Windsor series brought up in that locality. There is also a third fault that, crossing Waters brook about 700 feet downstream from the road bridge, trends northeasterly or obliquely to the other two. The effect of this latter fault is to bring down higher strata of the Pictou series against the Alma and Windsor rocks of Waters hill and it is these higher strata that are cut by McCulloch brook and that abut against the Stellarton series as a result of the New Glasgow fault. It is concluded, therefore, from structural considerations, that the New Glasgow conglomerate and the immediately overlying sediments of the Pictou series are older in age than the Westville and Albion and Thorburn formations of the Stellarton series. There are no structural reasons, however, for considering the Pictou series to be of pre-Middle River age, and it is provisionally held that the New Glasgow conglomerate lies at an horizon equivalent to the base of the Middle River formation, and that the latter formation is in large part synchronous to the Pictou series, but differs from it in lithological facies on account of its derivation from a tributary watershed that lay to the south and southeast.

Stellarton Series

As a detailed discussion of the Stellarton series will be presented in a later report dealing with the Pictou coal field, reference here will be confind to a brief summary of the stratigraphy.

The series may be considered conveniently as made up of the following formations: Middle River, Westville, Albion (including the basal Plymouth member), and Thorburn (including the Sutherland River and Ross Bridge members). These are not everywhere well-defined lithological units, as there is great variation of facies laterally, and a progressive overlap took place from west to east. The total maximum thickness of sediment is perhaps not less than 13,000 feet; of this total the Middle River and Westville formations together comprise a maximum of 8,000 feet. The Middle River formation, formerly wrongly assigned to the Millstone Grit, succeeds the Lismore formation, although the precise nature of the contact, whether faulted, or an unconformable one, is not certain. The Westville formation on Middle river overlies the Middle River strata without discordance. The relation of the Albion formation to the Westville was formerly considered to be a faulted one, but development of the Westville coal seams has disproved the presence of the supposed fault, and there is evidence to suggest that the Albion formation overlies the Westville unconformably. A well-exposed contact on East river shows the basal Plymouth member of the Albion resting unconformably upon highly tilted Lismore beds. The Thorburn formation overlies the Albion without discordance in the vicinity of East river, but eastward it appears to overlap, by means of the Sutherland River basal member, upon pre-Stellarton rocks.

As regards the general age of the Stellarton series as a whole the fossil evidence is considered sufficiently diagnostic to fix the Albion and Thorburn formations as Upper Westphalian. The best chronological guides must be considered the insect remains that are present at a number of horizons. These have not yet been studied in detail, but all are blattoids, and the majority belong to the family *Mylacridae* Scudder. The majority of these in turn must be assigned to the tribe of *Hemimylacridiens* Pruvost, although one or two true mylacrids occur. The mylacridien family of blattoids, according to Pruvost, is diagnostic of either the summit of the Westphalian or of the Stephanian.

All the formations within the district are peculiarly impoverished in plant remains. This is doubtless attributable to the widespread dominance of arenaceous beds and of red shales everywhere except in the Pictou coal field. In the latter district there is not so much a lack of plant material as a lack of any assemblage really representative of the floras of the times. Detached leaves or small fragments of stems belonging to a few ubiquitous, and in most instances long-ranging, species are characteristic of these Stellarton coal-bearing formations. The apparent reason for this was the long prevailing lacustrine environment of this coal basin, a unique geographic condition when compared with the other coal basins of the province.

The roofs of the coal seams are prevailingly black shales and the plant assemblage in one is closely like that in another. The most ubiquitous plant type is *Cordaites,* represented abundantly by leaves, commonly torn by driftage, and fruits. *Lepidostrobus* and *Lepidophyllum* come second in abundance. Isolated pinnules of a *Neuropteris* with vernation approaching that of *Linopteris münsteri* is likewise common. This species has been gathered elsewhere at Minto and at Sydney where it holds in the latter basin rather a limited zone in the Morien series. In both the latter coal basins it occurs at the summit of the Middle Westphalian. *Neuropteris scheuchzeri* and *Neuropteris tenuifolia* are present at several levels. *Alethopteris grandini* is very rare and *Taeniopteris* cf. *multinervia* was gathered at one locality. Both the latter are more typically Stephanian types. Among the animal remains *Anthracomya phillipsi* is quite common. The general assemblage in spite of its poverty in species supports the evidence of the insects in favour of an Upper Westphalian age for at least the Albion and Thorburn formations. No fossil evidence at all can be advanced for the age of the Middle River formation other than the bare occurrence of *Cordaites principalis,* of *Calamites,* and rarely of *Neuropteris gigantea?* The fossils gathered from the Westville formation are practically confined to those present in the roof of the Westville main coal, where the meagre assemblage comprises most of the long-ranging species recorded in the formations lying above. The more typical Upper Westphalian species, however, are absent and so the Westville horizon so far as the plant evidence alone is concerned may not be younger than the summit of the Middle Westphalian stage. That it is probably somewhat younger would follow from the inferred position of the New Glasgow conglomerate at the base of the Middle River formation. For the fossils gathered from the Pictou series above the conglomerate at Malagash point denote an age not earlier than late Middle Westphalian time. Moreover, there is a bed in Smelt brook that overlies the conglomerate, marked by an abundance of *Anthracomya phillipsi.* This freshwater pelecypod is characteristically an Upper Westphalian species.

Much of the Albion and Thorburn coal-bearing formations was probably lacustrine in origin. The facts leading to this conclusion are the great vertical depth of finely banded shales, the presence of excellently preserved insect wings at different levels, the rarity or sporadic occurrence of Stigmarial soils even beneath the coal seams, the high ash content and sudden lateral variations of thickness and quality of the coals themselves, the general high oil content in the shales, the abundance at different levels of fish scales, ostracoda, *Anthracomya,* and *Leaia,* the common occurrence of isolated pinnules and leaves of plants, many in a torn condition. The Stellarton series as a whole may be regarded as the result of combined lacustrine and fluvial deposition, the Pictou series as dominantly fluvial. It would follow from the above considerations that much of the coal within the Stellarton series was of drift rather than of in situ origin, a mode of origin, save for rare thin cannel coals, very rare in the other coal fields of the province.

TECTONIC HISTORY

With the exception of the Windsor series the Carboniferous rocks of the region are all fluvial, alluvial wash, or fluviolacustrine. In general they were deposited in a progressively subsiding basin that lay to the north of the Cobequid Mountain massif. This latter is now reduced to a narrow upland with elevations of only 800 to 1,000 feet. Its general Appalachian trend was not the result of the Appalachian revolution which affected the greater part of the eastern United States in late or post-Palæozoic time, but rather the effect of Hercynian stresses, for the Cobequid axis was the seat of several periodic uplifts during Carboniferous time. These movements may have been initiated in late Devonian time as the Cobequid axis was already outlined in the Mississippian. In the Pennsylvanian period alone three distinct maxima of uplift may be distinguished, one Lower Westphalian in age, one post-Lower Westphalian, and one very late- or post-Middle Westphalian. These may be respectively designated the post-Alma, the post-Lismore, and the post-Joggins disturbances. Following each uplift there was corresponding heavy local deposition of conglomerate, e.g., the Millsville conglomerate, the Joggins basal conglomerates, the New Glasgow conglomerate.

The alluvial basin or geosyncline, as well as the Cobequid massif, partook in these uplifts, but in most instances by warping unaccompanied by appreciable folding, so that disconformities rather than unconformities are the rule. An important exception was the uplift of the River John and Malagash areas during the post-Lismore disturbance.

The thrusting that gave rise to the uplifts took place from the south as the sediments in the basin that existed south of the Cobequids are more disturbed than those in the north. The Cobequid axis, however, was interrupted by a transverse downwarp as early as late Mississippian time. Its eastern representation is the McLellan Mountain-Brown Mountain massif. The Windsor salt-depositing sea swept through this gap and after its withdrawal Pennsylvanian sediments with the facies of those of the southern basin mingled by way of a tributary river with those of the northern. This gap was enlarged by progressive eastward down sinking and erosion during the deposition of the Stellarton series in Upper Westphalian time.

After the deposition of the late Westphalian sediments the whole region was uplifted. Folding that accompanied the uplift for the most part was of a broad, open type, but was closed and more severe along previously existing anticlinal axes. The loci of the major folding axes were determined by those already in existence. The northerly trending minor folds in the Pictou coal fields were doubtless determined by the resistant western end of the McLellan Mountain massif, the strata having been forced to curve as round a knot in conformity with it.

Finally an epoch of pronounced normal faulting took place at some time subsequent to the Palæozoic. The general easterly trend of the major faults was broadly directed by the structural axes of folding, but there are many minor faults with cross trends.

The outstanding economic effects of the tectonic disturbances to which the rocks have been subjected are: (1) the absence of the Joggins and Springhill coal-bearing formation within all but the western part of the district; (2) the isolation of the Pictou coal-bearing formations in a restricted downfaulted block of country; (3) the greatly disturbed nature of the coal seams within the Pictou coal field in the neighbourhood of the New Glasgow fault; (4) the extreme variability in thickness and quality of the coal seams in the Pictou coal field, a result of the peculiar geographic conditions that existed in the Cobequid gap during their sedimentation; (5) the disturbances that affect the salt deposit at Malagash; (6) the absence of the lower salt-bearing part of the Windsor in Lismore district. Finally, in the event that the age of the New Glasgow conglomerate has been wrongly interpreted as older than the Stellarton coal-bearing formations, there would be added to the above, (7) the absence of the Stellarton coals beneath the New Glasgow conglomerate. For even were the conglomerate younger than the coals, the structural fact remains that the conglomerate rests upon pre-coal-bearing formations in the area north of the Pictou coal field. Hence prospecting for the Pictou coals in this area is not warranted. In the extreme western part of the district where the New Glasgow conglomerate overlaps upon the Joggins formation there is a possibility of the occurrence of concealed coals.

CHEMISTRY OF THE POTASH-BEARING HORIZON OF THE MALAGASH SALT DEPOSIT, NOVA SCOTIA

By H. V. Ellsworth

CONTENTS

Illustrations

INTRODUCTION

The Malagash rock salt deposit has been worked steadily since its discovery in 1917 by A. R. Chambers and G. W. McKay and is becoming more and more important as a source of supply for the Maritime Provinces. A number of grades suitable for all ordinary purposes are produced merely by grinding and sizing the salt as mined from different parts of the deposit. The best quality as sold at present is almost equal in purity to chemically refined salt and is marketed in the form of fishery, dairy, and table salt. The less pure grades are sold for use as a refrigerant, as land and cattle salt, etc. Thus practically all the salt mined is disposed of, enabling the producers to meet successfully the competition of cheap foreign solar salts, usually of inferior quality.

Early in the development of the deposit (1919) an horizon was encountered in which the salt was found to contain small amounts of potash, in what might be called disseminated form, together with occasional small lenses of almost pure sylvite (potassium chloride). Although these sylvite lenses were rarely over 1 or 2 inches thick their presence excited great hopes of striking a potash horizon of commercial grade, and the writer made a rather careful examination and sampling of this horizon so far as was possible at that time, the intention being to continue the investigation as mining progressed. Unfortunately the analyses proved disappointing so far as commercial potash was concerned; later developments were not more encouraging and so no further detailed work was done, and the whole investigation was dropped. During 1924 the writer again visited the mine at the invitation of Mr. A. R. Chambers, so that the present article, which includes an account of the early examination and a discussion of developments up to the present, is not to be taken as representing in any sense a complete or detailed study, but only as a brief summary of what is known of the chemistry and structure of the deposit.

ACKNOWLEDGMENTS

The writer is greatly indebted to Mr. A. R. Chambers of New Glasgow, one of the proprietors of the deposit, and to Mr. John Cavanagh, engineer in charge at the mine, for many courtesies, and for assistance in every possible way.

GEOLOGY OF THE DEPOSIT

The geology of Malagash peninsula with reference to the salt deposit has been very thoroughly worked out by A. O. Hayes[1] who also describes the early history and development of the deposit and summarizes the early references to various salt springs in Nova Scotia and New Brunswick.

Hayes' main conclusions as to the geological history of the deposit are as follows:

"The salt at Malagash occurs as a stratified deposit interbedded with rocks of the Mississippian (Lower Carboniferous) period and apparently forms an integral portion of the Windsor (Carboniferous limestone) series.

"The salt strata were formed by evaporation of sea water in isolated lagoons and probably overlie limestone and gypsum measures which occur in the lower part of the Windsor series. The gypsum and salt may recur rhythmically interbedded, as do the limestone and gypsum on Smith island, Inverness county.

"The Malagash salt horizon lies along the axis of an anticlinal fold, and may, therefore, be crumpled locally and perhaps thickened by isoclinal folding and duplication of its strata. It is impossible to state positively whether the salt strata continue to great depths with the attitude found in the mine workings or are folded so as to retain a more shallow position; but they probably continue with local crumpling for several hundred feet at least and, as far as mining operations are concerned, no immediate difficulty may be looked for regarding depth.

"The dimensions of the salt deposit can be only roughly approximated. * * * * Assuming that the beds have not been duplicated by folding or deleted by faulting the actual thickness of the original beds is probably more than 300, and less than 500, feet, measured at right angles to the dip.

"The salt strata are probably offset by faults at certain localities, but the regularity of the structure along the coast to the north, for a distance of about three-quarters of a mile, suggests that the salt may extend without serious interruption for an equal distance along the strike, and the sedimentary character of the salt points to a continuation in depth parallel to the dip of the enclosing rocks."

The original thickness and present structure of the deposit naturally are of the greatest importance, not only as affecting the mining of the salt itself, which is won from steeply inclined beds by ordinary stoping methods (Plate VII), but also in regard to the possible occurrence of a workable potash horizon. Hayes' prediction of local crumpling in the salt strata has been amply verified by the more recent mining operations, which have now penetrated to over 200 feet in depth. The steeply inclined bed which

[1] Hayes, A. O.: "The Malagash Salt Deposit"; Mem. 121 (1920): with Map 1796, Malagash Peninsula; and Map 1797, Malagash Salt District.

supplies the present high-grade product has been folded almost into a horseshoe shape, and minor faulting, crumpling, thickening, thinning, and duplication of beds occur in extreme degree (Plate VI B). The structures indicate that the salt body has been subjected to at least two major external deformative forces which have acted in directions more or less at right angles: the first, due to the anticlinal folding along an east and west axis, has probably squeezed the salt up into the crest of the anticline; the second, due to transverse faulting[1] with accompanying or subsequent compressional stress in a direction approximately parallel to the anticlinal axis, has further folded and perhaps thickened it; and, finally, a possible lateral movement of the fault blocks may have introduced a shearing stress as a third component of the deformational forces. As a result of the combined action of these forces, the structure of the Malagash deposit in many respects resembles that of salt domes as described in the literature, though it is not intended to imply that it is necessarily circular in outline or that the mass has risen any great distance, if at all, from its point of origin, as is the case in many foreign examples. The extreme deformation and duplication of beds, the steep inclination of the strata, the location in the crest of an anticline, and the capping of residual gypsiferous material—all of which are features of this deposit—are cited by Hahn[2] as characteristic of salt domes in general. On the other hand there is no proof so far that the deposit ever actually penetrated through originally overlying rock formations. If, however, the lower part at least of the gypsiferous material capping the deposit is regarded as being really residual insoluble material resulting from the leaching away of the original upper part of the salt, there would seem to be a possibility that the mass did originally penetrate the upper formations. Unfortunately very little is known of this overlying gypsiferous material.[3]

Finally, a point worth noting which seems to support the idea that the Malagash salt body is to a certain extent dome-like in structure, is the fact that rather detailed drilling exploration carried out by Sir Alexander McGuire[4] farther west on the same anticlinal axes failed entirely to locate the salt horizon.

THE POTASH HORIZON

The potash-bearing strata were first encountered 25 feet along a drift run north from the shaft at a depth of 110 feet. The red colour of these beds, resembling that of some of the German potash salts, together with the occurrence of small lenses of pale yellowish crystalline sylvite, attracted attention and led to the discovery of the potash content. Subsequent observations have shown that the red-coloured strata do carry the most potash and that the sylvite lenses are associated only with the red-coloured salt. The red colour is probably due to hematite in the form of microscopic scales. As, in the experiments of Usiglio[5] on the evaporation of sea water, hematite was the first mineral to crystallize, the fact that it is present in greatest amount in the zone containing the most potash is hard to explain,

[1] Hayes, A. O.: loc. cit., Maps 1796, 1797.
[2] Grabau, A. W.: "Principles of Salt Deposition", p. 389.
[3] Hayes, A. O.: "The Malagash Salt Deposit"; Mem. 121, p. 15.
[4] Hayes, A. O.: Loc. cit.
[5] Grabau, A. W.: "Principles of Salt Deposition."

unless it is supposed that the volume of the zone has been greatly diminished by leaching and the hematite content correspondingly increased.

The salts of the red zone are somewhat hygroscopic. Old mine cuts through this zone are damp and corroded and bear a surface coating of hematite, clay, organic matter, and other insoluble impurities which have been left behind by the surface leaching of the soluble salts.

The thickness of the zone varies greatly. The maximum normal to the bedding is probably not over 25 feet and is attained at the 110-foot level, though part of this may be due to duplication. At the lower levels there are two red zones with a combined thickness of about half this amount.

A. R. Chambers[1] in a very interesting and suggestive paper has directed attention to a zone of yellow clay containing cracks filled with salt and potash minerals as indicating the possibility that the waters of the basin may have at one time gone to dryness. If so, this would seem to indicate favourable climatic conditions at least, for the occurrence of potash. It is possible that these dry spots—if such they were—might have been relatively higher parts of the basin from which the liquors had drained to lower levels during a dry season. Mr. Chambers also states that "year marks" are missing in the potash-bearing zone and that the salts of this zone appear to have suffered leaching.

SAMPLING

The writer's sampling was done in 1919 just after the drift north from the shaft had been opened and the surfaces were still fresh and clean. Series A, B, C, and E were 2-inch channel samples cut normal to the dip, each successive number representing 1 foot of the channel from the top downwards. Sample A 1 represents the uppermost foot of the red zone and C 6 represents the lowest part of the horizon accessible to sampling at the time. Series D consists of samples obtained by boring with an auger through the same strata as Series B; Series E samples are supposedly the same strata as Series A, but taken on the opposite side of the drift about 12 feet along the strike from Series A. The results, as may be seen, indicate that the potash content is not uniform along the strike of the beds, but is more or less patchy.

ANALYTICAL METHODS AND ANALYSES

All potash determinations were made by the standard modified chloroplatinate method, the potassium chloroplatinate being reduced by magnesium and the resulting platinum weighed.

In the case of the complete analyses special efforts were directed towards obtaining reliable results on the minute amounts of the minor constituents present, such as calcium, magnesium, bromine, SO_4, etc. To this end large weights (as a rule 50 grammes) of the water-soluble salts were treated in such a way as to remove a large proportion of the sodium chloride, leaving the minor salts in more concentrated form so that they could be precipitated in comparative freedom from the deleterious effects of concentrated salt solution. The sodium was obtained by difference and, therefore, is subject to the sum of the errors on the other constituents.

[1] Chambers, A. R.: "The Salt Deposits of Malagash, N.S."; Trans. Can. Inst. Min. and Met., vol. XXVII (1924).

Table I

Analyses of Samples Representing Channel Sampling Foot by Foot, Normal to Dip of Strata

(Analyst, H. V. Ellsworth)

Series	KCl	K_2O equivalent	H_2O insoluble after ignition	Total H_2O	KCl on sol. salt basis	K_2O on sol. salt basis
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
A 1	2·67	1·69	2·94	0·49	2·76	1·75
2	6·31	3·99	2·04	0·31	6·46	4·08
3	2·41	1·52	0·95	0·17	2·44	1·54
4	6·32	4·00	2·10	0·34	6·48	4·10
5	0·85	0·53	10·98	1·20	0·97	0·60
6	1·16	0·73	13·69	1·27	1·36	0·86
Average	3·29	2·08	5·45	0·63	3·41	2·15
D 1	1·01	0·64	15·79	1·94	1·23	0·78
2	0·89	0·56	11·03	1·79	1·02	0·64
3	0·74	0·47	7·53	1·13	0·81	0·51
4	1·22	0·77	10·47	1·98	1·39	0·84
5	0·92	0·58	6·25	1·15	0·98	0·62
6	0·63	0·40	4·65	1·03	0·67	0·42
Average	0·90	0·57	9·29	1·50	1·01	0·63
E 1	0·66	0·42	3·06	0·51	0·68	0·43
2	0·81	0·51	3·71	0·57	0·84	0·53
3	4·32	2·73	2·55	0·27	4·44	2·81
4	3·53	2·23	1·32	0·24	3·58	2·27
5	2·66	1·68	1·29	0·34	2·70	1·71
6	1·21	0·76	11·36	1·74	1·39	0·87
7	11·52	7·28	1·04	0·29	11·67	7·37
Average of 1 to 6	2·19	1·39	3·88	0·61	2·27	1·44

NOTE. H_2O insoluble weighed after ignition, hence results are appreciably lower than the true values, due to loss of water and combustion of considerable organic matter.

Table II

Average of Series A Samples

(Analyst, H. V. Ellsworth)

One hundred grammes each of the ground Series A samples were mixed together and used for a more complete average analysis—similarly with series B, C, and D.

	Per cent
Salts readily soluble in water	93·56
Insoluble, washed Cl free, but containing anhydrite	6·44

A

Part Soluble in Water

	Per cent
Na (diff.)	37·12
K	1·66
$\{K_2O$ 2·00; KCl 3·16$\}$	
Ca	0·47
Mg	0·02[1]
Fe, Al	Not detected
Cl	59·207
Br	0·03
I	Not detected
SO_4	1·04
CO_3	trace
B_2O_3	Not detected
H_2O	0·45
	100·00

B

Part Insoluble in Water

	Per cent
SiO_2 (total)	57·11
(SiO_2 combined approx.......23)	
(SiO_2 uncombined[1]..........34)	
Fe_2O_3	4·75
FeO	None
Al_2O_3	13·18
TiO_2	0·69
MnO	0·06
Cr_2O_3*	0·08
V_2O_3	Not detected
CaO	3·30
MgO	6·50
K_2O	1·83
Na_2O	0·18
SO_3	4·15
CO_2	1·32
P_2O_5	0·10
B_2O_3	Not detected
Cl	0·03
H_2S Gp. metals[3]	trace
Co, Ni	Not detected
Carbon	1·09
$H_2O-110°$	0·71
$H_2O+110°$	4·04
	99·12

A

Calculated Combinations

	Per cent
NaCl	94·91
KCl	3·16
$CaSO_4$	1·47
$CaCl_2$	0·11
$MgCl_2$	0·08
NaBr	0·05
H_2O	0·45
	100·23

B

Insoluble Residue

Calculated Approximate Mineral Composition

	Per cent
Quartz crystals and free silica	33–34
Silicates	45–46
Anhydrite	7·06
Hematite	4
Carbonates	2·6
Water	4·75
Carbon	1·09

Calculated Approximate Mineral Composition of Series A Samples as a Whole: i.e. (A plus B)

	Per cent
NaCl	88·79
KCl	2·96
$CaSO_4$	1·82
$CaCl_2$	0·09
$MgCl_2$	0·07
NaBr	0·04
Quartz and free silica	2·2
Silicates of Al, Mg, K, Fe, Ti, etc.	2·9
Carbonates (Mg or other)	0·17
Hematite	0·25
Carbon	0·06
H_2O	0·72
	100·07

[1] Quartz crystals and silica possibly of organic origin.
* Verified by duplicate determinations. Possibly from blasting powder.
[3] Perhaps copper.

Table III

Average of Series B Samples

(Analyst, H. V. Ellsworth)

	Per cent
A—Salts readily soluble in water	97·90
B—Insoluble, washed Cl free but containing anhydrite	2·10

A

Part Soluble in Water

	Per cent
Na (diff.)	37·48
K	1·85
{K_2O ....2·23; KCl........3·51}	
Ca	0·21
Mg	0·006
Fe, Al	Not detected
Cl	59·64
Br	0·005
SO_4	0·49
CO_3	Trace
H_2O	0·32
	100·00

B

Part Insoluble in Water

	Per cent
SiO_2 (total)	43·78
Al_2O_3	11·78
Fe_2O_3	2·99
TiO_2	0·62
MnO	0·06
CaO	10·85
MgO	5·96
K_2O	1·68
Na_2O	0·12
SO_3	14·36
CO_2	1·28
H_2O	4·31
Carbon	Present
	97·79

A

Calculated Combinations

	Per cent
NaCl	95·57
KCl	3·51
$CaSO_4$	0·71
$CaCl_2$	trace
$MgCl_2$	0·02
NaBr	0·006
H_2O	0·45
	100·26

B

Calculated Approximate Mineral Composition

	Per cent
Quartz crystals and free silica	20–22
Silicates	41–43
Anhydrite	24·42
Carbonates	2·5
Hematite	2
Carbon	1–2
Water	4·31

Calculated Approximate Mineral Composition of Series B Samples as a Whole: i.e. (A plus B)

	Per cent
NaCl	93·56
KCl	3·44
$CaSO_4$	1·20
$CaCl_2$	trace
$MgCl_2$	0·02
NaBr	0·006
Quartz crystals and free silica	0·45
Silicates	0·88
Carbonates	0·04
Hematite	0·04
Carbon	0·02
Water	0·54
	100·19

Table IV

Average of Series C Samples

(Analyst, H. V. Ellsworth)

	Per cent
A—Salts readily soluble in water	97·23
B—Insoluble, washed Cl free but containing anhydrite	2·77

A

Part Soluble in Water

	Per cent
Na (diff.)	38·60
K	0·27
$\left\{\begin{array}{l} K_2O \ldots 0·33 \\ KCl \ldots 0·52 \end{array}\right\}$	
Ca	0·27
Mg	0·013
Fe, Al	none
Cl	59·98
Br	0·020
I	Not detected
SO_4	0·61
CO_3	trace
H_2O	0·23
	100·00

B

Part Insoluble in Water

	Per cent
SiO_2	47·43
Al_2O_3	13·04
Fe_2O_3	4·49
TiO_2	0·66
MnO	0·10
CaO	8·02
MgO	5·98
K_2O	2·16
Na_2O	0·23
SO_3	11·17
CO_2	1·03
H_2O	5·20
Carbon	Present
	99·51

A

Calculated Combinations

	Per cent
NaCl	98·47
KCl	0·52
$CaSO_4$	0·86
$CaCl_2$	0·06
$MgCl_2$	0·05
NaBr	0·02
H_2O	0·23
	100·21

B

Calculated Approximate Mineral Composition

	Per cent
Quartz crystals and free silica	24–26
Silicates	45–16
Anhydrite	18·99
Carbonates	2
Hematite	4
Carbon	1–2
Water	5·2

A and B

Calculated Approximate Mineral Composition of Series C Samples as a Whole: i.e. (A plus B)

	Per cent
NaCl	95·75
KCl	0·50
$CaSO_4$	1·39
$CaCl_2$	0·05
$MgCl_2$	0·05
NaBr	0·02
Quartz crystals and free silica	0·70
Silicates	1·25
Carbonates	0·05
Hematite	0·11
Carbon	0·03
Water	0·37
	100·27

Notes, Tables II, III, IV, V, Soluble Salt Parts: A. The assumption that calcium and magnesium chlorides are actually present is based on the fact that the SO_4 ion found by analysis is insufficient to satisfy the Ca present. As these two constituents were determined on 10 and 50 gramme samples from which much of the NaCl had been removed, it seems reasonably probable that the discrepancy is not due to analytical error, especially as the same relationship was found for the whole series. Expressed in percentages the differences appear almost negligibly small, but in terms of actual weight of barium sulphate obtained they are much more convincing.

Thus, for Series A:

CaO=0·0654 grm. equivalent to SO_3 or 0·2720 grm. $BaSO_4$; whereas only 0·2526 grm. $BaSO_4$ was actually found.

Similarly, for Series B, C, D:

B: CaO=0·1458 grm.=SO_3 or 0·6070 grm. $BaSO_4$ calc.; 0·6011 grm. found.
C: CaO=0·1872 grm.=SO_3 or 0·7794 grm. $BaSO_4$ calc.; 0·7494 grm. found.
D: CaO=0·4591 grm.=SO_3 or 1·9113 grm. $BaSO_4$ calc.; 1·6903 grm. found.

The water present in the soluble salt parts analysed is no doubt combined with the $CaSO_4$ as gypsum $CaSO_4 \cdot 2H_2O$ and with the hygroscopic calcium and magnesium chlorides. It appears to be somewhat smaller in amount than might be expected, owing no doubt to the drying of the

Table V

Average of Series D Samples

(Analyst, H. V. Ellsworth)

	Per cent
Water soluble salts	88·89
H_2O insoluble	11·11

Part Soluble in Water

	Per cent
Na (diff.)	37·97
K	0·49
(K_2O...0·59)	
(KCl...0·93)	
Ca	0·65
Mg	0·095
Fe, Al	None
Cl	58·93
Br	0·015
I	None
SO_4	1·39
H_2O	0·46
	100·00

Selected Pale Yellowish Sylvite from Lens E7
(Analyst, H. V. Ellsworth)

	Per cent
KCl	92·89
NaCl	6·48
Ca	0·02
Mg	0·008
Fe, Al } H_2O soluble	None
Br	0·096
I	None
SO_4	0·03
H_2O	0·29
Insol	0·12
	99·94

Pure-looking Bed of Rock Salt 4 Feet Thick, 20 feet North of Shaft, Almost Pure White Except for a Slight Brownish Tinge, and Non-hygroscopic.

(Analyst, H. V. Ellsworth)

	Per cent
Na (diff.)	38·55
K	0·43
Ca	0·20
Mg	0·001
Fe, Al } H_2O soluble	None
Cl	59·78
Br	0·019
SO_4	0·47
H_2O	0·07
Insol	0·48
	100·00

Calculated Combinations

	Per cent
NaCl	97·91
KCl	0·82
$CaSO_4$	0·67
$CaCl_2$	None
$MgCl_2$	0·004
NaBr	0·024
H_2O	0·07
Insol	0·48
	99·97

---

soluble salt part after extraction, by which all these salts would lose more or less water of crystallization depending on the temperature. The calcium sulphate is present in the original salt sample before solution, as minute crystals of anhydrite. Nothing is known as to how the bromine is combined, the assumed NaBr being purely conventional. The bromine seems to be more or less associated with the potash, as the greatest percentages are found in the rich sylvite.

The absence of soluble iron salts seems to be established. This is a point worth noting, as in the mine one easily gets the impression that the reddish crust resulting from superficial leaching might be due to the oxidation of soluble iron salts. In the European deposits a soluble iron salt—douglasite ($2KCl.FeCl_2.2H_2O$)—occurs, and on this account several of the Malagash samples were tested for water-soluble iron with negative results, though in one or two, exceedingly minute traces were indicated.

Insoluble Parts: B. Microscopic examination of the insoluble residues reveals a highly heterogeneous assemblage of materials which may be roughly classified as: (1) crystals and crystalline fragments or cleavages; (2) amorphous or scaly material; and (3) brown to black ferruginous organic material. The crystals are chiefly quartz and anhydrite with a smaller amount of hexagonal crystals and rhombohedral cleavage fragments of carbonate, which by both measurement and analysis has been identified as magnesite by H. C. Rickaby.[1]

The scaly and ferruginous materials were not definitely identified, but have been roughly calculated as silicates and hematite. There is some greenish material present which may be glauconite.

A rough separation of combined and uncombined silica was attempted in the case of the Series A insoluble, by treating first with strong HCl to get rid of anhydrite, hematite, and carbonates, next with boiling concentrated sulphuric acid to decompose silicates, followed by washing and careful treatment of the remaining residue with dilute alkali in one case, with dilute HF in another. The results for quartz and free silica obtained may be considered as maximum values, since doubtless some of the very finely divided free silica also went into solution.

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[1] Univ. of Tor. Studies, 1923, pp. 47–48.

The following analyses of the Malagash salt have appeared in various publications and are here collected for reference:

Analyses of Upper 17 feet of Salt Body as Sampled by A. O. Hayes[1] in 1918

(Analyst, S. W. Baridon, Mines Branch, Dept. of Mines, Ottawa)

A. Part soluble in hot water	1	2	3
	Per cent	Per cent	Per cent
Sodium (Na)	38·57	23·15	37·42
Potassium (K)	0·17	0·16	0·14
Calcium (Ca)	0·18	0·81	0·31
Magnesium (Mg)	0·01	0·06	0·03
Chlorine (Cl)	59·58	35·85	57·85
Sulphuric acid (SO_4)	0·64	3·05	1·07
Iodine (I)	none	none	none
Bromine (Br)	none	none	none
	99·15	63·08	96·82
B. Part insoluble in hot water			
Silica (SiO_2)	0·61	21·85	1·60
Ferric oxide and alumina (Fe_2O_3 and Al_2O_3)	0·31	7·90	0·77
Lime (CaO)	0·06	0·25	0·06
Magnesia (MgO)	0·07	2·15	0·19
Soda (Na_2O)	....	0·93	0·09
Potash (K_2O)	....	trace	....
Sulphuric anhydride (SO_3)	0·10	0·22	....
Organic (combustible matter)	0·25	2·06	0·30
	1·40	35·36	3·01

	1	2	3
A	99·15	63·08	96·82
B	1·40	35·36	3·01
Total	100·55	98·44	99·83

Sample 3: top of salt to 8 feet depth
Sample 2: 8 feet to 16 feet depth
Sample 1: 16 feet to 17 feet depth

Analysis of a Sample Evidently from the Potash Zone

(Analyst, H. C. Rickaby[2])

	Per cent
Na	35·55
K	4·58
Cl	59·20
CaO	0·21
SO_3	0·30
Mg	0·08
Insoluble	0·35
Water	0·13
	100·40

Hypothetical composition	Per cent
NaCl	90·38
KCl	8·80
$MgCl_2$	0·19
$CaSO_4$	0·49

[1] Hayes, A. O.: "The Malagash Salt Deposit"; Mem. 121.
[2] Univ. of Tor. Studies, 1923, pp. 47 and 48.

Average Analysis of Salt Bed Worked During 1924[1]

(Analyst, Commercial)

	Per cent
Insoluble in water	0·36
Iron oxide and alumina	Traces
Calcium sulphate	0·401
Calcium chloride	0·118
Magnesium chloride	0·026
Sodium chloride	99·095

Analysis of Selected Pure White Salt Marketed as Table and Grocery Salt, from Bed Worked During 1924[1]

(Analyst, Commercial)

	Per cent
Insoluble in water	0·04
Iron oxide and alumina	Traces
Calcium sulphate	0·24
Magnesium sulphate	0·30
Sodium sulphate	0·0
Sodium chloride	99·63

Analysis of the Solids of Ocean Water

(Dittmar-Challenger Expedition)

Mean of seventy-seven analyses

Ions	Per cent	Salts	Per cent	Specific gravity of salts	Tons per cub. mile of sea water[1]
Cl	55·292	NaCl	77·758	2·17	131,526,080
Br	0·188	$MgCl_2$	10·878	2·18	18,399,360
SO_4	7·692	$MgSO_4$	4·737	2·65	8,012,480
CO_3	0·207	$CaSO_4$	3·600	2·97	6,089,440
Na	30·593	K_2SO_4	2·465	2·66	4,169,760
K	1·106	$CaCO_3$*	0·345	2·72	583,520
Mg	3·725	$MgBr_2$	0·217	....	367,360
Ca	1·197	....	....	....	....
	100·00	....	100·00	....	169,148,000

[1] 2,000 pounds, avoirdupois, each.
* Including all traces of other salts.

FOSSILS

In the case of modern basins containing concentrated sea salts and having a constant or intermittent inflow of ocean water it has been shown that various sea animals, particularly fish, in some cases seals, may be drawn into the basins where they become confused and finally die in great numbers. It follows that in a deposit formed under such conditions marine fossils should be found, and it would appear to be of the greatest importance when attempting to determine the origin of a salt deposit that the fossil content, if any, should be known. Unfortunately no particular attention has been given this aspect of the Malagash deposit, so that it is impossible to say if fossils of fish or larger animals are present. Some microscopic fossils have, however, been found. In a microscopic examin-

[1] Chambers, A. R.: "The Salt Deposits of Malagash, N. S"; Trans. Can. Inst. Min. and Met., vol. XXVII, pp. 2 and 3 (1924).

ation of the insoluble parts of the samples analysed the writer noted long, slender, dark-coloured objects composed of silica which were supposed at the time to be sponge spicules, but which E. M. Kindle, Chief Palæontologist, Geological Survey, identifies as spines of *Radiolaria*. Mr. Kindle states that the *Radiolaria* are chiefly if not entirely marine organisms, so that there is here, apparently, at least some slight evidence that the basin was subject to inflow of water direct from the sea. In the same residues a single, large, perfectly formed, torpedo-shaped diatom was observed. Some of the black organic matter present exhibits a fibrous spiral structure suggesting that of the stems of *Chara* or similar plants, and one mass resembling the spirally fluted sporangium of this plant was seen. It may be that some of the red colouring matter which, particularly in the potash horizon, in many places colours the salt quite a bright red, is really an organic iron compound. There are certain minute marine organisms which colour water red, and possibly some of these are present as fossils. A thorough examination of the insoluble matter of the Malagash salt would require a great deal of time and the services of a biological specialist, but probably would yield interesting and useful data. If, for example, it could be established that the Malagash deposit really was formed by the direct evaporation of sea water, as has been supposed, there would be good reason to look for potash deposits in suitable areas containing rocks of this period. If, on the other hand, the salt could be shown to be of connate origin, there would appear to be little possibility of important potash deposits.

CONCLUSIONS

Perhaps the most striking point brought out by the analyses is the very small—almost negligible—amount of soluble magnesium, or calcium salts other than calcium sulphate, present.

This applies not only to the deposit as a whole so far as it has been explored, but even to the potash-bearing zone and adjoining strata where such salts, and particularly those of magnesium, should be prominent if the deposit represented the normal succession of salts resulting from the complete and uninterrupted evaporation of sea water. The analyses indicate that nearly all the calcium found in the soluble parts of the various samples is combined as sulphate, but there is a small and consistent excess of calcium over SO_4 presumably not due to analytical error, which fact may be taken to mean that there is a very small amount of calcium chloride present. It is probable that the minute amounts of magnesium are also in the form of chloride. The presence of these very small amounts of calcium and magnesium chlorides in the salt of the red zone is also supported by the fact that the ground "soluble salt" parts of the samples, as prepared for analysis, showed a decided tendency to cake. The calcium sulphate found in the "soluble salt" parts is present in the original salt samples in the form of beautiful microscopic crystals of anhydrite. The amount of this obtained in solution in separating the "soluble salt" part depends on the time given to washing the "insoluble" part and the quantity of water used. The actual procedure was to wash the insoluble until the wash water gave no test for chlorine. In no case do the analytical features for $CaSO_4$ in the water soluble parts indicate the total amount present in the sample, as there was always a considerable quantity of the minute anhydrite crystals left with the insoluble. In the case of Series A, B, and C analyses the total $CaSO_4$ can be calculated, as both soluble and insoluble parts were analysed.

A second noteworthy fact is the dominantly chloride character of the soluble salts. All the sodium, potassium, and magnesium, and apparently a very small amount of calcium, are present as chlorides. There is no indication whatever of the presence of any of the numerous soluble sulphates commonly associated with potash-bearing salt deposits. The absence of such salts is highly significant and apparently must be taken to mean that this salt deposit is not the result of the straight evaporation of sea water alone. The magnesium which in a normal sea-water deposit would be in the form of soluble sulphates and chlorides here occurs almost wholly as insoluble compounds, partly as crystals of magnesite (and perhaps dolomite) partly—apparently—as a silicate, not yet identified, and possibly also as brucite. The calcium is almost entirely in the form of anhydrite.

The third remarkable feature is the presence of so much silica in the insoluble residues. Although a large proportion of the total silica apparently must be credited to silicates of aluminum, potassium, magnesium, etc., and a certain amount probably to fragmentary remains of animal or vegetable organisms such as diatoms, radiolarians, etc., and the siliceous bark of certain small aquatic or semi-aquatic plants, a considerable part is present in the form of beautifully crystallized, doubly terminated quartz crystals of microscopic dimensions, having the usual elongated prismatic crystal form of ordinary quartz. It seems unlikely that such minute, perfectly formed, unabraded crystals could have weathered out of rock, so that presumably they have precipitated from the salt solution in the same way as have the accompanying crystals of anhydrite and magnesite.

In the absence of chemical data for the complete sequence of strata in the Malagash deposit—which, owing to the complexity of structure, probably never will be perfectly worked out—it is perhaps better not to attempt generalizations. There are, nevertheless, certain points which seem to be fairly well established, viz:

(1) That the deposit on the whole, so far as at present explored, contains remarkably little magnesium, which is almost wholly in insoluble forms. The section of the potash zone analysed contains on the average 0·2 to 0·3 per cent Mg, the greater part of which is in combination as carbonate or silicate, whereas sea-water salts (analysis, page 191) contains 3·7 per cent soluble Mg, and sea-water mother liquors capable of depositing potash would contain much more than this.

(2) That probably the deposit also contains less calcium sulphate than might be expected from a sea-water deposit.

(3) If, as seems certain, the quartz crystals have precipitated from the salt solutions, the deposit carries far more free silica than could be precipitated by sea water. The amount of silica in sea-water solids is so small that it is not quoted separately in published analyses, probably never exceeding five-hundredths of one per cent. The Malagash potash zone samples contain at least from 1 to 2 per cent of free silica.

(4) The amount of carbonates in the potash zone also appears larger than might be expected from a straight sea-water deposition.

It is apparent from the above that if the deposit be assumed to have been derived directly from the evaporation of sea water alone or mainly, it is difficult to explain the absence of magnesium salts, potash salts being present. If one supposes it to have resulted only in part from sea water, in part from terrestrial waters, it is easy to account for the presence of silica and carbonates, but the absence of magnesium is still unexplained unless it should have happened that the terrestrial waters added little or no magnesium to the deposit, and that the amount of this element contributed by ocean water was relatively so small that it was almost completely precipitated. The precipitation of Mg as carbonate is effected by CO_2 and by double decomposition of calcium carbonate and magnesium sulphate—i. e. $CaCO_3+MgSO_4=CaSO_4+MgCO_3$. The large amount of organic matter present no doubt evolved considerable CO_2, and this—with calcium carbonate or, rather, bicarbonate brought in by terrestrial water—would easily account for the carbonates present. The greater part of the magnesium, however, appears to be present as silicate, the silica for which must have been brought in by terrestrial waters. It seems probable, therefore, that silica in solution, suspended or colloidal clay, calcium bicarbonate, and, no doubt, more or less organic debris, were contributed to the deposit by inflowing terrestrial waters. From the foregoing the salt deposition can be imagined as taking place in a depression containing sea water entrapped by the rising land—and perhaps subject for some time at least to periodical accessions of sea water—which also served as a catch basin for large amounts of terrestrial waters laden with silica, calcium bicarbonate, and organic detritus. The relative amounts of salt and fresh water must have been such that the silica and calcium carbonate contained in the land water were sufficient to precipitate the magnesium of the sea water. Such conditions might obtain if a shallow sea bottom were slowly elevated above sea-level. As it became land, if the climate were dry but not quite rainless, it would become subject to leaching by occasional rains and the more soluble magnesium salts would be the first to work back to the sea, while considerable sodium chloride might still be retained by adsorption, in pore spaces, and perhaps as small deposits or encrustations in minor depressions. Contemporaneously with the leaching away of magnesium salts over the whole new land area, the basin of deposition might become cut off from the sea and thereafter would receive mainly sodium chloride in the land waters, along with silica and calcium bicarbonate. Potassium salts would be mostly retained in the land because of the peculiar selective adsorption of such salts by clays and fine mineral particles.

It might also be argued that the Malagash deposit was originally a typical sea-water deposit and that the magnesium salts have been leached away since their deposition. This on the whole does not seem probable. It is true there are some indications of leaching in the potash zone, but there is nothing to show that large amounts of magnesium salts have been removed in this way.

Another speculation, perhaps worth considering, is connected with the structure of the deposit. If a fair-sized layer of typical potash and magnesian salts were originally present, it might, in the folding of the salt into its present form, be entirely pinched out for a certain distance on the flanks of the anticline and squeezed up into the crest whence it was subsequently removed by erosion and leaching. It seems likely that such a layer would be much more plastic than the sodium chloride enclosing it and would probably flow like putty. It might also have happened that the shaft was sunk on this pinched-out section.

ECONOMIC CONSIDERATIONS

The absence of appreciable quantities of soluble magnesium and calcium salts makes possible the production without refining of a really high-grade salt from certain parts of the deposit in which the insoluble impurities—chiefly anhydrite, silica, and organic matter—are sufficiently small

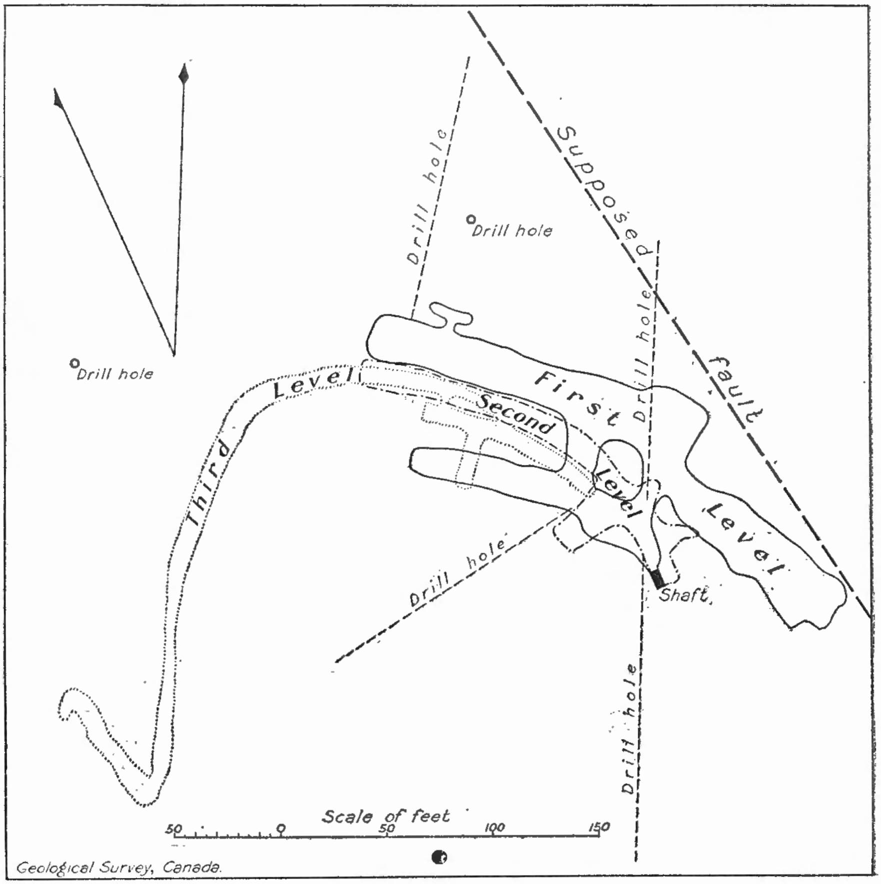

Figure 14. Plan of workings, Malagash salt mine, Cumberland county, N.S.

in amount. In producing the best grades of table and dairy salt care has to be exercised to cob out occasional fragments with a somewhat dark or brownish colour due to a slight amount of organic matter, for although such coloured salt may be chemically quite as good as the pure white material, its appearance is against it.

Analyses of commercial Malagash and other fishery salts, made by J. F. Logan, Ph. D.[1], McGill University, are as follows:

Ions	Malagash	Trapani	Iviza	Liverpool	Turk island
	Per cent	Per cent	Per cent	Per cent	Per cent
SO_4	0·952	1·720	1·142	0·656	1·753
Cl	59·845	58·935	59·620	59·855	58·745
K	0·195	0·435	0·292	0·136	0·346
Ca	0·324	0·235	0·306	0·262	0·544
Mg	0·005	0·660	0·206	0·011	0·480
FeO and Al_2O_3	none	traces	traces	none	traces
SiO_2, sand, etc., insol. in dil. HCl.	0·347	0·141	0·021	0·010	0·039
CO_3	none	traces	traces	none	traces

Analysis of Various Salts for Curing Fish[2]

Substance present	Turk Island salt	Trapani Italian salt	Iviza Spanish salt	Diamond Flake d omestic salt	Leslie velvet grain California salt
	Per cent	Per cent	Per cent	Per cent	Per cent
Sodium chloride	96·52	95·82	98·05	99·78	99·96
Calcium chloride	....	0·32	0·49	....	....
Calcium sulphate	1·53	....	....	0·37	0·067
Magnesium chloride	1·20	1·19	....	0·00	0·00
Magnesium sulphate	0·80	1·75	0·80	0·00	0·010
Sand, etc	0·13	0·15	0·06	0·00	0·022

In the above tables the Liverpool, Diamond Flake, and Leslie salts are artifically prepared by the evaporation of brine under controlled conditions; the Turk Island, Trapani, and Iviza are solar salts.

The absence of hygroscopic magnesium and calcium salts is strongly stressed by the producers of Malagash salt as a point of superiority over the solar salts commonly used in the fish-curing industry in the Maritime Provinces. It certainly seems reasonable to suppose that fish cured with non-mygroscopic salt will remain drier and keep better than if moisture-absorbing salts are present. The experiments by the United States Bureau of Fisheries[3] show that calcium and magnesium salts, moreover, have other harmful effects in decreasing the rate of penetration of salt into the fish. The following extract may be quoted:

"The physiologists have shown that in living animals compounds of calcium, barium, and magnesium have a marked effect in retarding or arresting penetration of membranes.

"By appropriate methods of measuring the rate of penetration of salt into fish it was found that if absolutely pure salt is used a very rapid penetration is obtained, but that even small additions (from 1 to 5 per cent) of these salts of calcium and magnesium cause a very pronounced retar-

[1] Logan, J. F.: "Report of the Analyses of Commercial Salts Used in Connection with the Fishing Industry in the Maritime Provinces"; McGill University, Montreal. For the Canadian Advisory Council of Scientific and Industrial Research.

[2] Taylor, Harden F.: "Principles Involved in the Preservation of Fish by Salt"; U.S. Bur. Fish., Doc. No. 919, p. 6.

[3] Loc. cit.

dation of penetration. For example, by appropriate methods of analysis it was found that pure salt penetrated as deeply in less than five and one-half days as did salt containing 1 per cent of calcium chloride in nearly seven days. Similarly, a salt containing 4·7 per cent magnesium chloride penetrated no farther in five days than pure salt did in three. In order to bring about a much more rapid penetration of the tissues, then, we have but to obtain a salt free from these impurities. The time gained by the use of pure salt enables fish to be salted at a much higher temperature and yet not spoil. Fish were salted in an incubator room in Washington at a temperature of 90° F. at first, rising to 100° F.—the hottest summer weather. No unpleasant odour developed and the fish upon being cooked and eaten were pronounced excellent.

"There was a further and somewhat unexpected difference between the effects of pure and impure salts. The flesh of the fish salted by impure salt is white, opaque, or chalky in appearance and much harder or firmer in consistency; that of fish salted with pure salt is translucent and somewhat yellowish and much softer. While the former white, firm fish is the customary quality demanded in commerce, there are strong reasons for believing the softer and yellowish fish produced in pure salt to be superior. There is reason for believing that the whitening of the fish in impure salt is explained by the fact that the calcium coagulates the protein, just as heat by coagulating egg white causes it to be white and firm. But where there is no calcium in the salt the protein retains its natural translucency and yellowish colour. The calcium in impure salt is retained by the fish, a matter that will be discussed later under the subdivision on flavour of salted fish."

The Malagash salt also shares another important advantage with the chemically refined salts in not being infected with a certain bacterium apparently invariably present in solar salts, which produces an objectionable red discoloration[1] on salted fish.

The question as to whether important deposits of potash ever existed or may yet be found in the Malagash deposit is one of the greatest interest, because of the large areas of similar rock formations in Nova Scotia and New Brunswick over which salt springs occur and which might possibly carry similar deposits. To the writer the evidence so far available which has been discussed in the preceding pages does not seem to favour the idea that large deposits of potash may occur. An important point to be considered in this connexion is the original thickness of the deposit, about which little is really known. This was estimated by Hayes to be between 300 and 500 feet. At the time of Hayes' observations, however, little of the deposit had been opened up and the positive evidences of thickening and duplication of beds now to be seen were not then apparent. To the writer it seems that considerable allowance should be made for the thickening of the deposit in the crest of the anticline.

The bromine content of the Malagash salt, though small, might be worth recovering if the salt should ever be chemically refined, as the demand for this element is steadily increasing and present supplies appear scarcely equal to the demand.

[1] Harrison, F. C., and Kennedy, Miss Margaret E.: "The Red Discoloration on Cured Codfish"; Rept. No. 11, The Honorary Advisory Council for Scientific and Industrial Research, Canada.

The Malagash deposit is well situated with regard to rail and marine transportation and coal supplies and no doubt is destined at some future time to become the basis of an important alkali industry.

AN INTERESTING REACTION OCCURRING IN THE MALAGASH SALT MINE

Since the above was written Dr. A. O. Hayes and Mr. Cavanagh noticed an encrustation of a crystalline salt on iron and brass fittings such as pipes, etc., in the mine, and forwarded a sample to the writer for identification. The salt proved to be nearly pure carbonate of soda. It is said to occur in considerable quantities, but as the analyses indicate no more than traces of alkali carbonate present in the rock salt itself it appeared to the writer that the sodium carbonate was probably produced by chemical action between the sodium chloride and the iron or brass in the presence of atmospheric carbon dioxide. To test this hypothesis an ordinary 3-inch wire nail was placed in a standing position in a small beaker with some chemically pure sodium chloride just covered by water. This was allowed to stand in the laboratory. In about eighteen hours the yellow colour of ferric chloride had become visible in the solution and salt immediately surrounding the nail head, and three days later a considerable encrustation had appeared on the nail just above the level of the sodium chloride solution. The nail was removed and the encrustation on being touched with a little dilute hydrochloric acid produced a vigorous evolution of gas, the process being observed under a binocular microscope. The encrustation further gave a strong alkaline reaction with litmus paper. Thus the presence of CO_2, and hence of sodium carbonate in the encrustation, was proved beyond doubt.

Once the end of the nail in the salt had become somewhat attacked the reaction seemed to proceed more rapidly and merely standing over night was sufficient to produce a well-marked encrustation showing a very strong alkaline reaction. Although the sodium chloride solution had now a pronounced yellow colour a test with potassium ferricyanide showed that considerable ferrous chloride was present.

The reaction may perhaps be explained by supposing that owing to impurities such as—for example—carbon and carbides in the iron, the system acts as would a multiplicity of microscopic wet batteries, iron and carbon or other impurity being the plates and the sodium chloride solution the electrolyte. Thus, iron dissolves to ferrous chloride in the first instance and sodium metal—which, since water is present, becomes sodium hydrate—appears at the other pole, the action being comparable to that of the gravity cell where zinc dissolves and copper is deposited on the positive copper plate. The sodium hydrate owing to its peculiar affinity for moisture creeps up the nail above the sodium chloride solution, is acted on by atmospheric CO_2, and eventually results in the formation of a ring of sodium carbonate well above the salt solution.

An unexpected feature of this little experiment was the rapidity with which the action took place. Although it might be supposed that weeks would be required for perceptible results, actually it is only a matter of hours once the nail becomes somewhat corroded.

GEOLOGY AND ORE DEPOSITS OF STIRLING AREA, RICHMOND COUNTY, NOVA SCOTIA

By L. J. Weeks

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Illustrations

INTRODUCTION

The primary purpose of the field work at Stirling, Richmond county, Cape Breton, during the summer of 1924, was to study the zinc-lead-copper deposits, but at the same time the general geology of the district was investigated. Stirling, a hamlet, is about 4 miles from Framboise cove on the south coast of Cape Breton. It is 35 miles from the railway at St. Peters, and about 40 miles from the railway at Sydney, and may be reached by road from either place. The *S.S. Arcadia* makes a weekly trip along the coast in summer, stopping at Fourchu, 10 miles from Stirling. No passengers are carried, but the steamer affords an economical method of bringing freight into the country.

The results of the field work are given in the following report. The writer acknowledges with pleasure the generous advice received during its preparation from Professors A. Knopf, H. E. Gregory, A. M. Bateman, and C. R. Longwell of the Department of Geology, Yale University, and the kindness of Professor C. P. Berkey, of Columbia University, in lending his unpublished manuscript on the ores of the region. It is a pleasure to note the courtesies extended to the writer in the field, both by the people of Stirling, and by Mr. F. M. Connell and other officials of the Eastern Mining and Milling Company. Mr. Connell gave the writer free access to all assay plans and diamond-drill records owned by his company. Mr. John G. Macleod of Stirling assisted very efficiently in the chain surveys of the area.

The previous geological work in this region, so far as it relates to the strata in the vicinity of Stirling, may be summarized as follows. Robb,[1] in 1876, recognized the older age of a greater part of the rocks of Cape Breton, but merely called them pre-Carboniferous. Fletcher divided these older rocks into Devonian, Cambrian, and Precambrian. He subdivided

[1] Robb, Charles: Geol. Surv., Canada, Rept. of Prog. 1874-5, pp. 166-194.

the Precambrian into two groups, a syenitic-felsitic group and an unconformably overlying limestone series. The syenitic-felsitic group he regarded as sedimentary in origin.[1] The first attempt at a modern classification of the strata in the immediate vicinity of Stirling was made by A. O. Hayes,[2] who found this complex to be composed, at least locally, of tuffs and acid flows, cut by deep-seated intrusives. He did not discuss the limestone series or its relations to the lower complex.

GENERAL CHARACTER OF THE DISTRICT

TOPOGRAPHY

Cape Breton is a tilted or warped plateau, probably—since it is relatively uplifted on the north and depressed on the south—representing an old erosion surface. The flat but tilted character of the bedrock surface where underlain by the older crystalline rocks is apparent throughout Richmond county. Streams and lakes as a rule are located on bedrock, whereas the intervening hills and knolls are barren of rock exposures. This suggests that the hills are of glacial material, an idea that is well substantiated on the sea-coast as practically the whole southern coast is flanked by cliffs ranging in height from a few feet to over 100 feet, composed entirely of glacial debris. These are commonly underlain by flat outcrops of bedrock, usually running a considerable distance out to sea as reefs. Rock outcrops are found inland at increasing elevations above sea-level, but the flat character of the bedrock surface is maintained, and a mantle of drift overlies all. A few miles south of Bras d'Or lake, at Big Pond, the elevations of stream bottoms are around 300 feet. Here, as at points of lower elevation, the hills are of glacial material, only the streams yielding rock exposures.

An abrupt scarp runs along the south shore of East bay on Bras d'Or lake, an elevation of more than 400 feet being attained less than a mile from the lake, which is at sea-level. But here a change in the bedrock character also occurs, the higher country being underlain by much harder rock. Across East bay, elevations of 600 feet are found, again in the harder rocks. The foreshore of the lake, on both sides, is underlain by softer sediments.

Topographically the area examined is situated on the Atlantic watershed of Mira hills. The relief is low and the country is thickly dotted with lakes and ponds. Along the coast rocky shoals and ledges extend several miles out to sea, but outcrops along the shore are not plentiful as a rule, except at the tips of promontories. Where outcrops are found, the bedrock almost invariably has a low, flat character, although it may be overlain by a cliff, from 50 to 100 feet high, composed of glacial drift. At Capelin cove, where there is little or no glacial drift, the bedrock at a few points rises to the exceptional height of 15 feet above the sea.

[1] Fletcher, H.: Geol. Surv., Canada, Rept. of Prog. 1875-6, pp. 411-463; 1876-7, pp. 402-456; 1877-8, pt. F, pp. 1-32; 1879-80, pt. F, pp. 1-125.
[2] Hayes, A. O.: Geol. Surv., Canada, Sum. Rept. 1917, pt. F, pp. 30-32; 1918, pt. F, pp. 20-21.

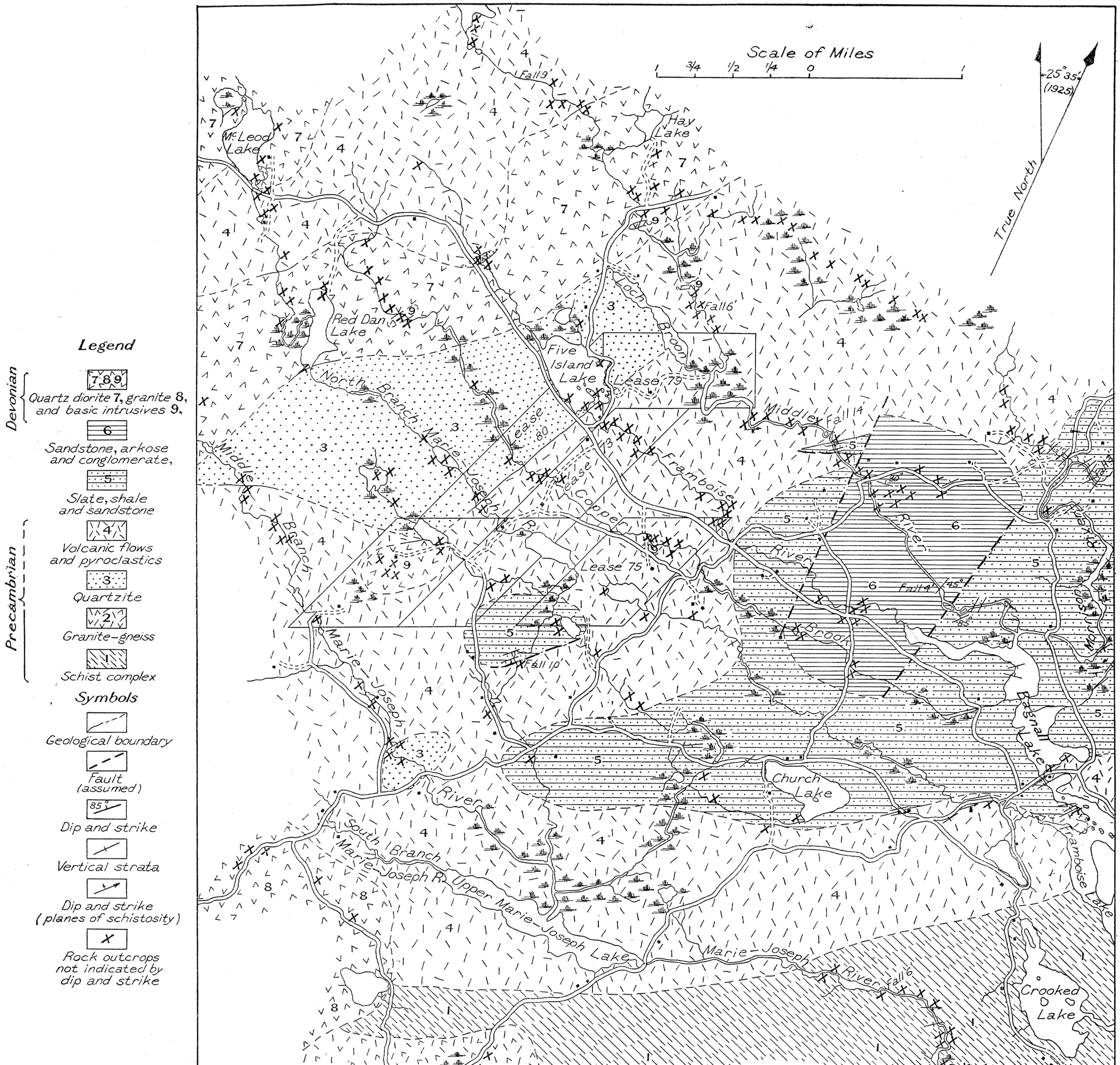


Figure 15. Stirling area, Richmond county, Nova Scotia.

The coast is of the "estuary" type. Rivers run into the sea through long, narrow lakes, many of them salt. Framboise lake is the most striking example in the map-area. Marie-Joseph lake is another example, and outside, on the south coast, Grand River, Saint Esprit, Mullcuish, and Belfry lakes show characteristics typical of such conditions. On Framboise river, a depth of 42 feet is found 2½ miles from the coast. These estuaries, with few exceptions, cannot be entered from the sea by boats. Louisburg and Fourchu have the only natural harbours on the southeast coast, although a few inlets can be entered by motor boats and shallow-draft fishing craft. This general condition is due to the action of the sea, which, in reworking the glacial sands and gravels, has effectively dammed these estuaries with sand barriers, some of which rise 20 feet above high tide. These are, in seasons of heavy rainfall, penetrated by a small channel, locally termed a "gut," through which the drainage is discharged. During dry seasons, and especially in the case of small streams, the lake water is usually discharged by seepage through the gravel.

The sea is at present encroaching on the land at rates ranging up to 5 and 8 feet a year. This encroachment is due solely to the eating away of glacial material at places where bedrock is not exposed at or above sea-level, but in general the coast has many features suggestive of a comparatively recent submergence.

Inland, bedrock is found only in the beds of streams, and on the shores of lakes. Between the streams are rolling, thickly wooded hills, some of them 200 feet in elevation, their heights above the neighbouring streams being in most cases less than 100 feet. These hills are formed of rounded boulders and gravels of glacial origin.

There are a few large areas of flat land on which bedrock appears. Such an area is located along Middle river just below the Mira road. This flat is bounded on all sides by hills of glacial material. Another similar and larger area lies to the east of the map-area, on the north side of the Fourchu road.

Lakes are very numerous in Stirling region, and it is evident that at one time they were even more plentiful, there being for every present lake, two or three former lakes now filled with vegetation. With a few exceptions noted below, all the lakes are the result of glaciation and the general upsetting of the drainage systems resulting therefrom. Four general processes were observed to have given rise to the lakes.

First and most commonly, the river valley was filled with glacial material, making a dam and forcing the water to escape at some point not in its former drainage line, and commonly over bedrock. The formation of Upper Marie-Joseph lake, Five Island lake, Red Dan lake, Giant lake, and numerous other smaller and unnamed lakes and ponds was due to this process.

Second in importance is the direct damming of a river valley by glacial debris, without subsequent upsetting of the drainage system. It is in many cases difficult to differentiate between these two processes, but the first is suggested if the lake has its outlet flowing over bedrock.

The third process consists of the damming by the sea of a wide-mouthed estuary. A barrier beach is piled up 20 or more feet above the level of the sea. The water of the lake naturally escapes at the lowest point in the beach and this point in most cases is at one end of the beach where bedrock outcrops and the erection of a barrier by the sea has been prevented. Hence, many of these estuary lakes discharge over bedrock, are of fresh water, and are as much as 10 feet above sea-level. An exceptionally violent storm may completely change the drainage of these estuary lakes, and even change a freshwater lake to a saltwater lake, or vice versa.

The fourth process of lake formation consists of the formation of a rock basin by glacial scouring. The only known example is a small, shallow lake about three-eighths of a mile long on the north branch of Marie-Joseph river about one mile above William MacLean's farm. It is entirely surrounded by bedrock, except at its inlet, and outcrops are found in the stream above the lake at no great distance.

As one proceeds along a river, for every lake that is passed one will come upon two or three "stillwaters." This term is used locally to define a quiet section of a river, where, though the stream is of normal width, the water is abnormally deep. Such sections are bounded as a rule by a few hundred yards of peaty soil. The stillwaters meander back and forth across this boggy area, and have no perceptible current. They doubtless mark the locations of former lakes.

Without a single exception the lakes discharge over gravel or bedrock in a running stream, and their inlets are clogged with peat, making a stillwater of the entering stream for a distance varying from 100 yards to nearly a mile. Red Dan lake, on the north branch of Marie-Joseph river, is an excellent example of this general condition. For practically three-quarters of a mile above the lake, the river meanders through a forest-covered peat bog, the stream varying in depth from 4 to 14 feet. It flows almost 200 yards out into the lake through a triangular "delta" of peaty soil. As the stream enters the middle of the longest side of the lake, it is conceivable that in time this peat delta will divide the lake into two parts. Many other lakes show this delta of peat around their inlets, and all available evidence indicates that the lakes tend to become filled with vegetation, the process beginning at the head of the lake. It thus appears that the lakes are undergoing transformation into stillwaters, and that the stillwaters found today represent extinct lakes.

The streams flow sluggishly, as a rule, and abound in swamps and bogs, but many of them locally occupy steep-walled gorges varying in depth up to 25 feet. A waterfall occurs at the head of each gorge, and commonly several others are present along its course. The gorges are not long, a length as great as one-quarter mile being exceptional. An example of such a gorge is afforded by Morrison river, which drains Giant lake. At the lake outlet, the stream flows over a 4-foot fall in slate, and for a considerable distance below runs through a freshly cut gorge in the same material. About 1½ miles below the lake, a broad, flat, swampy area, with several small ponds in it, extends from the river almost to a long arm of the lake reaching to the south. The former drainage system probably followed this low, swampy ground, and the gorge in the present river is undoubtedly post-Glacial.

The Marie-Joseph drainage system is also abnormal. Tributary streams enter upper Marie-Joseph lake from the west, northwest, north, and northeast. The outlet flows somewhat north of east, and then southeast to the sea. Three of the main tributaries enter the lake in the middle of the north side. Immediately opposite, on the other shore, is low country extending to the sea at Capelin cove. Rock outcrops are lacking along this line, but the drift is thought not to exceed 20 feet in thickness. Capelin cove is a large gash in a somewhat regular coast-line. With its accompanying lake it extends inland one mile. The present Marie-Joseph drainage cannot be accounted for on the grounds of structure. It appears reasonable to conclude that it was originally a consequent drainage system, flowing southerly to the sea at Capelin cove, and that it has readjusted itself to a new topography in post-Glacial time.

That the original drainage was of a regular pattern, in parallel systems extending north and south at right angles to the coast, is at least suggested by the arrangement of post-Glacial gorges on Middle river, Framboise river, and Copper brook. These streams now run east, are about half a mile apart, and enter Bagnall lake. Gorges occur on these streams a little west of respective crossings of the southwest-trending Mira road, and are on a nearly north and south line. Therefore, these streams, in their present east and west directions, all encountered bedrock at about the same meridian, along what may have been a north-south, rocky divide of the old drainage system. West of the north and south line marked by these post-Glacial gorges, all three rivers run through a flat, swampy, and boggy area in which no outcrops occur and which continues to the sea through Upper Marie-Joseph lake and Capelin cove. It possibly marks the site of a pre-Glacial stream. A short distance east of the line marked by the gorges, the present system is southward and apparently perpetuates the pre-Glacial drainage pattern. It is concluded, as already stated, that the line of gorges represents a pre-Glacial interstream divide, which separated streams running south. In post-Glacial time, after the dumping of vast loads of debris, the streams were unable to follow their former beds, and the three streams mentioned, in seeking the lowest outlets, followed an east-west course across the site of what had been a divide.

GLACIATION

Evidence is everywhere abundant that Stirling area has been overridden by the continental ice-sheet. Smoothed and polished rock platforms occur on the shores of lakes and streams, and along the sea-coast. Great thicknesses of drift are found, cliffs cut in this material reaching heights of 100 feet along the coast.

Occurrences of glacial striæ, in a condition sufficiently well preserved to permit determining their bearings, are, however, not numerous. Only eight directions were thus obtained. Three of them were on the rocks surrounding Five Island lake and of these observations two coincided exactly, the bearing being true south. The third was south 10 degrees east. On Middle river, striæ were found striking south 9 degrees east. Framboise lake, a quarter mile or so below the Fourchu road, is bounded by glaciated rocks, on which were striæ averaging south 15 degrees east. Three striated localities were found on the coast between Framboise and Capelin coves. These striæ are at variance with those found inland. Near Fox cove the bearing was observed to be due east. Between Fox and Capelin coves, the direction of last ice movement was south 73 degrees east. At Capelin cove it was found to be south 14 degrees east.

Glacial drift in the region is composed of rounded pebbles and boulders in a finer mixture of sand and clay. Boulders above a foot in diameter are not plentiful, the most common size being from 4 to 6 inches. As a rule, the drift deposits are quite heterogeneous as regards rock types present. In any one locality, however, boulders corresponding to the underlying bedrock appear to predominate, as is quite noticeable in areas underlain by granite, diorite, or gneiss.

CLIMATE, POPULATION, INDUSTRIES, ETC.

Figures for the annual precipitation in Stirling area are lacking. The writer was told by inhabitants that snow is quite abundant during the winter months and storms are frequent. The snow usually leaves in April. Owing to the close proximity of the sea without sheltering prominences, a great deal of foggy weather is experienced during the summer.

The country is well wooded, but trees do not as a rule attain large sizes. Along the coast, where they are exposed to high winds and storms, they are replaced by dwarf varieties. Fir is most abundant, followed by red and black spruce. Then comes hardwood, birch, beech, and maple. White and yellow pine and tamarack are also found, but are not plentiful. It is said that sixty years ago the southern part of Cape Breton island was completely covered with a fine growth of hardwood. Practically all this standing timber was destroyed during a terrific gale in 1873, the timber mentioned above being second growth since this storm.

The population is small, about fifteen families residing in the community of Stirling, a post office village. That the population at one time was larger, is shown by the numerous vacant farms in the region.

Fishing is the chief industry, employing practically all the male population. Lobsters, cod, and swordfish are found in the coast waters. A lobster cannery is located at Fourchu, the largest fishing settlement in the vicinity. The land is fertile and is tilled to some extent, potatoes, grain, truck, and hay being grown.

Several waterfalls are found in the locality. Morrison falls on Middle river offer the best prospect of waterpower. There are two falls, 120 feet apart, the upper one having a drop of 14 feet and the lower one of 8 feet. Middle river drains an area of roughly 25 square miles above the falls, the drainage area including two lakes each about three-quarters of a mile in length, besides numerous smaller ones. Several smaller falls are found on Middle river, both above and below Morrison falls.

GENERAL GEOLOGY

The following table gives a summary of the succession as found in Stirling area. All the rock groups, with the exception of the superficial deposits, fall into Fletcher's pre-Carboniferous group.

Table of Formations

Recent		Peat, marine sand
Pleistocene		Glacial drift
	Unconformity	
Devonian ?		Quartz diorite, granite, basic intrusives
	Intrusive contact	
? (May possibly be later than the intrusives)		Sandstone, arkose, conglomerate
	Unconformity	
		Slate shale, with a conformable sandstone member
	Unconformity (?)	
		Volcanic flows, tuffs
	Unconformity	
Precambrian (?)	Relations uncertain	Quartzite, quartzitic conglomerate
Precambrian		Schist complex, cut by a granite gneiss

THE SCHIST COMPLEX

What are believed to be the oldest rocks exposed in the region occur along the Atlantic coast, excellent exposures being found from Fourchu to Capelin cove. The exact character and origin of these rocks are somewhat obscure, owing to their having undergone intense metamorphism. At Winging point, near the outlet of Big Framboise lake, they appear, from their green colour, their texture, and the presence of large bombs and angular fragments drawn out into lenticules, to be volcanic. Under the microscope, very little is discernible that throws light on their origin. Evidence of intense crystalloblastic deformation is quite marked, and epidote is a common alteration mineral.

Beds of a reddish, fine-grained mica schist occur at Red cape, interbanded in green schist. The colour and somewhat sandy texture suggest a sedimentary origin. These beds are conformably included in the volcanic rocks. Near Capelin cove, and intruded by granite gneiss, were found rocks that are very distinctly volcanic. Small phenocrysts of quartz and feldspar are observable in a dense groundmass. The deformation of these rocks is marked, the groundmass being squeezed and sheared around the phenocrysts, resulting in a rock very similar to the nearby granite gneiss. On Marie-Joseph river, just north of the lake of the same name, are excellent exposures of much metamorphosed volcanic rocks. They vary in grain from porphyries to fine-grained chlorite schists, the latter probably resulting from the deformation of tuffs. All have taken on a prominent schistosity after which they were considerably faulted, as is shown by marked changes in strike, in some cases in the same exposure. Where the fault is exposed, intense brecciation is seen adjacent to the fault-plane.

These rocks have undergone metamorphism comparable in intensity to that affecting only one other rock group in the area, viz., the granite gneiss of Capelin cove and vicinity. As this gneiss is seen to be intrusive into the schists, it is later in age, but probably has undergone a similar amount of deformation. Fletcher gives a Precambrian age to these rocks, placing them in the lower of his two Precambrian groups. Where sediments occur in this group, no fossils have been found. Their metamorphism is undoubtedly more severe than that undergone by any Palæozoic rocks in Nova Scotia. A Precambrian age is, therefore, considered as well substantiated.

GRANITE GNEISS

This rock is well exposed in the vicinity of Capelin cove. In hand specimen it is a flesh red, granitic-appearing rock, with a banding of the ferromagnesian minerals, which, though not so apparent in a small piece, is very well marked in outcrop. That it is intrusive into the schists is shown along the shore near the contact with them and where it penetrates them along the planes of schistosity. This suggests that the gneiss was intruded after the metamorphism of the schists, but these lit par lit injections in some places are widely separated and are usually at least several feet wide, and since the planes of schistosity in the schist complex usually coincide with any visible original bedding, it is quite possible that the gneiss was intruded before the deformation of the schists had taken place.

Microscopically, the rocks shows intense cataclastic deformation with the production of a marked mortar structure, giving it a texture easily confused with porphyritic. The quartz crystals have been pulverized around their borders, leaving what is apparently a phenocryst of quartz in a cryptocrystalline groundmass. Plagioclase is present, usually filled with tiny crystals of zoisite. Orthoclase has been altered to sericite and kaolin. The quartz is biaxial and possesses a wavy extinction, both resulting from strain.

This gneiss has not been observed in relation to any other rocks than those of the schist complex. Because the gneiss, like the schists, is so greatly deformed, it is thought to be Precambrian, and because the deformation these rocks have undergone is so much greater than that exhibited by any other strata, it is thought that the gneiss and schists are the oldest groups of the district, although it is just possible that the quartzite about to be described may be earlier than this gneiss, since the quartzite would not so readily show the effects of deformation.

QUARTZITE

These rocks are well exposed on Five Island lake, Copper brook, north branch of Marie-Joseph river, and on the two lakes and their joining brook, to the west of the last-named river. A very small and isolated exposure is found on the middle branch of Marie-Joseph river.

The quartzite is recognizable in all its exposures by its clean, white, massive appearance, absence of feldspar, and the high degree in which quartz has filled the interstices between the original grains. Occasionally conglomeratic bands are met with, the pebbles usually being white quartz. These rocks are cut by many dykes of diabase. On Five Island lake these dykes are very plentiful, usually are a foot or so wide, and are of no great persistence.

Microscopically, the rocks are seen to be composed of rounded grains of quartz with a cement of silica, usually deposited in optical continuity with the grains. Small flakes of muscovite and chlorite are common. The quartz has been strained.

Very little was observed which would throw light on the age of these rocks. They are quite massive, there being very seldom any resemblance to bedding, even conglomerate bands, where found, being of an extremely irregular nature. The main area of these rocks is separated, along its east side, from the supposedly younger series of volcanics by a fault whose presence is suggested by the nearly straight contact 2 miles long, and by the intensely fractured condition of the rocks adjacent to the contact. The direction of displacement of this fault is uncertain. On Framboise river, above Five Island lake, a small remnant of the quartzite lies between the quartz diorite and the volcanics. A bedding plane was observed here indicating that the strata dip under the volcanics to the north.

THE YOUNGER (?) SERIES OF VOLCANICS

This group consists of a thick series of volcanic flows and pyroclastics. The following extrusives and their corresponding pyroclastics have been recognized microscopically: rhyolite, andesite, latite, quartz keratophyre, and dacite. Among the pyroclastics, both tuffs and volcanic agglomerate were recognized.

The best sections are found on Middle river, Framboise river, and Copper brook. It is impossible to carry a definite horizon from one stream to another, partly on account of the lack of interstream outcroppings and gaps in the stream sections themselves, but also because no distinct horizon markers occur. Generally, a bed or flow varies but little from its neighbours, and extreme varieties are only found over considerable distance. Geographically these volcanics occupy two areas, separated by a belt of quartz diorite averaging one-half mile in width. One area is in the northwest corner of the map-area, the second lies in the central and north-central parts of the area.

An andesite found on Framboise river is schistose in outcrop, but the foliation is barely recognizable in hand specimens. Under the microscope the rock is found to be composed of abundant phenocrysts of oligoclase-andesine and quite abundant magnetite in a finer grained chloritized groundmass. Some of the chlorite masses resemble augite crystals, of which they are probably an alteration product. No pronounced schistosity is recognizable, but the phenocrysts are broken and sheared, and in some cases the groundmass shows flow structure and has been recrystallized.

A quartz keratophyre found on Framboise river is quite massive. Phenocrysts of quartz are discernible in the hand specimen. Under the microscope the rock is found to be composed of a few large phenocrysts of quartz and albite, is a cryptocrystalline groundmass of similar minerals, slightly chloritized. Some mechanical deformation has taken place, as is evidenced by the wavy extinction and cracking of the quartz phenocrysts.

A rhyolite on the north branch of Marie-Joseph river is composed of orthoclase, quartz, and a little plagioclase in a cryptocrystalline groundmass. In hand specimen the rock is greenish and shows distinct, clear quartz phenocrysts. The quartz is strained, but there is no suggestion of schistosity.

Volcanic breccia as found on Loch Lomond road consists of fragments of volcanics, usually rhyolite, in a finer grained groundmass, presumably of tuffaceous material.

Tuffaceous rocks showing evidence of subaqueous deposition occur in places. On Middle river, near the contact with the slates, well-banded tuffs are exposed grading downward into massive, unsorted tuff beds. Rocks of this type are also present on the north and middle branches of Marie-Joseph river.

Some of the rocks of this group show a more distinct schistosity than the rest. Near the mining prospect are several exposures of rocks showing such characteristics. Some are fine-grained volcanic rocks, probably tuffs, altered to a mass of chlorite. Others are sericite schists probably derived from more acidic types of lava.

These volcanics may be younger than the quartzites which at one locality appear to dip beneath them. Their relation to the supposedly older schist complex is in doubt. Both are composed of volcanic flows and tuffs, and might well be members of the same series. The distinction drawn between these groups is based entirely upon their respective degrees of metamorphism. Whereas in the schist complex no rocks are found in an unmetamorphosed condition, or even approximating it, the supposedly younger volcanics are as a rule almost undeformed. Exposures of fine chlorite schist occur, but these rocks are local and are probably due to local shearing.

On Middle river the volcanics dip under a group of sediments which are presumed to be younger. On the north branch of Marie-Joseph river, these sediments dip toward the volcanics, but are separated from them by a fault.

OLDER SEDIMENTARY GROUP

These rocks are well exposed on Giant lake. They are mostly grey slates, with some sandy shales, overlain by fine red sandstone. The strata dip at high angles. Their thickness is unknown, but the exposures on Morrison river suggest a total not less than 1,000 feet. The sandstone member is composed of fine-grained, red, crossbedded sandstone, fractured, and cut by quartz veins. On Morrison river it is underlain by grey sandstone, which is abruptly underlain by the grey slates.

No fossils were found in the slates and sandstones. They are believed to be younger than the volcanics. Similar strata nearby on Mira river are fossiliferous and were assigned to the Cambrian by Matthew.

YOUNGER SEDIMENTARY GROUP

On Middle and Framboise rivers are exposures of a coarse, red, arkosic and commonly conglomeratic sandstone. In places it is quite friable, whereas in others it is well cemented, but in no case approaches a quartzite in character. The rocks as a rule do not show bedding, but in places bedding is distinct, the angle of dip being between 20 and 35 degrees. The dips along the east and west sides of the area of these beds are outward, toward the bounding, supposedly older group of slates, which dip toward the red formation. Little doubt, therefore, exists that the boundary is a fault-line.

The strata are unfossiliferous. They are thought to be younger than the previously described sediments, because of their lower angles of dip, the absence of quartz veins, and their less cemented condition.

LATER INTRUSIVES

Two stocks of quartz diorite occur in the northwest corner of the map-area. They intrude the volcanics and quartzites. The rock is coarse grained, grey, and composed of approximately equal amounts of light and dark minerals. Under the microscope the rock is seen to be formed of acidic labradorite, quartz, hornblende, chlorite, and magnetite. The quartz has been somewhat strained, but the rock is quite fresh and undeformed. The hornblende is primary and some of it has altered to chlorite.

Outcrops of granite occur in the map-area only on the Saint Esprit road and the road to Capelin cove. A larger area is crossed by the Loch Lomond road some 3 or 4 miles west of the map-area. The rock on the Saint Esprit road is poorly exposed, being much weathered and fractured. The only dark minerals found were hornblende, with small amounts of chlorite and biotite.

Bodies of diabase with a variety of textures outcrop in various localities. Porphyries also occur, such as a small body of diabase porphyry on Copper brook. A small stock of coarse diabasic or gabbroid rock cuts the volcanics between the north and middle branches of Marie-Joseph river.

These various rock types probably belong to one intrusive epoch. The stocks and dykes cut all rock groups in the area, with the possible exception of the sandstone on Middle river. It is possible that the granite and quartz diorite are to be correlated with the Devonian granites of the mainland of Nova Scotia.

STRUCTURE

The red sandstone measures on Middle and Framboise rivers appear to form a downfaulted block, but otherwise do not seem to be much faulted, although more deformation may exist than is apparent. This series, as indicated by the attitudes observable in a few places, seems to lie in an anticlinal fold.

The slates and shales, alone of all the strata, usually present distinct evidence of bedding. These strata are highly inclined and show many changes in the directions of their dips. This varying attitude is thought to be due to faulting rather than folding.

The supposedly younger group of volcanics shows considerable faulting with the production of fracture zones tens of feet wide. At the foot of Five Island lake the rocks are broken and sheared for a distance of over 100 feet from the contact with the quartzite. The contact itself is not exposed, but in all probability it is a fault-plane with a downthrow on the east. Rocks of the schist complex appear to be traversed by many faults, as indicated by abrupt changes in the strike of schistosity. Actual fault-planes may be observed in the flat reefs at Red cape.

STIRLING ZINC DEPOSITS

(*See* Figure 16 and Plate VIII)

LOCATION AND DEVELOPMENT

The Stirling zinc deposits are about one-quarter mile southwest of Stirling post office. They were discovered in the late nineties and were then prospected for copper, Young's pit being dug at that time. An active interest, however, was not taken in the possibilities of the locality until 1916, when several areas were staked. Diamond drilling was done by Hayden and Stone Company, of Boston, careful assays of the core being made. Shot drilling was later done by the New Jersey Zinc Company of New York. Seven or eight trenches have been dug in the immediate vicinity of the deposits, and three or four more on the hill southwest of the ore croppings and on the north branch of Marie-Joseph river, about half a mile away. The latter trenches did not uncover ore, in fact the trenches on the hill did not reach bedrock. The ore croppings in the trenches have been assayed on several occasions.

Since the field work covered by this report was done, in 1924, an option on the property has been obtained by the American Cyanamid Company of New York. A graded road has been built to the prospect, several buildings erected, and work commenced on a two-compartment shaft. The locations of the shaft, buildings, and road are shown in Figure 16, from information supplied by F. J. Alcock of the Geological Survey, who spent a few days in the area during 1925.

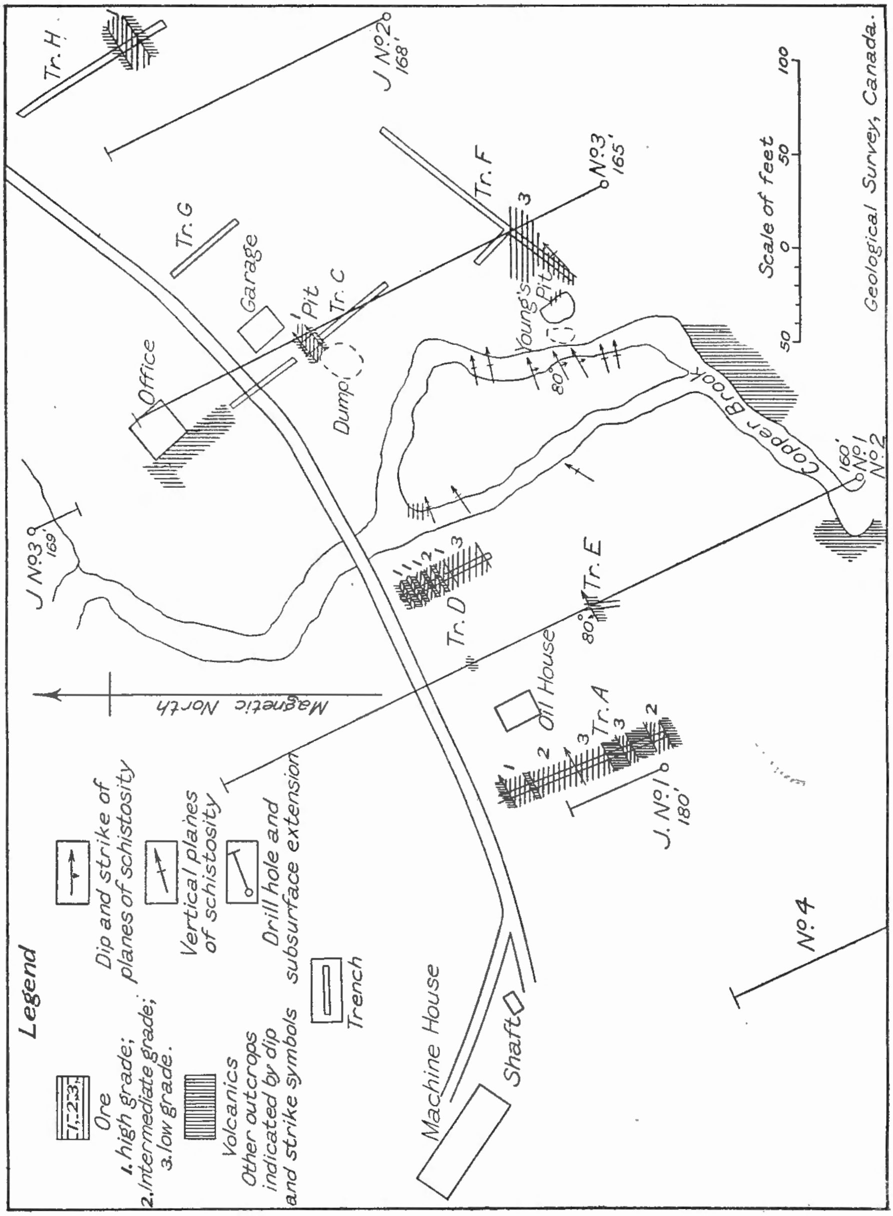


Figure 16. Stirling zinc deposit, Richmond county, N.S.

GENERAL GEOLOGY

The mineral deposits occur as replacements of members of the supposedly younger volcanic series. The predominant rock is rhyolite or rhyolite tuff. Some much altered and sheared greenstone occurs nearby, and is evidently an altered tuff, possibly of a more basic nature. In the brook at the main prospect is sericite or talc schist. The rocks show all gradations from a quite sheared or schistose phase, to an almost massive, apparently unaltered, phase.

The volcanic rocks have undergone considerable faulting in the surrounding region, and there is some evidence of such displacements in the immediate vicinity of the deposits. Gouge-like material in trench "C" evidently marks a zone of slipping, but it is not known whether the faulting, if it does occur, is older or younger than the period of mineralization.

CHARACTER OF THE ORE

The ore in all its phases is extremely fine in grain, so much so that a high magnification is at times necessary to determine the mineral content microscopically. Gangue and ore minerals are alike in size and intimately admixed. The metallic minerals are sphalerite, galena, chalcopyrite, and pyrite. The gangue minerals consist mostly of quartz and feldspar with small amounts of other minerals common to volcanic rocks, they being unreplaced residuals of the original country rock. With the exception of yellow streaks richer in pyrite and chalcopyrite, the high-grade ore is quite uniform in mineralogical composition. The yellow streaks cut the otherwise dark grey ore, and are parallel to the strike of the ore-body and the schistosity of the volcanics. Locally the lower grades of ore vary considerably in mineralogical composition. In hand specimen the high-grade ore, except for the wavy streaks of pyrite and chalcopyrite, is black or dark grey, with a slight bluish tint and a faint metallic lustre. The galena, chalcopyrite, and pyrite are usually visible with a hand lens. The lower grades of ore form complete gradations from high-grade ore to country rock with slight mineralization. As a rule the boundaries between ore and country rock are abrupt, especially in the case of high-grade material, but adjacent to the ore-body some mineralization usually occurs, pyrite being most common. Samples of ore collected by D. D. Cairnes in 1916 were assayed in the laboratory of the Mines Branch, Ottawa. The results are reproduced below.

Assay of Stirling Ore

Sample No.	Trench	Per cent copper	Per cent lead	Per cent zinc	Ounce per ton	
					Gold	Silver
20	C	2·09	4·21	29·44	0·08	1·96
21	C	1·36	1·76	11·71	0·06	tr.
22	F	0·52	1·40	3·71	0·06	tr.
23	F	0·23	0·11	3·88	0·04	0·25
24	F	0·67	2·34	7·90	0·04	tr.
25	A	0·25	1·04	3·71	0·04	tr.
26	A	3·43	7·52	27·05	0·06	7·38
27	A	2·20	4·78	17·66	0·08	1·26
28	A	0·32	2·18	5·71	0·04	0·20
29	A	0·82	0·26	6·84	0·03	tr.

DESCRIPTION OF THE ORE-BODY

The present exposures of ore or mineralized matter occur in a limited tract (*See* Figure 16) on either side of Copper brook. The showings, natural and artificial, occur in a zone striking northwest, 460 feet long and of varying width. The country in the immediate vicinity of the ore exposures is low, sloping gently upward from Copper brook—which crosses the zone at about its centre—and is bounded by hills and knolls of glacial detritus. Natural outcrops are confined, with few exceptions, to the banks of Copper brook. The first discovery of ore was made on Copper brook at locality "B," but is now concealed. One hundred feet to the east a pit 18 feet deep—now partly filled—was sunk, and two trenches, one on either side of the pit, were run to crosscut the ore zone. The southern trench is filled at present with debris from the pit. The northern trench (trench "C") shows greenstone at its north end. One hundred and twenty feet south is Young's pit, representing the first development of the property, and now almost filled in, but showing low-grade material on the wall. Trench "F," just to the east, shows 40 feet of low-grade ore to where the trench is now filled in. Some 80 feet northeast of the first-mentioned pit, a trench ("G") was dug across the supposed extension of the ore zone. This is filled at present, but ore is said to have been found in the southern part. One hundred and ten feet farther northeast, a trench ("H") 90 feet long shows ore for a space of 11 feet at its southern end. Thirty feet west of locality "B" on Copper brook, a trench 50 feet long was dug during the 1925 season. One hundred and twenty feet southeast is found one of the earlier workings, trench "A," which during the season was cleaned out to bedrock over a distance of 90 feet. Bands of ore and schist are well exposed here. West of this trench, the surface of the ground rises quite steeply over a knoll of glacial material, and trenches dug here did not reach bedrock.

Other than the exposures along the brook and in the trenches, there are no outcrops of ore, but five drill-holes give further information. These holes, spaced at intervals along the zone from trenches "A" to "H," and driven so as to cross the mineralized zone in depth, indicate the presence of ore in varying grades to a depth of 210 feet. Though the information derivable from trenches and drill-holes is not positive, it seems reasonable to conclude that the mineralized area is continuous over a length of at least 500 feet, and is in no case narrower than 6 feet, a maximum width of 90 feet having been measured.

DESCRIPTION OF THE TRENCHES

In this description the terms high grade, intermediate grade, and low grade are applied respectively to ore with assay contents of zinc of 20 per cent and over, from 10 per cent to 19 per cent, and for less than 10 per cent.

Mineralization is represented in trench "A" by five bands of ore, one high grade on the north, separated from the remainder by 1·1 feet of fine-grained, slightly schistose greenstone, two intermediate, and two low-grained belts. The wider of the two intermediate-grade belts contains 2 feet of estimated high-grade ore, but when assayed as a whole, the body is intermediate in grade. The succession and widths of ore and country rock are shown in Figure 16.

In trench " D " are four bands of high-grade ore, separated by thin bands of greenstone, and one band each of intermediate and low-grade ore. These values are estimated, but the values were checked by a study of the ores in polished section. The writer is indebted to Mr. A. A. Paré for estimations, widths, and specimens of these bands, as this trench was only dug out once during the summer, and at a time when the writer was unable to be present. The succession in this trench, as given by Mr. Paré, is shown in Figure 16.

In trench " C " no exposures are observable, as debris from the pit has been thrown into the trench. The pit is 10 or 12 feet deep at present, and on two opposite walls exposes high-grade ore belonging to the same body. The total length of the rock face in the pit is 8 feet. At the north end, over a width of 1·6 feet, is exposed a white, much altered, but still compact schist. The schist in the direction of the ore zone quickly grades into a white soapy material, very soft and friable, and containing no carbonates. It is like putty when wet, and previous workers have suggested that it is gouge. The transformation from this material to high-grade ore is abrupt. High-grade ore persists for 5·6 feet to where a band of schist extends up and down the face. The remainder of the face (0·8 feet) is partly high-grade, partly intermediate-grade ore, both containing many bands and leaves of schist.

Trench " H " was not dug out until two days before the writer left the field. No details were determined, as water was kept out only with difficulty. The width of ore, however, was measured as 11·0 feet, with a few stringers of schist. The ore is estimated to be of high or medium grade.

Young's pit represents the oldest workings on the Stirling property. It is at present filled with refuse, and the rock pile has been culled of most of the mineral specimens. Where rock shows it is weathered, being quite full of limonite. Some unweathered specimens were found on the rock pile, which showed mineralization, pyrite being predominant. The ore is apparently a low-grade replacement of volcanic rocks by pyrite, together with a little sphalerite and chalcopyrite.

Trench " F " was not cleaned out during the summer, and in it the rock is poorly exposed. This trench very nearly follows the strike, so no data as to widths of ore, etc., could be obtained. The ore appears to be a replacement of a volcanic by pyrite and some sphalerite. The pyrite occurs in minute cubes. The whole is cut by stringers of quartz, and is very similar in all respects to the material found in Young's pit very close by.

A small zone of mineralization is located on Copper brook, nearly a mile below the main workings. No work has been done on the property, which was staked and is still owned by John G. Macleod of Stirling. The mineralized zone crops on the brook for a few yards and consists of a pyrite replacement of a rhyolite. No other metallic minerals were observed, either in the field or in thin or polished section. The deposit, in all probability, is genetically related to the ores of the main prospect.

A small trench was dug on Framboise river by Mr. John Madore of Stirling, at a point a few hundred yards below the road around Five Island lake. The rock in outcrop is a white, slightly mineralized, tuffaceous schist. This locality is approximately on the strike of the main ore-body. The material is a replacement of the schist by pyrite. No other metallic minerals were observed.

Inhabitants of the locality state that specimens of zinc ore have been found on Middle river. The writer is unable to either verify or disprove these statements, as no signs of such were observed during two traverses down the river. Pyrite mineralization was occasionally found, but in no great abundance.

MINERALOGY OF THE DEPOSITS

A suite of polished sections from the main ore deposits was prepared and studied under the reflecting microscope. Certain relations were observed that were constant for all specimens.

The metallic minerals, in order of abundance, are sphalerite, pyrite, chalcopyrite, and galena. In addition are silicate gangue minerals which vary in amount and composition from place to place.

The pyrite represents the earliest stage of mineralization. It occurs in all specimens and forms distinct crystals surrounded by the other ore minerals. Occasionally a tongue of sphalerite cuts into a pyrite crystal suggesting a replacement of the latter by the later sphalerite. That the pyrite underwent some deformation prior to the deposition of the later ore minerals, is shown by the cracked and brecciated condition of many of the pyrite crystals, and by the presence of sphalerite, galena, and chalcopyrite filling the cracks and interstices of these pyrite fragments. It is principally on this latter evidence that the pyrite is thought to be the oldest mineral present.

In all polished sections, sphalerite, galena, and chalcopyrite appear to be contemporaneous. This observation is based on the mutual intergrowth of these minerals. Galena and sphalerite are commonly found forming intergrowths, as are chalcopyrite and galena. Intergrowths of sphalerite and chalcopyrite are not so common, but in two cases a perfect intergrowth of all three ore minerals was observed.

SUPERFICIAL CHANGES

The deposits are remarkably free from the effects of oxidation. When trench "D" was extended beyond its original length in 1924, the ore newly exposed was practically fresh, a very thin coating of limonite being the only gossan present. In all trenches already dug, fresh, glistening ore is exposed within a few inches of the rock surface.

In all trenches but "C," the water table is within a few inches of bedrock surface. In the pit, water accumulates to within about 6 feet of the surface of the ground, leaving 3 or 4 feet of bedrock above it. Here was observed the only case of weathered ore. The top of the ore-body is here covered with a few inches of honeycombed rock, holding much limonite and with a green copper stain, but still containing some fresh ore minerals, chalcopyrite being recognizable. Below this the ore is weathered along joints and cracks for 2 or 3 feet, to where massive, unaltered ore is found.

Whether or not secondary enrichment has taken place would naturally affect considerably the development of this property. If the present high-grade ores are an enrichment of lower grade material, this latter will inevitably be found in depth, and may possibly be of too low a grade to be profitably worked. Several specimens of high-grade ore from diamond-drill cores were examined microscopically. It is not known from what holes these specimens came nor from what depths, though it is known that none of the drill-holes penetrated high-grade ore at a vertical depth of less than 100 feet. The mineral relations found in the specimens were identical in all respects with those obtaining in specimens found at the surface. In neither group of specimens were any relations observed that would suggest secondary enrichment of the ores.

GENESIS OF THE DEPOSITS

The ores are replacements of volcanic rocks. In the higher grades of ore, the gangue material occurs in isolated blebs in the ore minerals, these relations being reversed in the lower grades. The gangue in both cases consists of remnants of altered volcanics. Phenocrysts of feldspar, much sericitized, are recognizable and the original volcanic texture is determinable in many cases.

The ores probably are related genetically to one of the three intrusives of the area. Since the earliest, the granite gneiss, is believed to be older than the country rock, any relations between the granite gneiss and the ores are evidently out of the question. The other intrusives consist of stocks of quartz diorite and of granite, the former outcropping within a quarter of a mile of the deposit. Both cut the volcanic country rock. Both intrusives are believed to belong to the same period of igneous activity, and it is assumed that the ore deposits are a product of this general intrusive period.

Evidently the ore-bearing solutions came up from below. They replaced the volcanics along the slightly developed planes of schistosity since the ore-body apparently is conformable to the lines of schistosity where the latter are visible.

DEVELOPMENT, TREATMENT, ETC.

At time of writing, no underground development had been undertaken. Several diamond and shot-drill holes have been sunk which show the presence of ore in depth, but sufficient data to map the subsurface contours of the ore-body have not been obtained. One point, however, might be mentioned. In studying the relations of the ore bands in trenches "A" and "D", as shown in Figure 16, the writer was impressed by the fact that the five belts of ore (four of them high grade, the other intermediate grade, all of them separated from their neighbours by thin bands of schist) at the north end of trench "D" were equal in width to the broad band of intermediate ore in trench "A", and that the broad band of low-grade ore occupying the rest of trench "D" is very nearly equal in width to a corresponding band of low-grade ore in trench "A". The strikes of schistosity in both trenches further appear to indicate that these are continuations of each other. If the five belts of high and intermediate-grade ores first mentioned in trench "D" were assayed as a whole, including the thin intervening bands of schist, as was the corresponding belt of intermediate-grade ore in trench "A", it is very probable that the whole would be classed as intermediate-grade ore, in which case evidence for the correlation of these bands is further strengthened. Were such the case, the band of high-grade ore at the north of trench "A" has no equivalent, as yet, in trench "D". There is a bare possibility that if these assumed relations are correct, the continuation of this high-grade band of ore may be found by producing trench " D ". If this band of ore were found to the north of trench "D", it would show the ore to have a continuity along the strike which cannot now be accorded to it.

The greatest problem presented by these ores is that of treatment. Their extremely fine grain, and the intimate admixture of the ore minerals with themselves and with the gangue minerals, present difficulties which must be successfully overcome for profitable development. It is possible, however, that a great deal of the gangue and pyrite could be successfully removed during a process of concentration, leaving a relatively pure mixture of sphalerite, galena, and chalcopyrite, since both the pyrite and masses of gangue minerals occur in relatively larger blebs, compared with the ore minerals, which cut each other intimately.

SUMMARY AND CONCLUSIONS

The Stirling zinc deposits are replacements in parallel bands of an old volcanic complex, consisting in greater part of acid flows and tuffs. Ore is exposed over a lineal extent of 450 feet. The width is somewhat obscure, but is 90 feet in trench "A", including two bands of schist. The ore minerals are sphalerite, chalcopyrite, and galena mixed with varying amounts of pyrite. Traces of gold and silver are shown in the assay returns. The gangue consists of blebs of silicate minerals, representing unreplaced parts of the original volcanic rocks. Though the presence of ore in depth has been shown, the subsurface form of the ore-body is somewhat vague with the data at hand. Further exploration would be necessary to estimate the tonnage available.

INVESTIGATION OF PEAT BOGS IN NOVA SCOTIA

By A. Anrep

CONTENTS

Illustrations

INTRODUCTION

Thirty peat bogs in the province of Nova Scotia were investigated during 1924, in order to determine the area, depth, and qualities of peat contained in each. Of the thirty bogs, twenty-nine with a combined area of 3,453 acres are suitable for the production of peat litter, and one for peat fuel. R. M. Williams acted most satisfactorily as field assistant.

Fifteen of the bogs lie within an 8-mile radius of Canso. Eight are situated on the east side of Isaac Harbour within a radius of 6 miles of Goldboro. Five occur west of Country Harbour, beginning at Country Harbour head and extending northerly. Two are situated half a mile west of Isaac Harbour village.

A reconnaissance was made of the country surrounding Antigonish, but no bogs of commercial importance were encountered.

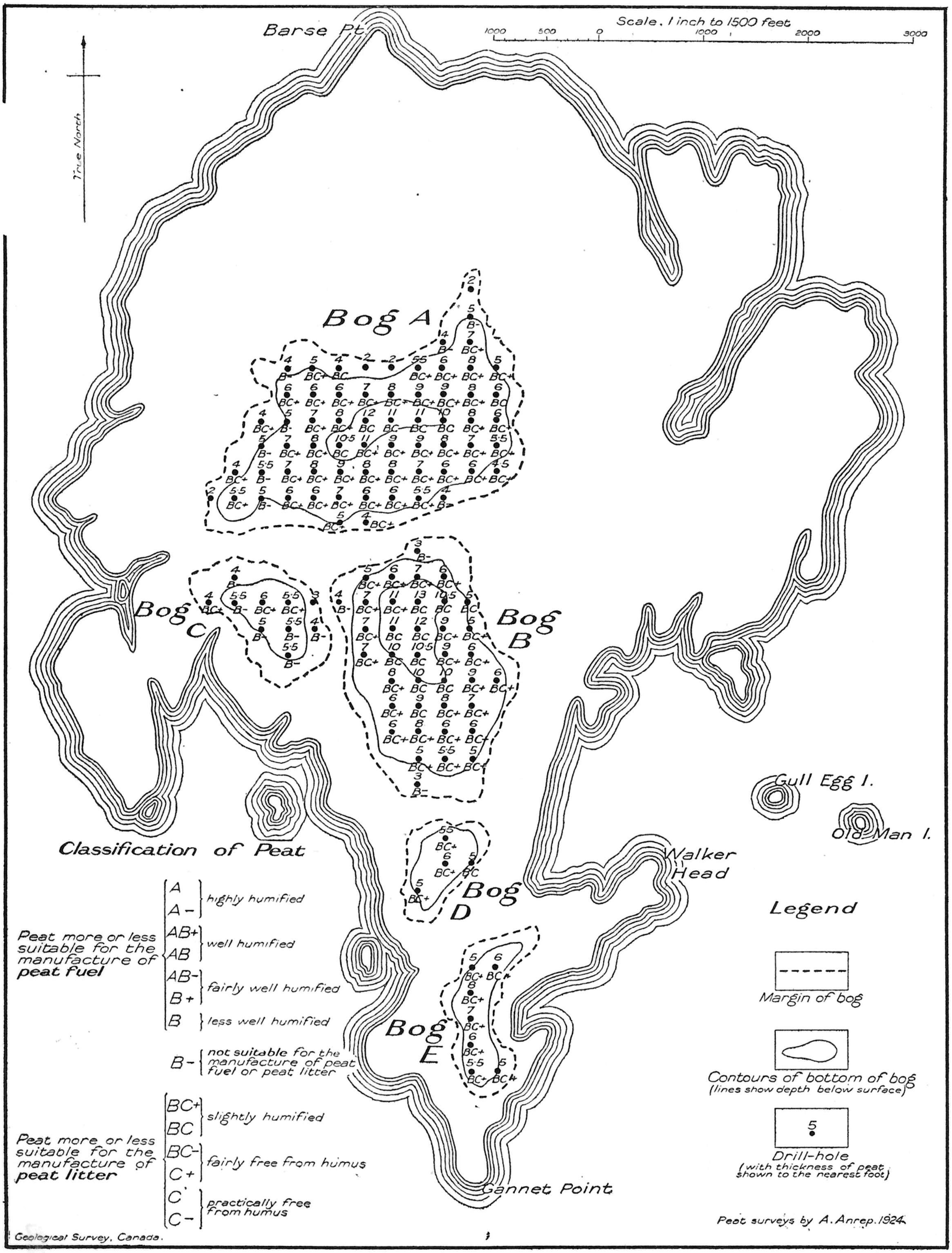


Figure 17. Andrew Island peat litter bogs, Wilmot township, Guysborough county, Nova Scotia.

ANDREW ISLAND PEAT LITTER BOGS, WILMOT TOWNSHIP[1]

(*See* Figure 17)

These bogs are five in number and lie along a north-south line 3 miles of Canso. They are designated, respectively, bogs A, B, C, D, and E. Bog A has a total area of 114 acres. Of this area:

	Cubic yards
36 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	174,000
69 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	779,000
9 acres have a depth of more than 10 feet, with an average depth of 11 feet and contain	159,000

Bog B has a total area of 76 acres. Of this area:

27 acres have a depth of less than 5 feet, with an average depth of 4 feet, and contain	174,000
37 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	418,000
12 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	213,000

Bog C has a total area of 25 acres. Of this area:

16 acres have a depth of less than 5 feet, with an average depth of 4 feet, and contain	103,000
9 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	87,000

Bog D has a total area of 12 acres. Of this area:

7 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	34,000
5 acres have a depth of between 5 and 10 feet, with an average depth of 5 feet, and contain	40,000

Bog E has a total area of 18 acres. Of this area:

9 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	44,000
9 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	87,000

The peat in all five bogs is of the same quality. Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after draining, there is available in:

	Tons
Bog A:	
69 acres with an average depth of 5 feet, containing	33,380
9 acres with an average depth of 9 feet, containing	780
Bog B:	
37 acres with an average depth of 5 feet, containing	17,910
12 acres with an average depth of 9 feet, containing	10,450
Bog C:	
9 acres with an average depth of 4 feet, containing	3,480
Bog D:	
5 acres with an average depth of 3 feet, containing	1,440
Bog E:	
9 acres with an average depth of 4 feet, containing	3,480

The total tonnage is 70,920 tons, or 94,560 tons of peat litter having 25 per cent moisture.

[1] All figures in this report are approximate. A ton is considered as 2,000 lbs. A cubic yard of drained bog is assumed to be equal to 120 pounds of dry peat litter and 200 pounds of dry peat fuel.
In the table of fuel analyses, figures in column R refer to fuel as received, and in column D to fuel dried at 105°C. The analyses were made on the fuel as received and the other results were calculated therefrom.

Partial Analysis of Samples

—	Samples from depths of		
	0–3 feet	3–6 feet	6–9 feet
	%	%	%
Absorption factors for moisture-free peat	11·9	11·7	12·0
Absorption factor for peat with 25% moisture	8·7	8·5	8·8
Ash (dried at 105°C.)	3·9	11·7	2·9

The peat in these bogs is fairly free from humus and is suitable for the manufacture of peat litter. Towards the margin it occasionally becomes more humified, but is still suitable for litter. Samples show that the peat is composed mainly of sphagnum mosses slightly mixed with eriophorum and in spots towards the margin carex plants are found. These bogs have fairly good depth and the surface is free from knolls and trees. The bogs could be drained easily as the land slopes towards the sea. The bottom is a thin layer of sand resting on granite.

GLASGOW HEAD PEAT LITTER BOG, WILMOT TOWNSHIP

(*See* Figure 18)

The bog is about 2 miles east of Canso. It has an area of about 64 acres. Of this area:

	Cubic yards
15 acres have a depth of less than 5 feet, with an average depth of 4 feet, and contain	97,000
33 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	373,000
12 acres have a depth of between 10 and 15 feet, with an average depth of 11 feet, and contain	213,000
4 acres have a depth of more than 15 feet, with an average depth of 16 feet, and contain	103,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after draining, there is available:

	Tons
33 acres with an average depth of 5 feet, containing	15,970
12 acres with an average depth of 9 feet, containing	10,450
4 acres with an average depth of 14 feet, containing	5,320

The total tonnage is 31,740 tons, or 42,320 tons of peat litter having 25 per cent moisture.

Partial Analysis of Samples

—	Samples from depths of			
	0–3 feet	3–6 feet	6–9 feet	9–12 feet
	%	%	%	%
Absorption factors for moisture-free peat	12·4	12·4	9·6	13·2
Absorption factor for peat with 25 per cent moisture	9·0	9·0	6·9	9·7
Ash (dried at 105°C.)	2·6	2·4	3·2	3·1

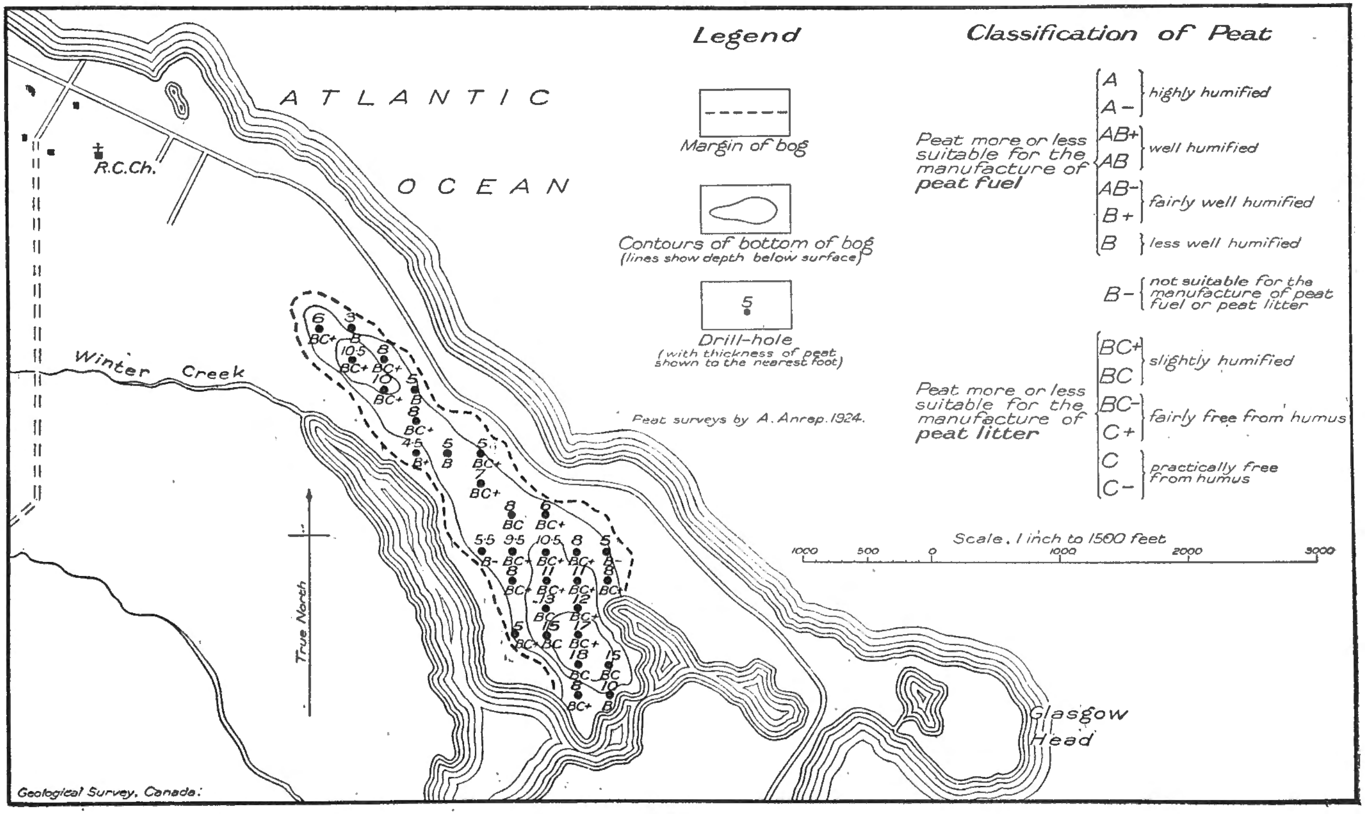


Figure 18. Glasgow head peat litter bog, Wilmot township, Guysborough county, Nova Scotia.

The peat is not humified and will produce good peat litter. The upper layers are comparatively free from humus, hence a first-class litter may be obtained therefrom. The peat is formed of various sphagnum mosses, principally *Sphagnum fuscum*. While drilling, it was found that the bottom layers were composed of carex and eriophorum plants and also that the peat was free from roots and stumps. A thin layer of sand forms the bottom of the bog.

The bog is situated on a peninsula and can be drained easily. The bog having a considerable depth and being situated close to Canso, is suitable for the manufacture of peat litter on a commercial scale.

CANSO PEAT LITTER BOG, WILMOT TOWNSHIP

(*See* Figure 19)

The bog lies about one-half mile south of Canso. It has an area of about 288 acres. Of this area:

	Cubic yards
163 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	789,000
85 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	823,000
40 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	710,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially and allowing 2 feet shrinkage in depth after draining, there is available:

	Tons
85 acres with an average depth of 4 feet, containing	32,910
40 acres with an average depth of 9 feet, containing	34,850

The total tonnage is 67,760 tons, or 90,340 tons of peat litter having 25 per cent moisture.

Partial Analysis of Samples

—	Sample from depths of		
	0–3 feet	3–6 feet	6–9 feet
	%	%	%
Absorption factors for moisture-free peat	15·0	13·7	8·9
Absorption factor for peat with 25 per cent moisture	11·0	10·1	6·4
Ash (dried at 105°C.)	2·5	3·5	8·5

The peat in this bog is fairly free from humus, has a fairly good depth, and the surface is free from knolls and trees. The bog could be drained easily in a southeast direction and being in close proximity to the town of Canso is suitable for the manufacture of peat litter on a commercial basis. The surface layers to a depth varying from 1 to 3 feet are composed mainly of sphagnum mosses slightly intermixed with eriophorum. The bottom of this bog is formed of sand intermixed here and there with granite boulders.

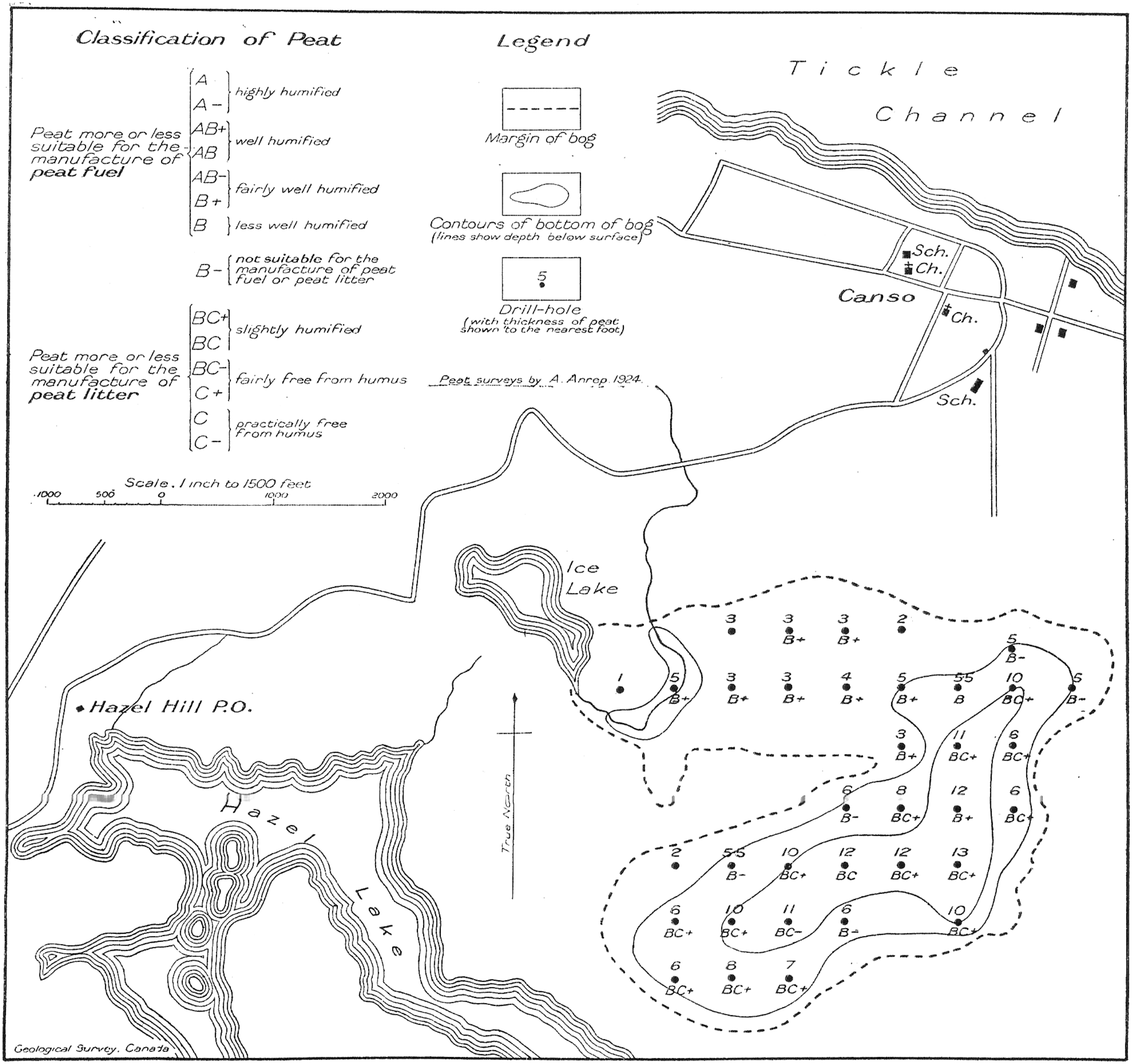


Figure 19. Canso peat litter bog, Wilmot township, Guysborough county, Nova Scotia.

YELLOW MARSH PEAT LITTER BOG, WILMOT TOWNSHIP

(*See* Figure 20)

The bog is about 3 miles west of Canso. It has an area of about 30 acres. Of this area:

	Cubic yards
12 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	58,000
12 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	116,000
5 acres have a depth of between 10 and 15 feet, with an average depth of 13 feet, and contain	105,000
1 acre has a depth of more than 15 feet, with an average depth of 15 feet, and contains	24,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after draining, there is available:

	Tons
12 acres with an average depth of 4 feet, containing	4,650
5 acres with an average depth of 11 feet, containing	5,320
1 acre with an average depth of 13 feet, containing	1,260

The total tonnage is 11,230 tons, or 14,970 tons of peat litter having 25 per cent moisture.

Partial Analysis of Samples

—	Sample from depths of	
	0–6 feet	6–12 feet
	%	%
Absorption factors for moisture-free peat	13·9	13·8
Absorption factors for peat with 25 per cent moisture	10·2	10·1
Ash (dried at 105°C.)	3·2	3·9

The bog has a considerable depth. The surface is quite level, and is free from trees. The peat is fairly free from humus and is composed mainly of sphagnum mosses. It is suitable for the manufacture of peat litter, but only on a small scale. The bog is traversed through the middle by the Canso road.

Drainage can be effected either in a north or south direction.

GASPEREAU PEAT LITTER BOG, WILMOT TOWNSHIP

(*See* Figure 21)

The bog is 2½ miles southwest of Canso and about ½ mile south of Hazel lake. It has an area of about 78 acres. Of this area:

	Cubic yar
20 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	97,000
37 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	418,000
14 acres have a depth of between 10 and 15 feet, with an average depth of 11 feet, and contain	248,000
7 acres have a depth of more than 15 feet, with an average depth of 17 feet, and contain	192,000

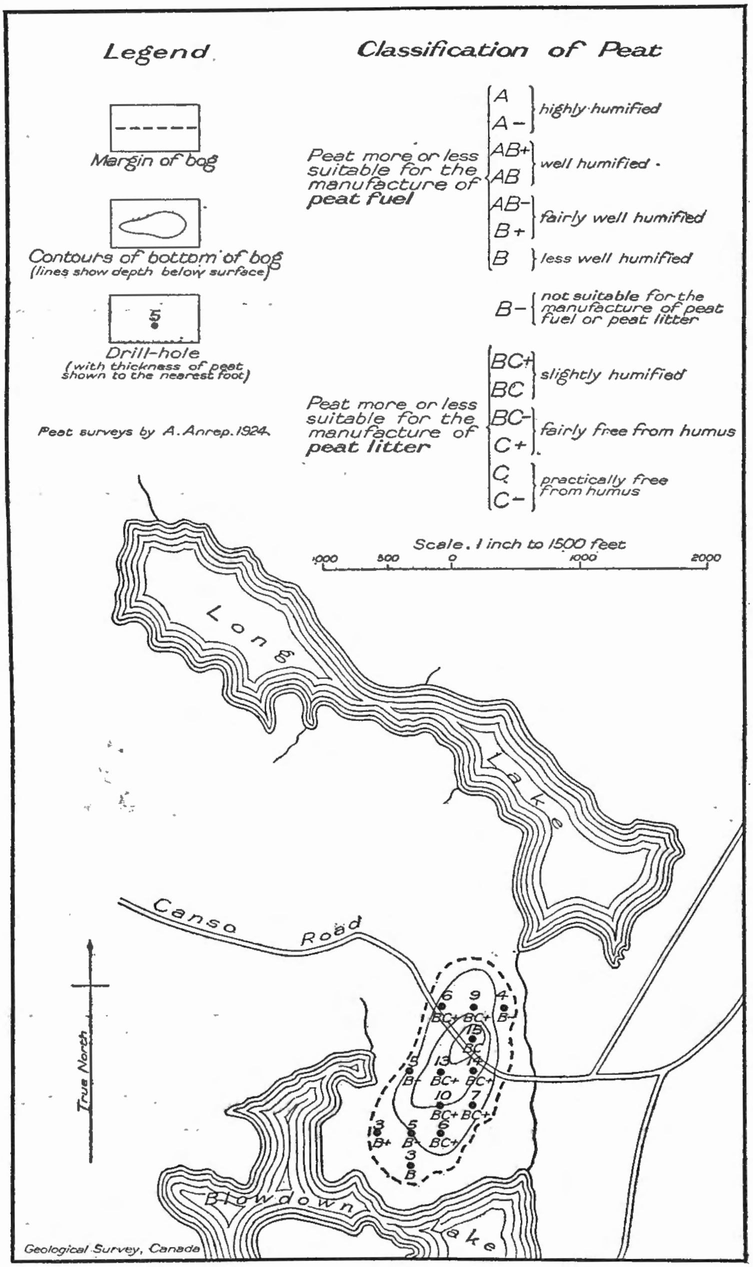


Figure 20. Yellow Marsh peat litter bog, Wilmot township, Guysborough county, Nova Scotia.

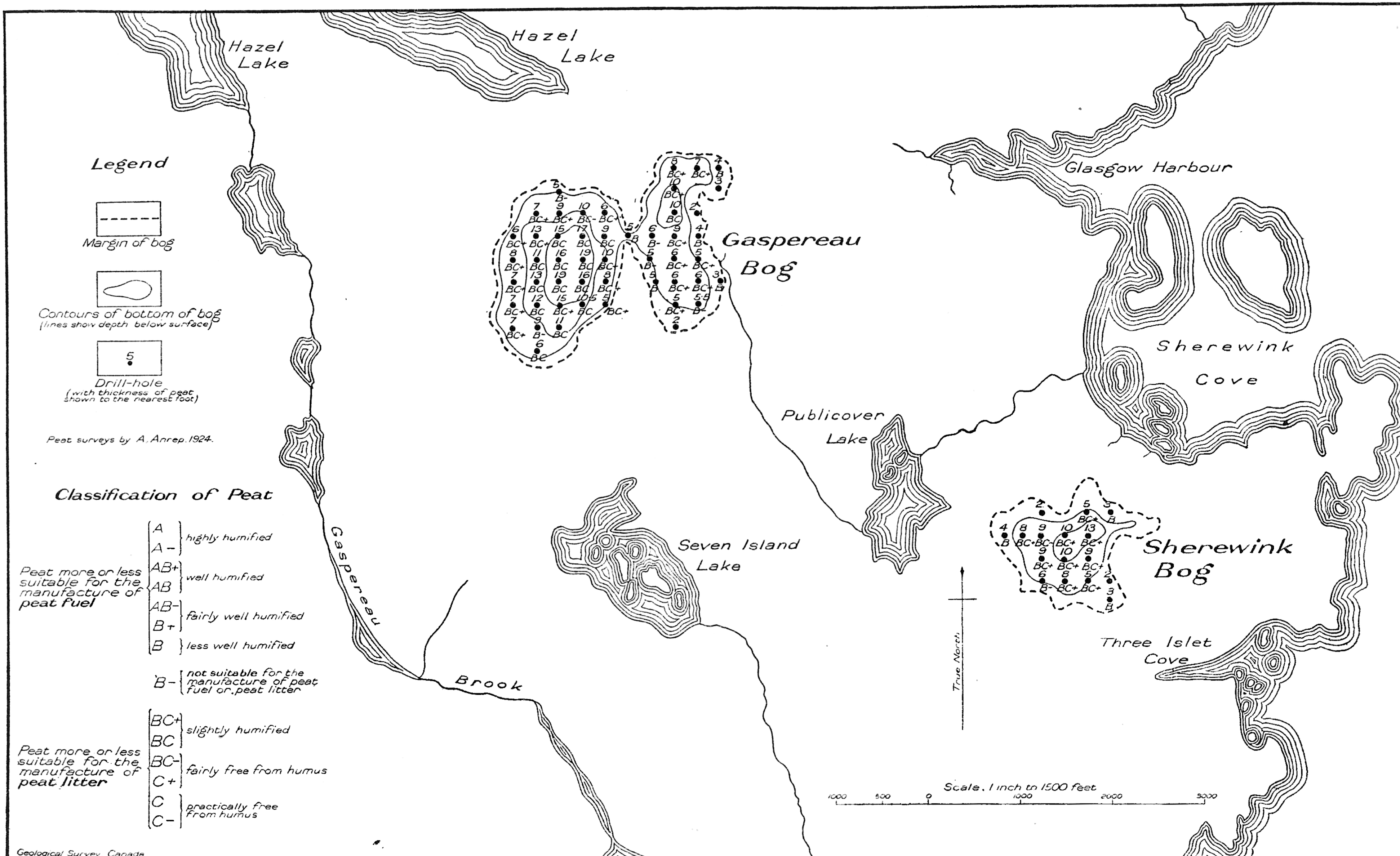


Figure 21. Gaspereau and Sherewink peat litter bogs, Wilmot township, Guysborough county, Nova Scotia.

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after draining, there is available:

	Tons
37 acres with an average depth of 5 feet, containing	17,910
14 acres with an average depth of 9 feet, containing	12,200
7 acres with an average depth of 15 feet, containing	10,160

The total tonnage is 40,270 tons, or 53,690 tons of peat litter containing 25 per cent moisture.

Partial Analysis of Samples

—	Sample from depths of		
	0–3 feet	3–6 feet	6–9 feet
	%	%	%
Absorption factor for moisture-free peat	15·7	15·7	7·8
Absorption factor for peat with 25 per cent moisture	11·5	11·5	5·6
Ash (dried at 105° C.)	2·3	2·2	2·0

The peat is fairly free from humus, has a considerable depth, and the surface is comparatively free from knolls and trees. The peat is composed mainly of sphagnum mosses slightly mixed with eriophorum and towards the margin near Gaspereau brook varieties of carex plants can be found. On the whole it is suitable for the manufacture of peat litter. This bog is divided from the Canso bog by a narrow, steep ridge. The bog can be drained southerly towards Seven Island lake. The bottom of the bog is of granite.

SHEREWINK PEAT LITTER BOG, WILMOT TOWNSHIP

(*See* Figure 21)

The bog is about 3 miles southeast of Canso. It lies north of Three Islet cove. It has an area of about 32 acres. Of this area:

	Cubic yards
15 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	73,000
14 acres have a depth of between 5 and 10 feet, with an average depth of 8 feet, and contain	181,000
3 acres have a depth of more than 10 feet, with an average depth of 12 feet, and contain	58,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
14 acres with an average depth of 6 feet, containing	8,130
3 acres with an average depth of 10 feet, containing	2,900

The total tonnage is 11,030 tons, or 14,700 tons of peat litter containing 25 per cent moisture.

Partial Analysis of Samples

—	Sample from depths of	
	0–3 feet	3–6 feet
	%	%
Absorption factor for moisture-free peat	13·6	13·8
Absorption factor for peat with 25 per cent moisture	9·9	10·1
Ash (dried at 105°C.)	2·3	2·5

The peat is composed mainly of sphagnum mosses, is fairly free from humus, has a good depth, and the surface is comparatively free from knolls and trees, thus making it suitable for the manufacture of peat litter. The drainage of this bog can be carried southeast to Three Islet cove. The area is very small, and can be worked on only a small scale, mainly for local consumption.

DOBSON PEAT LITTER BOG, WILMOT TOWNSHIP

(*See* Figure 22)

The bog is about 12 miles west of Canso and is immediately south of Dobson lake. It has an area of about 36 acres. Of this area:

	Cubic yards
9 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	44,000
22 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	248,000
5 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	81,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
22 acres with an average depth of 5 feet, containing	10,650
5 acres with an average depth of 8 feet, containing	3,870

The total tonnage is 14,520 tons, or 19,360 tons of peat litter containing 25 per cent moisture.

Partial Analysis of Samples[1]

—	Samples from depth of
	0–10 feet
	%
Absorption factor for moisture-free peat	7·8
Absorption factor for peat with 25 per cent moisture	5·6
Ash (dried at 105°C.)	6·7

[1] Owing to smallness of samples, the absorption factors are possibly too high in value.

The peat is composed mainly of sphagnum mosses slightly intermixed with eriophorum. It is fairly free from humus, has a good depth, and the surface is comparatively free from knolls and trees, thus making it suitable

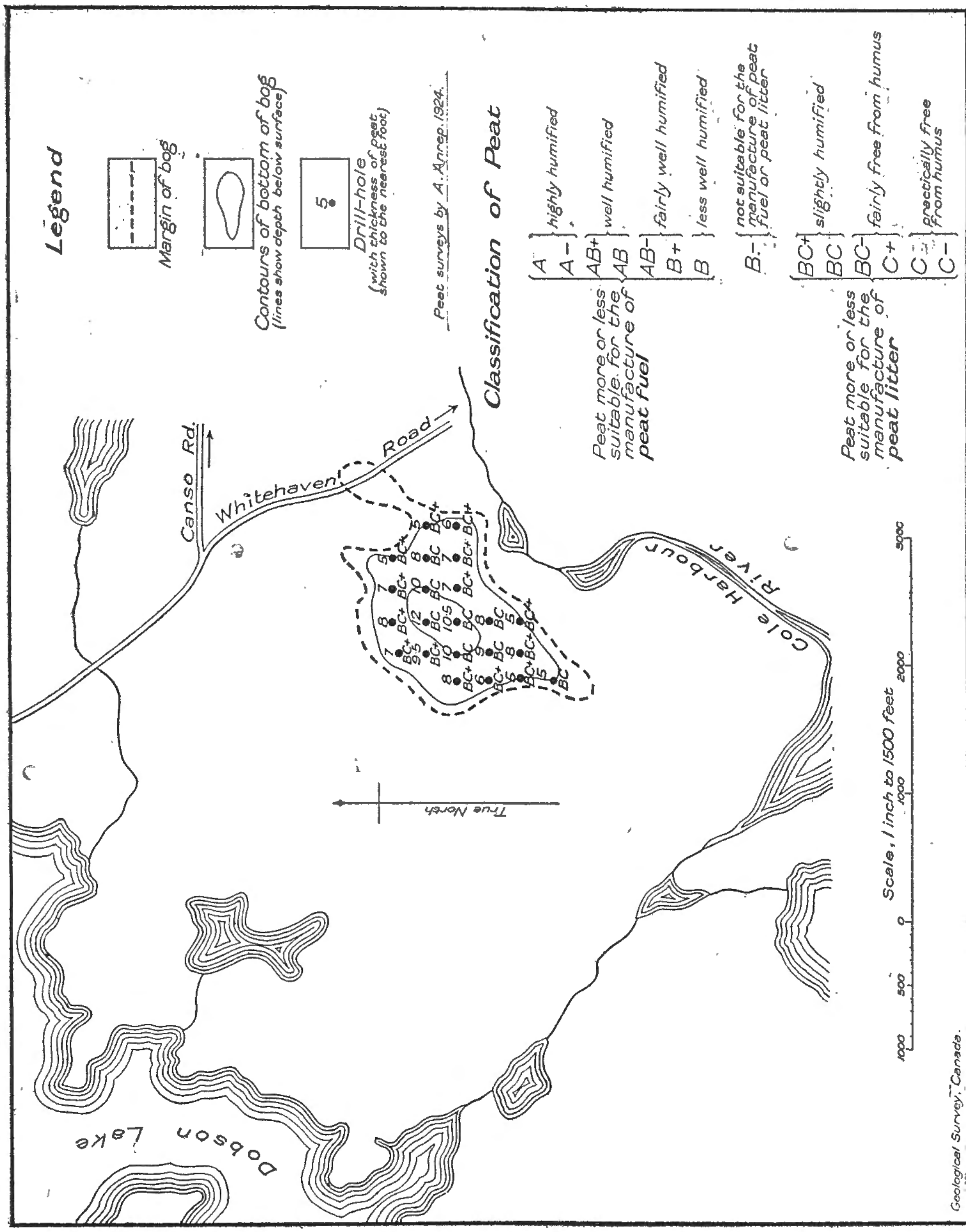


Figure 22. Dobson peat litter bog, Wilmot township, Guysborough county, Nova Scotia.

for the manufacture of peat litter. The area is too small for the manufacture of peat litter by an expensive mechanical plant, but the peat can be utilized for local consumption. This bog can be drained in a southerly direction.

FOX ISLAND AND LILY POND PEAT LITTER BOGS, WILMOT TOWNSHIP

(*See* Figure 23)

These bogs are three in number and lie 7 miles west of Canso and are south of Fox Island bay. They extend in an east-west direction and are designated, respectively: Bog A, Fox island; Bog B, Fox island; and Bog C, Lily pond.

Bog A, Fox island, has a total area of 21 acres. Of this area:

	Cubic yards
11 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	53,000
10 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	97,000

Bog B, Fox island, has a total area of 22 acres. Of this area:

11 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	53,000
9 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	87,000
2 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	32,000

Bog C, Lily pond, has a total area of 41 acres. Of this area:

18 acres have a depth of less than 5 feet, with an average depth of 4 feet, and contain	116,000
19 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	183,000
4 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	71,000

The peat in all three bogs is the same quality. Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after draining, there is available in:

	Tons
Bog A, Fox island:	
10 acres with an average depth of 4 feet, containing	3,870
Box B, Fox island:	
9 acres with an average depth of 4 feet, containing	3,480
2 acres with an average depth of 8 feet, containing	1,550
Bog C, Lily pond:	
19 acres with an average depth of 4 feet, containing	7,360
4 acres with an average depth of 9 feet, containing	3,480

The total tonnage is 19,740 tons, or 26,320 tons of peat litter having 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of			
	0–3 feet Bog C	0–6 feet Bog C	0–10 feet Bog A	Bog B
	%	%	%	%
Absorption factors for moisture-free peat	15·5	16·6	12·7	12·7
Absorption factors for peat with 25 per cent moisture	11·4	12·1	9·3	9·3
Ash (dried at 105°C.)	3·0	2·8	2·3	2·4

The peat in Bogs A and B, Fox island, is composed mainly of sphagnum mosses slightly intermixed with eriophorum and carex plants. It is fairly

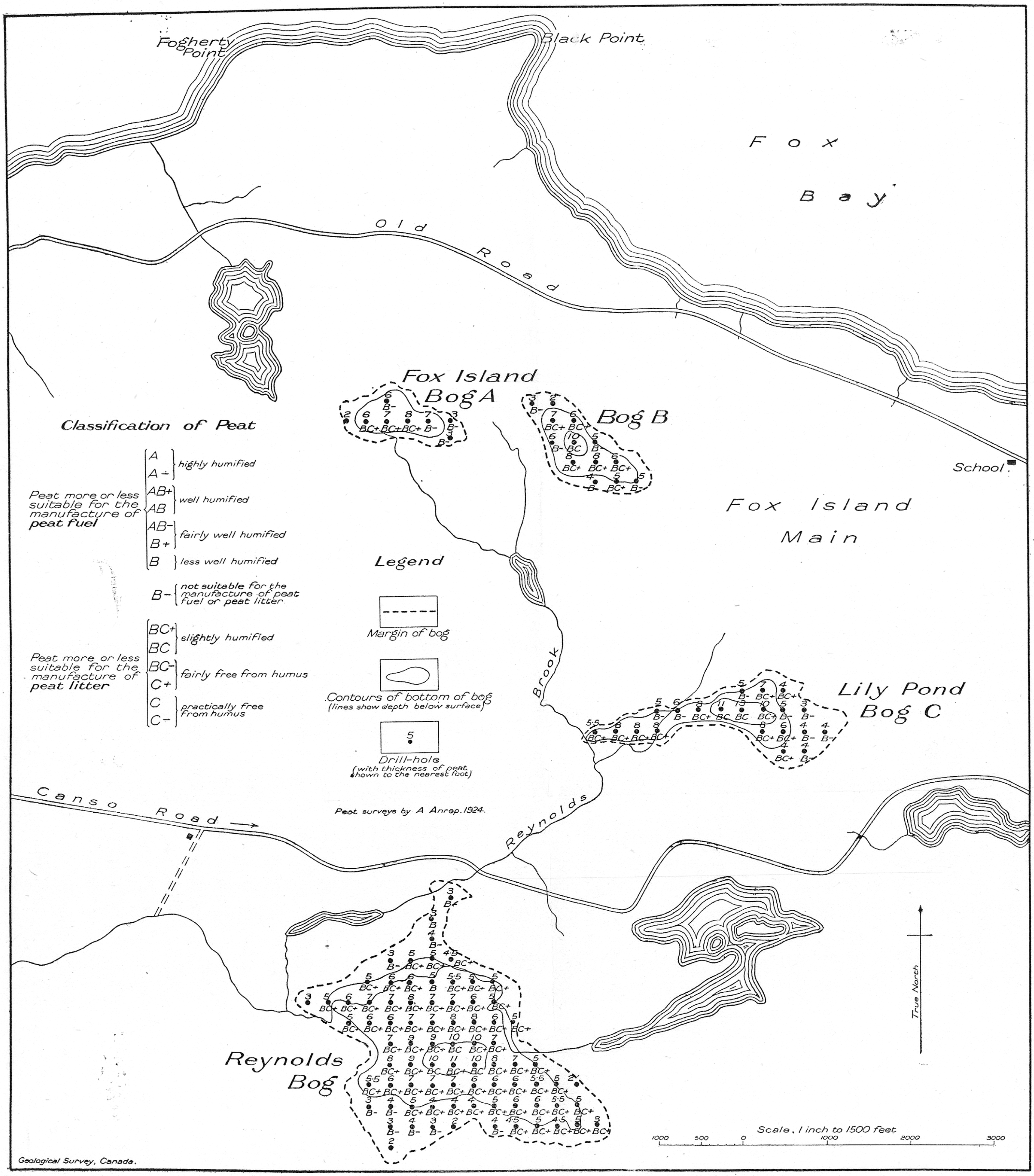


Figure 23. Fox Island, Lily Pond, and Reynolds peat litter bogs, Wilmot township, Guysborough county, Nova Scotia.

free from humus, has a good depth, and the surface is comparatively free from knolls and trees, thus making it suitable for the manufacture of peat litter. The peat in Bog C, Lily pond, is composed mainly of sphagnum mosses slightly intermixed with eriophorum and carex plants. It is fairly free from humus, has a good depth, and the surface is comparatively free from knolls and trees, which makes it suitable for the manufacture of peat litter. The bogs are too small to be used for the manufacture of peat litter by an expensive mechanical plant, but can be utilized for local consumption.

REYNOLDS PEAT LITTER BOG, WILMOT TOWNSHIP

(*See* Figure 23)

The bog is about 7 miles west of Canso and is immediately south of the post road. It has an area of about 134 acres. Of this area:

	Cubic yards
62 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	300,000
65 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain..........	629,000
7 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain..........	113,000

Excluding the average underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
65 acres with an average depth of 4 feet, containing..........	25,170
7 acres with an average depth of 8 feet, containing..........	5,420

The total tonnage is 30,590 tons, or 40,790 tons of peat litter containing 25 per cent moisture.

Partial Analysis of Samples

—	Samples from depths of	
	0–3 feet	3–6 feet
	%	%
Absorption factor for moisture-free peat..........	13·6	15·1
Absorption factor for peat with 25 per cent moisture..........	10·0	11·0
Ash (dried at 105°C.)..........	2·1	2·2

The peat in this bog is fairly free from humus and hence would produce a good peat litter. The peat is composed of various sphagnum mosses slightly intermixed with eriophorum. The bog has a fairly good depth and the surface is comparatively free from knolls and trees. Being decidedly a high moor as the surface of the bog undulates in the form of a cupola towards the centre, it can be drained easily in a westerly direction. Though the area of the bog is not very large, it can be utilized for the erection of a peat litter plant on a commercial basis. The bottom of this bog is of a compact sand.

INDIAN HEAD PEAT LITTER BOGS, STORMONT TOWNSHIP

(*See* Figure 24)

These bogs are five in number and lie about 2 miles west of Goldboro or Isaac Harbour. They extend in an east-west direction. They are designated, respectively, Bogs A, B, C, D, and E.

Bog A has a total area of 297 acres. Of this area:

	Cubic yards
131 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	634,000
152 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	1,717,000
14 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	226,000

Bog B has a total area of 81 acres. Of this area:

26 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	126,000
55 acres have a depth of between 5 and 10 feet, with an average depth of 6 feet, and contain	532,000

Bog C has a total area of 260 acres. Of this area:

100 acres have a depth of less than 5 feet, with an average depth of 2 feet, and contain	323,000
150 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	1,694,000
10 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	177,000

Bog D has a total area of 77 acres. Of this area:

25 acres have a depth of less than 5 feet, with an average depth of 4 feet, and contain	161,000
43 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	486,000
9 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	160,000

Bog E has a total area of 114 acres. Of this area:

39 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	189,000
70 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	191,000
5 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	81,000

The peat in all five bogs is of the same quality. Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially and allowing 2 feet shrinkage in depth after draining, there is available in:

Bog A:

	Tons
152 acres with an average depth of 5 feet, containing	73,570
14 acres with an average depth of 8 feet, containing	10,840

Bog B:

55 acres with an average depth of 4 feet, containing	21,300

Bog C:

150 acres with an average depth of 5 feet, containing	72,600
10 acres with an average depth of 9 feet, containing	870

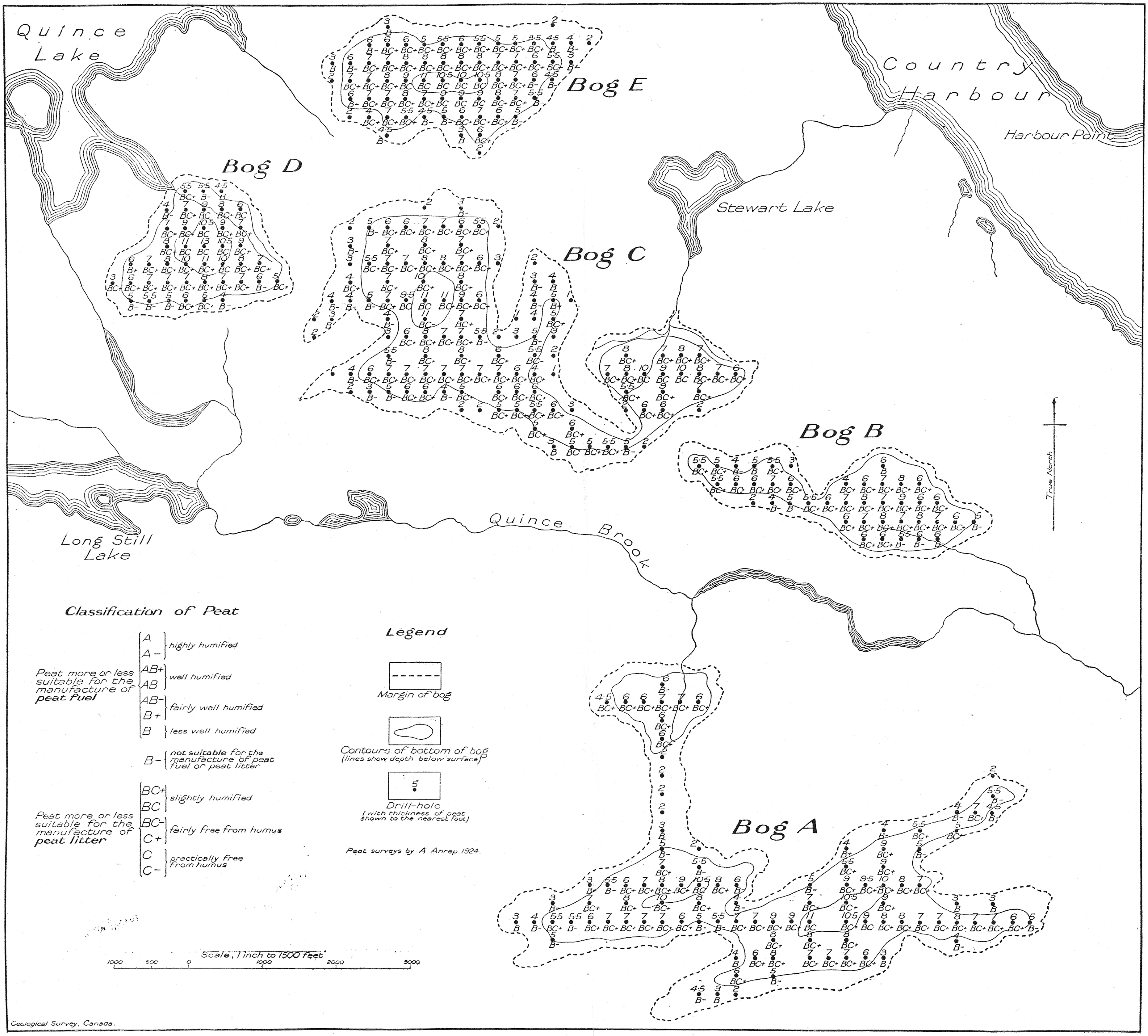


Figure 24. Indian Head peat litter bogs, Stormont township, Guysborough county, Nova Scotia.

Bog D:

	Tons
43 acres with an average depth of 5 feet, containing	20,810
9 acres with an average depth of 9 feet, containing	7,840

Bog E:

70 acres with an average depth of 5 feet, containing	33,880
5 acres with an average depth of 8 feet, containing	3,870

The total tonnage is 245,580 tons, or 327,440 tons of peat litter having 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of						
	0–3 feet	3–6 feet	6–9 feet	0–10 feet			
	Bog A	Bog A	Bog A[1]	B	C	D	E
Absorption factor for moisture-free peat	14·0	10·6	7·4	13·3	13·7	14·2	13·6
Absorption factor for peat with 25 per cent moisture	10·2	7·7	5·3	9·8	10·0	10·4	9·9
Ash (dried at 105°C.)	10·7	3·3	5·8	3·6	10·6	4·8	9·1

The bogs are not humified and the upper layers are comparatively free from humus and hence a good peat litter would be available. The peat is composed mainly of sphagnum mosses with, in certain places, eriophorum and carex plants. The bogs have a fairly good depth and a surface comparatively free from knolls and trees. The bogs lie at elevations of 110 to 210 feet above sea-level. They can be drained into Quince brook, which flows in an easterly direction.

CHIMNEY ROCK PEAT LITTER BOG, STORMONT TOWNSHIP

(*See* Figure 25)

The bog is about 3½ miles northeast of Goldboro. It has an area of about 310 acres. Of this area:

	Cubic yards
55 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	266,000
165 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	1,863,000
85 acres have a depth of between 10 and 15 feet, with an average depth of 12 feet, and contain	1,646,000
5 acres have a depth of more than 15 feet, with an average depth of 16 feet, and contain	129,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
165 acres with an average depth of 5 feet, containing	79,860
85 acres with an average depth of 10 feet, containing	82,280
5 acres with an average depth of 14 feet, containing	6,780

[1] Owing to smallness of samples, the absorption factors are possibly too high in value.

The total tonnage is 168,920 tons or 225,230 tons of peat litter containing 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of		
	0–3 feet	3–6 feet	6–9 feet
	%	%	%
Absorption factor for moisture-free peat	12·8	12·8	6·2
Absorption factor for peat with 25 per cent moisture	9·4	9·4	4·4
Ash (dried at 105° C.)	3·1	4·2	13·3

The peat is fairly free from humus, with the exception of the area having a depth of less than 5 feet where it is more humified. However, taking the whole area into consideration, the peat in this bog will yield fairly good peat litter. The peat is composed mainly of sphagnum mosses slightly intermixed with eriophorum and with carex plants towards the margin. The surface is free from knolls and trees and, therefore, quite level. The drainage could be carried in a southerly direction towards Hay lake. The bottom of this bog is formed of compact sand.

GIFFIN PEAT LITTER BOG, STORMONT TOWNSHIP

(*See* Figure 25)

The bog is about 2 miles northeast of Goldboro. It has an area of about 65 acres. Of this area:

	Cubic yards
28 acres have a depth of less than 5 feet, with an average depth of 4 feet, and contain	181,000
36 acres have a depth of between 5 and 10 feet, with an average depth of 8 feet, and contain	465,000
4 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	65,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
36 acres with an average depth of 6 feet, containing	20,810
4 acres with an average depth of 8 feet, containing	3,240

The total tonnage is 24,050 tons, or 32,070 tons of peat litter containing 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of	
	0–3 feet	3–9 feet
	%	%
Absorption factor for moisture-free peat	12·5	6·7
Absorption factor for peat with 25 per cent moisture	9·1	4·8
Ash (dried at 105° C.)	13·3	10·6

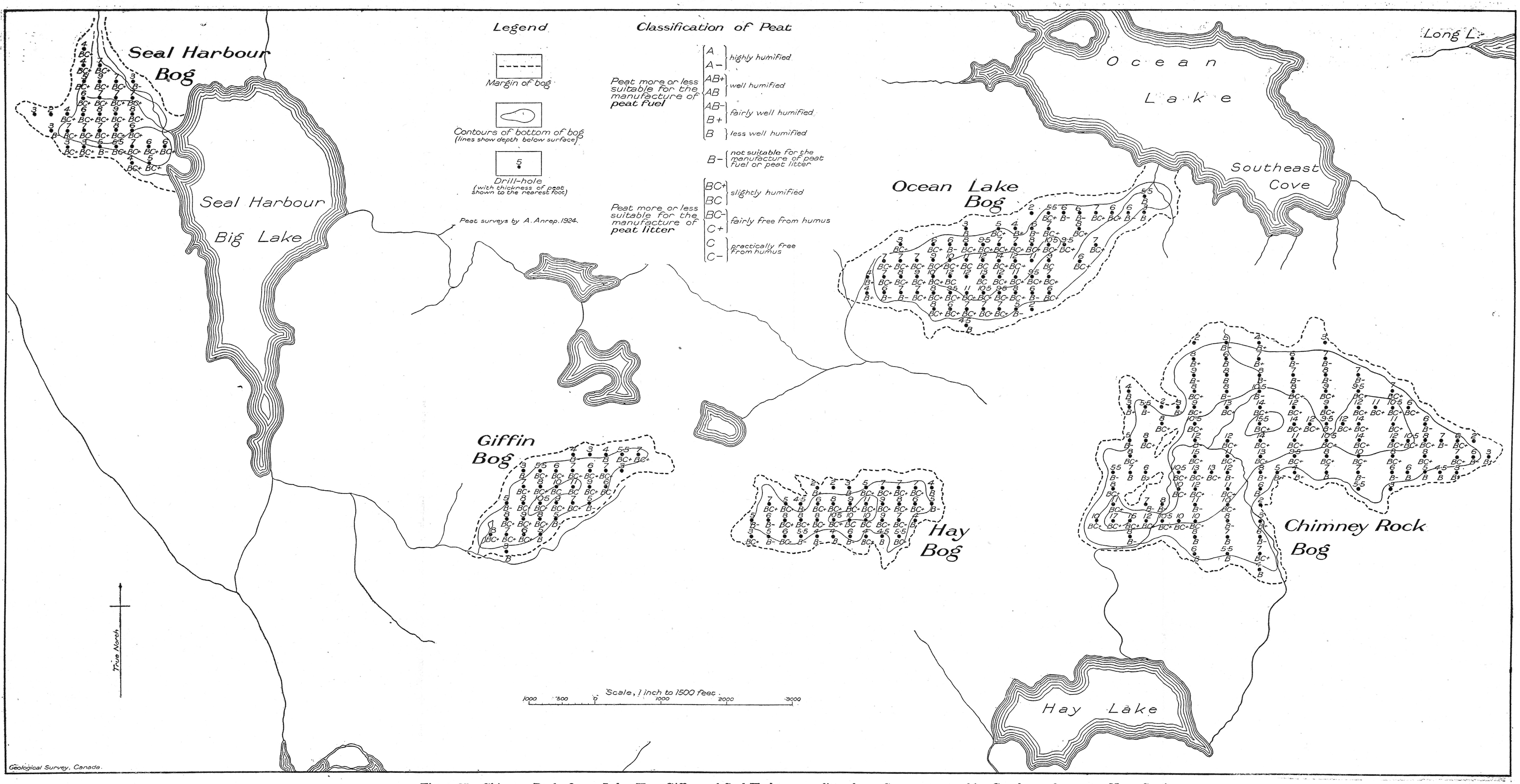


Figure 25. Chimney Rock, Ocean Lake, Hay, Giffin, and Seal Harbour peat litter bogs, Stormont township, Guysborough county, Nova Scotia.

The peat is composed mainly of sphagnum mosses lightly intermixed with eriophorum and occasionally with carex plants. It is fairly free from humus, has a comparatively good depth, and the surface is practically free from knolls and trees, thus making it suitable for the manufacture of peat litter on a small scale. This bog can be drained in a southerly direction.

OCEAN LAKE PEAT LITTER BOG, STORMONT TOWNSHIP

(*See* Figure 25)

The bog is about 4 miles northeast of Goldboro. It has an area of about 155 acres. Of this area:

	Cubic yards
53 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	257,000
84 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	949,000
18 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	290,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
84 acres with an average depth of 5 feet, containing	40,660
18 acres with an average depth of 8 feet, containing	13,940

The total tonnage is 54,600 tons, or 72,800 tons of peat litter containing 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of	
	0–6 feet	6–9 feet
	%	%
Absorption factor for moisture-free peat	11·3	10·8
Absorption factor for peat with 25 per cent moisture	8·2	7·8
Ash (dried at 105° C.)	4·5	3·7

The peat is fairly free from humus, with the exception of that part having a depth of less than 5 feet, which is more humified. However, taking the whole area into consideration, the peat in this bog will yield fairly good peat litter. The peat is composed mainly of sphagnum mosses slightly intermixed with eriophorum and with carex plants towards the margin. The bog has a considerable depth and the surface is free from knolls and trees and, therefore, quite level. Drainage could be carried in a northerly direction towards Ocean lake.

HAY PEAT LITTER BOG, STORMONT TOWNSHIP

(*See* Figure 25)

The bog is about 2½ miles northeast of Goldboro. It has an area of about 75 acres. Of this area:

	Cubic yards
35 acres have a depth of less than 5 feet, with an average depth of 4 feet, and contain	226,000
35 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	395,000
5 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	81,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
35 acres with an average depth of 5 feet, containing	16,940
5 acres with an average depth of 8 feet, containing	3,870

The total tonnage is 20,810 tons, or 27,750 tons of peat litter containing 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of	
	0–6 feet	6–9 feet
	%	%
Absorption factor for moisture-free peat	12·9	6·2
Absorption factor for peat with 25 per cent moisture	9·4	4·4
Ash (dried at 105° C.)	3·6	10·5

The peat is composed mainly of sphagnum mosses lightly intermixed with eriophorum. It is fairly free from humus, has a good depth, and the surface is comparatively free from knolls and trees, thus making it suitable for the manufacture of peat litter. The available tonnage is too small for the manufacture of peat litter by an expensive mechanical plant, but could be utilized for local consumption. This bog can be drained in a southeasterly direction.

MULGRAVE PEAT LITTER BOG, STORMONT TOWNSHIP

(*See* Figure 26)

The bog is about 1½ miles east of Goldboro. It has an area of about 324 acres. Of this area:

	Cubic yards
71 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	344,000
185 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	2,089,000
68 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	1,207,000

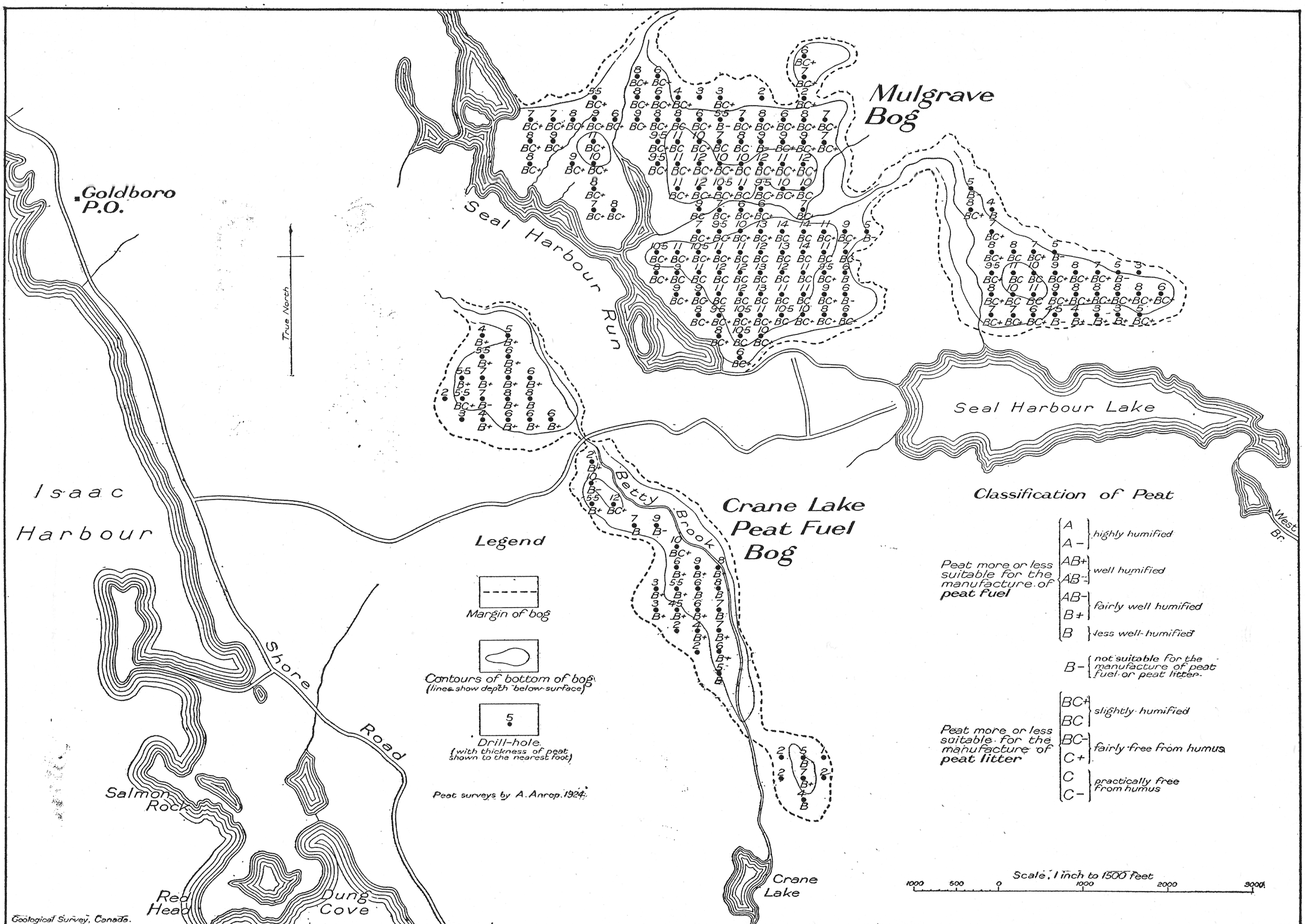


Figure 26. Mulgrave peat litter, and Crane Lake peat fuel, bogs, Stormont township, Guysborough county, Nova Scotia.

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
185 acres with an average depth of 5 feet, containing	89,540
68 acres with an average depth of 9 feet, containing	59,240

The total tonnage is 148,780 tons, or 194,340 tons of peat litter containing 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of		
	0–3 feet	3–6 feet	6–9 feet
	%	%	%
Absorption factor for moisture-free peat	15·0	11·0	6·3
Absorption factor for peat with 25 per cent moisture	11·0	8·0	4·4
Ash (dried at 105° C.)	5·7	8·5	6·5

The peat is fairly free from humus and is composed mainly of sphagnum mosses slightly intermixed with eriophorum and towards the margin of Seal Harbour river with several varieties of carex plants, thus making it suitable for the manufacture of peat litter. This bog has a considerable depth and the surface is free from knolls and trees. But the bog is cut up considerably by a number of streams which flow into Seal Harbour river, and the eastern part of the bog is separated from the western by a ridge of high land.

CRANE LAKE PEAT FUEL BOG, STORMONT TOWNSHIP

(*See* Figure 26)

The bog is about 1½ miles southeast of Goldboro. It has an area of about 139 acres. Of this area:

	Cubic yards
61 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	295,000
78 acres have a depth of more than 5 feet, with an average depth of 7 feet, and contain	881,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

78 acres with an average depth of 4 feet, containing 30,200 tons of peat fuel.

Analyses of Samples

—	Sample			
	No. 1		No. 2	
	As received	Dried at 105° C.	As received	Dried at 105° C.
Moisture.......%	8·6	....	6·7	
Ash.......%	9·3	10·1	6·9	7·4
Volatile matter.......%	54·7	59·9	58·8	63·0
Fixed carbon (by difference).......%	27·4	30·0	27·6	29·6
Sulphur.......%	0·6	0·7	0·6	0·7
Nitrogen.......%	1·0	1·0	1·1	1·2
Calorific value—				
In calories per gramme, gross.......	4,750	5,200	4,930	5,285
In B.T.U. per 16 gross.......	8,550	9,360	8,880	9,510
Fuel ratio—				
Fixed carbon to volatile matter.......	0·50	....	0·45	....

The peat is fairly well humified, has high cohesive properties, and is suitable for fuel. The bog is rather narrow, in certain places shallow, and is cut through the middle by a brook. The erection of a mechanical plant is, therefore, not warranted, but peat fuel could be manufactured on a small scale for domestic use. The peat is formed principally of sphagnum mosses heavily intermixed with eriophorum. The surface of the bog in spots is broken by knolls. The bottom of the bog consists of sand.

SEAL HARBOUR PEAT LITTER BOG, STORMONT TOWNSHIP

(*See* Figure 25)

The bog is about 2½ miles north of Goldboro. It has a total area of about 67 acres. Of this area:

	Cubic yards
31 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	150,000
36 acres have a depth of more than 5 feet, with an average depth of 7 feet, and contain	406,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

36 acres with an average depth of 5 feet, containing 17,420 tons, or 23,230 tons of peat litter containing 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of	
	0–3 feet	3–6 feet
	%	%
Absorption factor for moisture-free peat.......	10·0	7·8
Absorption factor for peat with 25 per cent moisture.......	7·2	5·6
Ash (dried at 105°C.).......	6·7	9·1

The peat is composed mainly of sphagnum mosses slightly intermixed with eriophorum. It is fairly free from humus, has a good depth, and the surface is comparatively free from knolls and trees, thus making it suitable for the manufacture of peat litter. The volume of peat is too small for the manufacture of peat litter by an expensive mechanical plant, but the peat can be utilized for local consumption. The bog can be drained into Seal Harbour lake.

MEADOW PEAT LITTER BOG, STORMONT TOWNSHIP

(*See* Figure 27)

The bog is about 4 miles north of Goldboro. It has a total area of about 177 acres. Of this area:

	Cubic yards
69 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	334,000
83 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	937,000
25 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	444,000

Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially, and allowing 2 feet shrinkage in depth after drainage, there is available:

	Tons
83 acres with an average depth of 5 feet, containing	40,170
25 acres with an average depth of 9 feet, containing	21,780

The total tonnage is 61,950 tons, or 82,600 tons of peat litter containing 25 per cent moisture.

Partial Analyses of Samples

—	Samples from depths of	
	0–3 feet	3–10 feet
	%	%
Absorption factor for moisture-free peat	13·7	14·3
Absorption factor for peat with 25 per cent moisture	10·0	10·5
Ash (dried at 105° C.)	6·7	4·8

The peat is fairly free from humus, with the exception of that area, having a depth of less than 5 feet, which is more humified. However, taking the whole area into consideration, the peat will yield fairly good peat litter. It is composed mainly of sphagnum mosses lightly intermixed with eriophorum. The bog has a very good depth and the surface is free from knolls and trees. The drainage could be carried in an easterly direction towards Meadow lake. This bog is suitable for the erection of a mechanical peat litter plant. The bottom is composed of sand.

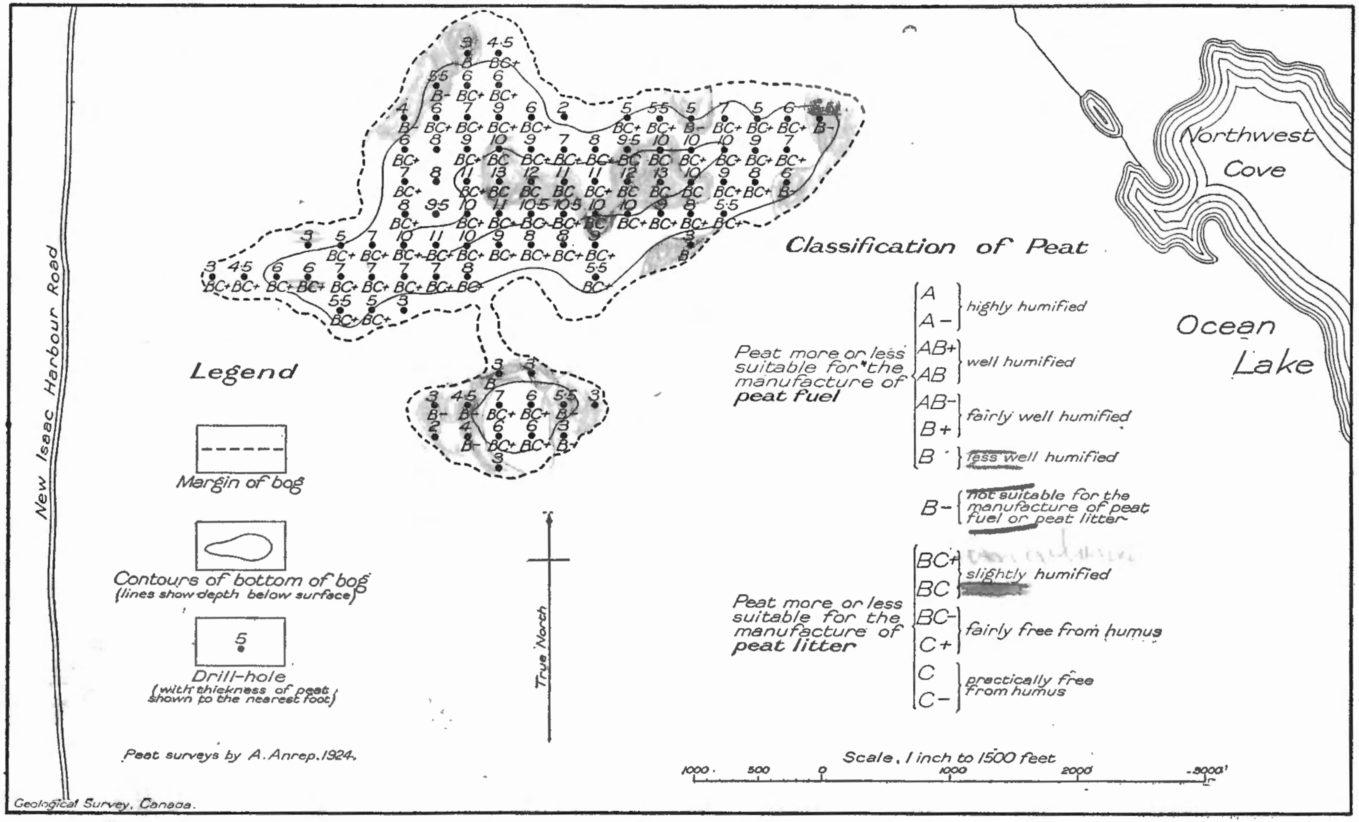


Figure 27. Meadow peat litter bog, Stormont township, Guysborough county, Nova Scotia.

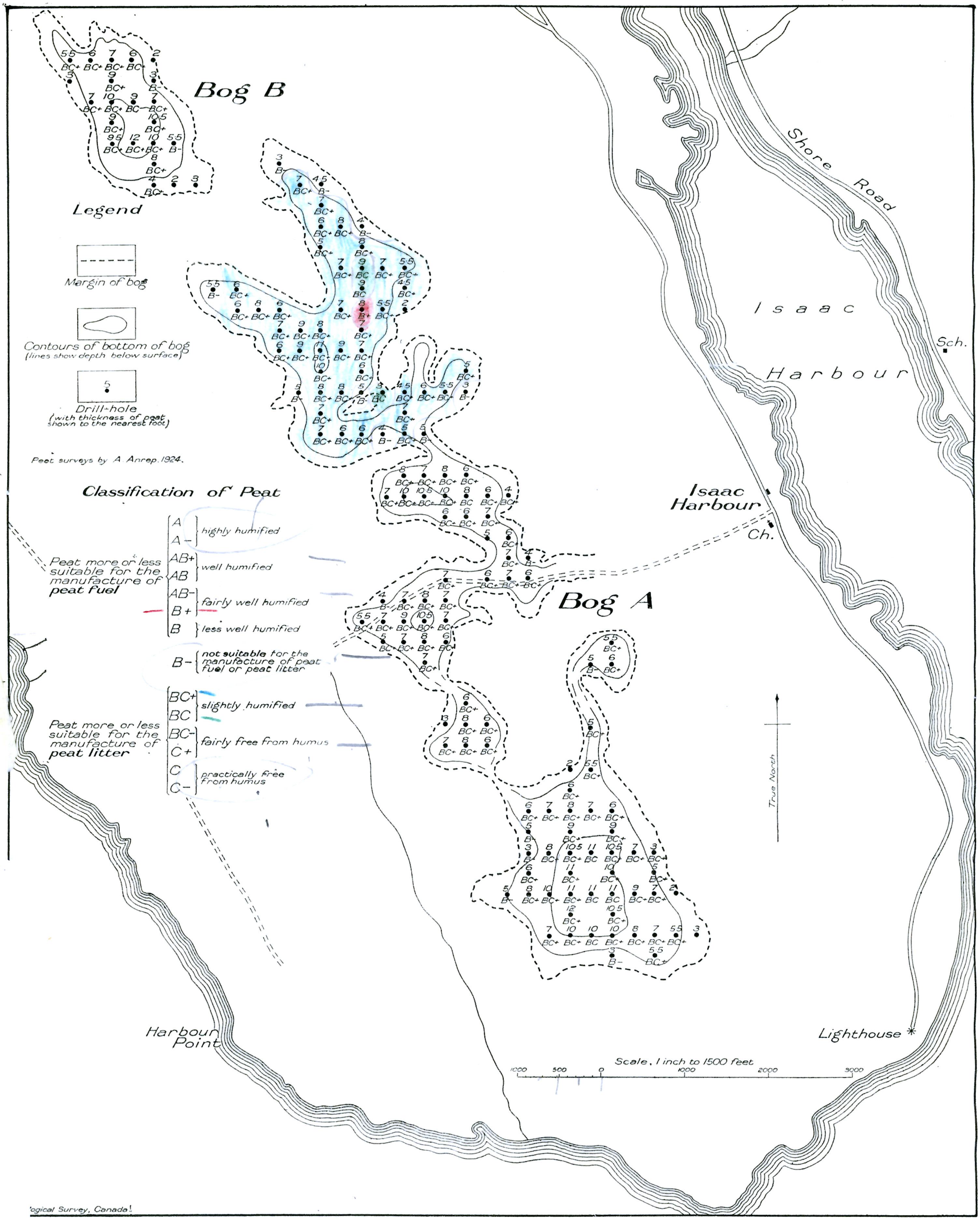


Figure 28. Isaac Harbour peat litter bogs, Stormont township, Guysborough county, Nova Scotia.

ISAAC HARBOUR PEAT LITTER BOGS, STORMONT TOWNSHIP

(*See* Figure 28)

These bogs are two in number and lie about ½ mile west of Isaac Harbour village and ½ mile east of Country Harbour. They are designated, respectively, Bog A and Bog B.

Bog A has a total area of 400 acres. Of this area:

	Cubic yards
147 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	711,000
229 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	2,586,000
24 acres have a depth of more than 10 feet, with an average depth of 11 feet, and contain	426,000

Bog B has a total area of 57 acres. Of this area:

21 acres have a depth of less than 5 feet, with an average depth of 3 feet, and contain	102,000
30 acres have a depth of between 5 and 10 feet, with an average depth of 7 feet, and contain	339,000
6 acres have a depth of more than 10 feet, with an average depth of 10 feet, and contain	97,000

The peat in the two bogs is of the same quality. Excluding the acreage underlain by peat 5 feet or less in depth as not being of value commercially and allowing 2 feet shrinkage in depth after drainage, there is available in:

Bog A:

	Tons
229 acres with an average depth of 5 feet, containing	110,840
24 acres with an average depth of 9 feet, containing	20,910

Bog B:

30 acres with an average depth of 5 feet, containing	14,520
6 acres with an average depth of 8 feet, containing	4,650

The total tonnage is 150,920 tons, or 201,230 tons of peat litter having 25 per cent moisture.

Partial Analyses of Samples[1]

—	Samples from depths of				
	0–3 feet Bog A	3–6 feet Bog A	6–9 feet Bog A	0–6 feet Bog B	6–9 feet Bog B
	%	%	%	%	%
Absorption factor for moisture-free peat	19·7	20·5	7·7	23·3	26·2
Absorption factor for peat with 25 per cent moisture	14·5	15·1	5·6	17·2	19·4
Ash (dried at 105° C.)	4·7	5·4	5·7	3·2	3·6

Bogs A and B are not humified and the upper layers are comparatively free from humus and hence a good peat litter would be available. The peat is composed mainly of sphagnum mosses slightly intermixed with eriophorum and towards the margin carex is to be found. These bogs have a fairly good depth and the surface is comparatively free from knolls and trees. The position of these bogs is similar to the Indian Head bogs, forming planes at a comparatively high elevation. They can be drained either towards Isaac Harbour or Country Harbour.

[1] Owing to smallness of samples, the absorption factors are possibly too high in value.

DEEP BORINGS IN ONTARIO, QUEBEC, AND MARITIME PROVINCES

By E. D. Ingall[1]

Illustration

The Borings Division of the Geological Survey exists for the purpose of accumulating records of borings made in any part of Canada, so that the information of a general geological character thus rendered available may be utilized for the guidance of operators and in geological research in arriving at a fuller understanding of the strata in depth. Diamond-drill borings intended to ascertain the extent of ore reserves in metalliferous mines were doubtless prosecuted in the various mining camps, but these do not come within the scope of the Borings Division.

Owing to the near exhaustion of the pools of natural gas and of petroleum in the peninsula of Ontario, boring operations during 1924 were slight as compared with those in past years. Since the first attempt to exploit petroleum at Oil Springs in the Petrolia field in 1858, boring operations have been continuously and actively prosecuted and have resulted in the discovery of other pools of varying importance. In the Welland, Kent, and Essex fields natural gas pools were opened up which have proved of much value in the development of manufacturing industries throughout the southern part of Ontario peninsula and in adjacent parts of the United States. With the exception of the borings in search of salt along the shores of lake Huron in the counties of Huron and Bruce, well boring was carried on chiefly in the counties of Lambton, Essex, Kent, Elgin, Norfolk, Haldimand, and Welland. Along this zone of country bordering St. Clair river and lake, and extending along the north shore of lake Erie, thousands of borings have been put down since the initial operations in 1858. In earlier years tests were put down merely to reach the shallow oil horizon of the Petrolia field. Lately, deeper and deeper tests have been made and in many localities the whole Palæozoic section has been tested down to the Precambrian formations of the old sea bottom.

Logs of a large number of the borings put down in Ontario in the past are now available for reference in the files of the Borings Division. For a considerable proportion of these sets of samples are also available illustrative of the character of the strata passed through. These have already been used during the progress of the borings in making geological determinations in aid of the operators. They are available for further study by chemical and microscopic methods in extension of the knowledge of the sedimentary formations. The tabulation on page 241 gives particulars of the records and samples received from Ontario during 1924.

[1] Information regarding boring records for British Columbia and the Yukon, the Prairie Provinces, etc., will be found in Parts A and B of the Geological Survey Summary Reports.

Part	Lot	Location: Township	Location: Concession	Location: County	Location: At or near village, lake, river, etc.	Description: Year made	Description: Elevation above sea-level	Description: Total depth in feet	Description: Gas, oil, water	Description: Character of water	Description: To first rock — Depth in feet	Description: Number of samples received	Remarks (Local name, pool, district, name of drilling company, driller, casing, temperature, etc., etc.
	1	Warwick	I	Lambton		1923–24		595		Feet Fresh at 95 " 120 " 160 Saline 595	93	24	Canadian Dutch Oil Co.
	23	Moore	I	"		1924		930				84	Coste No. 5
	30	Dawn	IX	"		1923–24		3,913				219	Coste No. 4
	181	Romney	T.R.	Kent		1923–24		1,350				115	Union Natural Gas Co., No. 246
	162	Raleigh	T.R.	"		1923–24		1,095				85	" " No. 245
	176	Tilbury E.	T.R.	"		1923–24		1,395				115	" " No. 247
	165	"	T.R.	"		1923–24		1,300				40	" " No. 244
	19	Harwich	II	"		1921–24		545			35	51	E. P. Rowe
	12	Tilbury E.	M.R.S.	"		1921–24		1,390	Dry		155	20	Union Natural Gas Co., No. 198
	10	"	XI	"		1921–24		1,408	Gas		155	12	" " No. 199
N ½	12	"	M.R.S.	"		1921–24		1,343	"		150	17	" " No. 197
	11	"	XI	"		1921–24		1,393	"		150	13	" " No. 195
	23	Dunwich	N. of A. V	Elgin		1923–24		1,725				301	Dominion Natural Gas Co. (Beecroft No. 1)
	9	S. Walsingham	XIII	Norfolk		1924		1,360				149	Dominion Natural Gas Co.
	12	Glanford	VIII	Wentworth		1923–24		525	Gas	Fresh at 160	68	47	Lime and Cement Works (Marshall No. 2)
	14	"	VIII	"		1923–24		480	"			42	Lime and Cement Works (Marshall No. 1)
	24	Dunn	IV	Haldimand		1923–24		900	"		24	193	Church of England No. 1
	11	Seneca	I	"		1921–24		507			62	90	Dominion Natural Gas Co.
	9	Moulton	II	"		1922–24		692	Gas		76	9	Clover Gas and Oil Co.
W ½	13	"	III	"		1922–24		690	"		78	9	Clover Gas and Oil Co.
	12	Walpole	XIV	"		1922–24		350				33	Springvale Oil and Gas Co.
	10	"	XIV	"		1921–24		864	Gas			10	Springvale Oil and Gas Co.
	9	Moulton	II	"		1922–24		693	"		67	9	Clover Gas and Oil
	11	Walpole	XIII	"		1921–24		860	"			8	Springvale Oil and Gas Co.
	3	Crowland	VIII	Welland		1923–24		686				10	Industrial Gas Co.
		"		"	Town of Welland	1924	589	188·4					Dept. of Railways and Canals (D.D. Cores No. 1)
	....	"		"	"	1924	587·2	177·1					Dept. of Railways and Canals (D.D. Cores No. 2)
	17	Eastnor	W.B.R. IV	Bruce	Spry	1923–24		1,597				160	Mulberry Creek Oil Co.
	6	Caledon	I	Peel		1923–24		600				125	Caledon Natural Gas Co.
	11	Vaughn	III	York		1923–24		2,730				321	R. I. Henderson
S ½	2	Emily	XI	Victoria	Lindsay	1923–24		440	Water and gas	Sulphurous		84	Northern Development Co.
	....			Carleton	City of Ottawa	1923–24		1,090	Water			56	W. Bell Co. for Can. Nat. Ry. at Central station.

The work of collecting information regarding boring operations in the peninsula of Ontario has been carried on for the past few years through the co-operation of Colonel R. B. Harkness, the Provincial Government Commissioner of Gas, to whom thanks are due for records and samples received. Apart from the logs of wells received through the Commissioner of Gas, direct communication was maintained with operators at points where, owing to the situation of the boring, geological information of especial value might result. Logs of two of these as worked out from the examination of the samples are given herewith. Thanks to the co-operation of the Wainfleet Natural Gas Syndicate, a complete set of samples down to 675 feet was received. This gave a chance to study the character of the strata in detail in a district where it had not been found possible in the past to acquire much material of this kind.

Wainfleet Natural Gas Syndicate, Lots 41-42, Con. IV, Wainfleet Tp., Welland County, Ontario

(Description of Samples Based on Laboratory Examinations by Borings Division)

Feet	
200–210	Grey and brown dolomite
210–220	" "
220–230	Light brown and grey dolomite. Selenite fragments
230–240	" " "
240–250	" green grey "
250–260	" dolomite
260–270	" " selenite fragments
270–280	" " "
290–300	" " "
300–310	" " "
310–320	Light brown and white " "
320–330	Brown dolomite, selenite fragments
340–350	" "
350–360	" "
360–370	" "
370–380	" "
380–390	" "
390–400	Grey-brown dolomite. Gypsum
400–410	" " "
410–420	" " "
420–430	White and light mottled grey dolomite
430–440	" " " colours darker
440–450	Light brown-grey dolomite
450–460	" " with chert
470–480	White and light grey dolomite
480–490	Brown-grey, calcareous shale
490–500	" "
500–510	" " and dolomite
510–520	White and grey, mottled dolomite
520–525	" "
525–530	Light grey and brown, mottled dolomite
530–535	White and light brown, mottled dolomite
535–540	Very light brown dolomite
540–545	White sandstone. calcareous
545–550	" " "
550–555	" " red and green shale
555–560	Red and green shale and white sandstone
560–570	" " "
570–575	" " "
575–580	White sandstone, green and red shale
580–590	" " "
590–650	Light green-grey, sandy shale
650–655	White sandstone
665–675	"

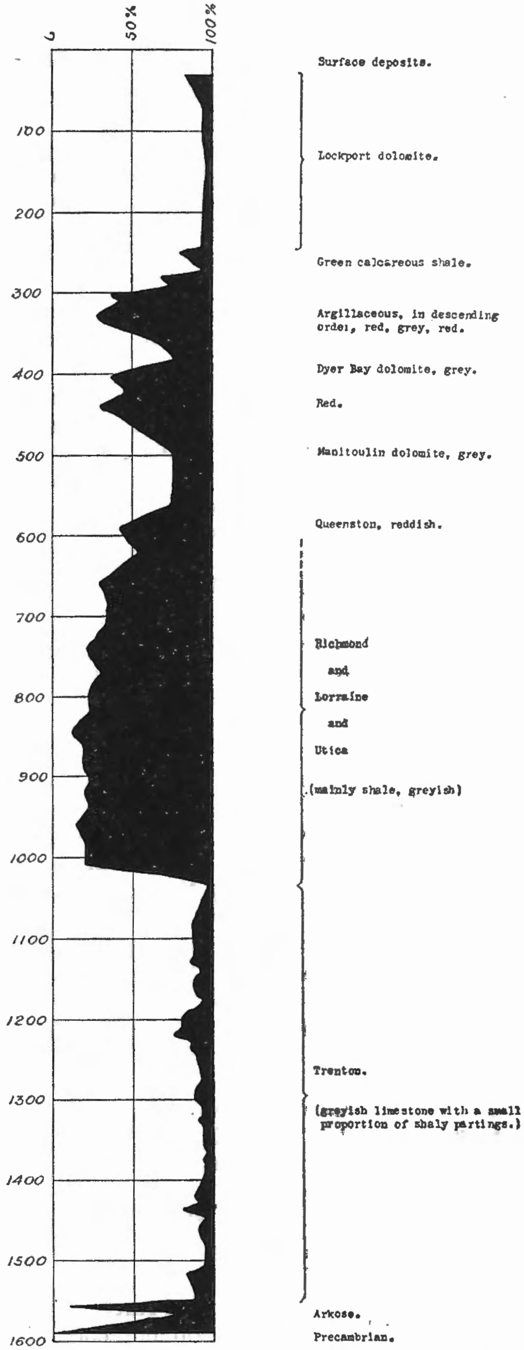


Figure 29. Graphic log of boring, Mulberry Creek Oil Company, lot 17, IV W.R.B., Eastnor township, Bruce county, Ont. The black part of the graph indicates the proportion of the individual samples insoluble in acid.

The Division was also in direct communication with the Mulberry Creek Oil Company operating in Bruce peninsula between Georgian bay and lake Huron. The set of samples from this boring is of especial interest, being located in a district where tests of the strata in depth by boring have been few. It forms also an important connecting link between the exploratory borings for oil made on Manitoulin island in past years, and the work done in the southern part of the province. The graphic log below gives the interpretation of the samples by the acid test for soluble carbonates as worked out by D. C. Maddox. It also illustrates the value of the graphic method in clearly presenting the lithological evidence for correlation with the stratigraphical succession as established by surface geological surveys.

According to the published geological map (No. 1715) this boring started in the Lockport dolomite of the Niagara series. It will be noticed on reference to the graphic log that this was corroborated by the solubility curve which shows almost 100 per cent soluble matter down to about 240 feet. The boring then passed through the preponderately shaly groups below, as shown by the great decrease in the average of soluble constitutents. Increase in the solubility contents is shown at depths 360 to 380 feet and at 500 to 560 feet. These horizons would coincide with the Dyer Bay dolomite and the Manitoulin dolomite, of Williams' section. At about 1,010 feet will be noticed a sudden increase in the proportion of solubles, indicating a passage into the Trenton limestone series. The last few samples show the presence of the usual " arkose " found everywhere at the base of the sedimentary series in the peninsula of Ontario. At 1,590 feet the boring ended in the Precambrian granitic and gneissic rocks of the old sea bottom.

Thanks to the co-operation of the Wallace Bell Company, of Montreal, samples were received from a boring put down in the yard of the Central Station at Ottawa, for the purpose of obtaining a supply of cooling water. This started in the top of the Trenton and was carried to a depth of 1,090 feet. It was interesting as corroborating the geological section for Ottawa as established by the logs of other wells at various points in the city and vicinity. A number of wells put down in the city limits have met with varying success owing, apparently, to the fact that no definite water-bearing horizon exists in the series of strata underlying Ottawa. Thus the attainment of a considerable water supply will depend on encountering by chance some wide-open fissure system that will ensure drawing a supply from a large area.

From the province of Quebec no records of, or samples from, deep borings were received. In past years borings for oil and gas have been made, periodically, and records and sets of samples were received. For several years, however, all interest in the possibilities of the undisturbed Palæozoic of the Eastern Townships has subsided.

A number of core-drill borings, testing mineral deposits, are carried on every year in various parts of Nova Scotia. These are described in the reports of the Provincial Department of Mines. The results, however, being of private and local interest only, do not come within the scope of the Borings Division. The study of the tests made by the coal mining companies in proving the extension of the coal beds come within the scope of the investigations being made by W. A. Bell for the Geological Survey.

In the Moncton gas and oil field, thanks are due to the New Brunswick Gas and Oil Company for their continued co-operation. For many years logs and sets of samples have been receivd through them from their own borings and those of their affiliated company, the D'Arcy Exploration Company. These borings were directed by the companies' geological staff and the records represent the interpretations of scientifically trained observers. The Borings Division has on file, therefore, a large accumulation of valuable records with corroborative sets of samples illustrative of the deep-seated geology of this district to depths of 2,000 to 4,000 feet. The records received from the New Brunswick Gas and Oil Company during 1924 are given in the tabulation following.

Location		Description							Remarks
County	At or near village, lake, river, etc.	Year made	Elevation (above sea-level)	Total depth in feet	Gas, oil, water	Character of water	To first rock — Depth in feet	Number of samples received	(Local name, pool, district, name of drilling company, driller, casing, temperature, etc., etc.)
						Feet			
Albert..........	Stony Creek....	1910-24	310	3,132	....	....	....	219	New Brunswick Gas and Oil Co. No. 9
"	"	1923-24	332	2,475	....	....	....	28	" " " No. 48
"	"	1924...	....	2,410	....	....	....	10	" " " No. 55
"	"	1921-24	387	3,102	....	....	....	89	" " " No. 56
"	"	1922-24	317	2,795	....	....	....	23	" " " No. 58
"	"	1923-24	....	2,156	....	....	....	407	" " " No. 59
"	"	1924....	280	2,105	....	....	....	397	" " " No. 60
"	"	1924....	289	3,110	....	Fresh at 74	....	621	" " " No. 61
"	"	1924....	282	3,501	....	Fresh at 80		603	" " " No. 62
						Salt at 2,240	15		
"	"	1924....	439	2,737	Oil.....	at 55	15	517	" " " No. 63
"	"	1924....	276	3,810	....	Fresh at 44	8	75	" " " No. 64
Westmorland....	Gautreau.......	1924....	....	1,875	....	....	....	13	D'Arcy Exploration Co., Gautreau No. 1.
Northumberland	Rogersville.....	1920-24	....	3,605	....	at 70	....	39	D'Arcy Exploration Co., Rogersville No. 1

Samples of cuttings received during 1924 were: for the Eastern provinces of Canada, Ontario, 2,451; New Brunswick, 3,041; total 5,492.

OTHER FIELD WORK

Geology

R. C. Emmons. Mr. Emmons made a fairly detailed geographical and geological survey of the townships of Otter, Haughton, Bridgland, and Kirkwood, north of Thessalon, Ontario. The Precambrian strata underlying this area are especially interesting from the standpoint of the general knowledge of the geology of the Canadian Shield and also contain small bodies of copper, gold, and cobalt-silver minerals. The results of Mr. Emmons' work in this district during 1923 and 1924 are embodied in Memoir 143, recently published.

E. Thomson. Mr. Thomson completed a detailed geographical and geological survey of an area of 400 square miles between latitudes 47° 30′ and 47° 45′ and longitudes 82° and 82° 30′, near Woman River, Ontario. The area contains iron formations and is geologically favourable for the existence of other metalliferous deposits. It is proposed to continue field work in an adjacent map-area before publishing a report upon the work done.

H. V. Ellsworth. Mr. Ellsworth continued a systematic investigation of the radioactive and rare-element mineral occurrences of Canada, begun in 1921. During the field season of 1924 occurrences were studied in Ontario between Parry Sound and Ottawa, and in Nova Scotia. Reports upon the occurrences of these minerals throughout Canada are in course of preparation.

M. E. Wilson. Mr. Wilson continued a detailed geological survey of an area near Madoc, Ontario, which is mineralized with talc, fluorite, pyrite, arsenic, gold, etc., and is also of much importance from the standpoint of general geological understanding of the Canadian Shield. Two maps on a scale of 1 inch to 1 mile, and a memoir, are in course of preparation.

R. W. Goranson. Mr. Goranson made a detailed investigation of a deposit of zinc ore on Calumet island, Quebec. His laboratory investigation and preparation of a report are being carried on now at Harvard University.

H. C. Cooke. Mr. Cooke made a geographical and geological exploration of the country near Bell river, north of the Canadian Northern railway, in northern Quebec. The area explored is part of a region in which valuable gold and copper ore deposits have recently been found and in which prospecting is being actively conducted. The results of Mr. Cooke's field work are being embodied in a general report upon the region of northern Quebec, which will be accompanied by two geological maps on a scale of 1 inch to 8 miles, representing a total area of 125,000 square miles.

F. A. Kerr. Mr. Kerr made a detailed geological survey of the Springhill coal basin and vicinity, Nova Scotia. A memoir, and a geological map on a scale of 1 inch to 1 mile are being prepared.

E. R. Faribault. Mr. Faribault continued the systematic geological survey of Nova Scotia. This survey has been in progress for many years and a series of sheets of uniform size on a scale of 1 inch to 1 mile have already been issued for all except the southwestern end of the province. This year, Mr. Faribault finished the Annapolis Royal sheet (No. 120) and commenced the Clementsport sheet (No. 119).

Topography

E. E. Freeland. Mr. Freeland carried on geographical surveys in the vicinity of French river, Ontario. He also carried a transit and tape traverse along the Canadian Pacific railway from the astronomic station at Pickerel to a point beyond Paget station. This traverse is for the control of the geographic surveys in the area. This work was carried out in connexion with the geological investigations in the area.

R. Bartlett. Mr. Bartlett made a transit and stadia control traverse up Eastman river, Quebec. This traverse, which started at the mouth of the river, was carried to a point about 200 miles upstream. Five hundred and seventy-five miles of shoreline was mapped by means of a transit-stadia traverse 340 miles long, of which about 50 miles is rough water and rapids. Sixty-three permanent reference posts for future work were established. A new route over part of the course was surveyed and much information relative to side routes was obtained.

A. G. Haultain. Mr. Haultain completed the topographical mapping, on a scale of 3,000 feet to 1 inch with contour interval of 50 feet, of the Chipman, N.B., sheet. This area of 207 square miles, which includes part of Minto coal basin, lies between latitudes 46° 00′ and 46° 15′ and longitudes 65° 45′ and 66° 00′. He continued, also, the topographical surveying, started in 1921 but not completed, of an area between latitudes 45° 45′ and 46° 00′, and longitudes 64° 45′ and 65° 00′. A little more work is required on this sheet in order to complete it.

K. G. Chipman. Mr. Chipman commenced systematic topographical surveying in southwestern Nova Scotia. The work was started in the vicinity of Aylesford, N.S., and carried down Annapolis valley. Good progress was made in the work and four sheets, each 15 minutes of latitude and longitude, were completed. The Geological Survey has conducted surveys for many years in this part of Nova Scotia with the result that a great amount of information has been obtained. The systematic topographical work, now in progress, is a continuation of these activities in this part of the province, and is for the purpose of revising and correlating the various phases of this past work for publication in the modern standard map-sheet form.

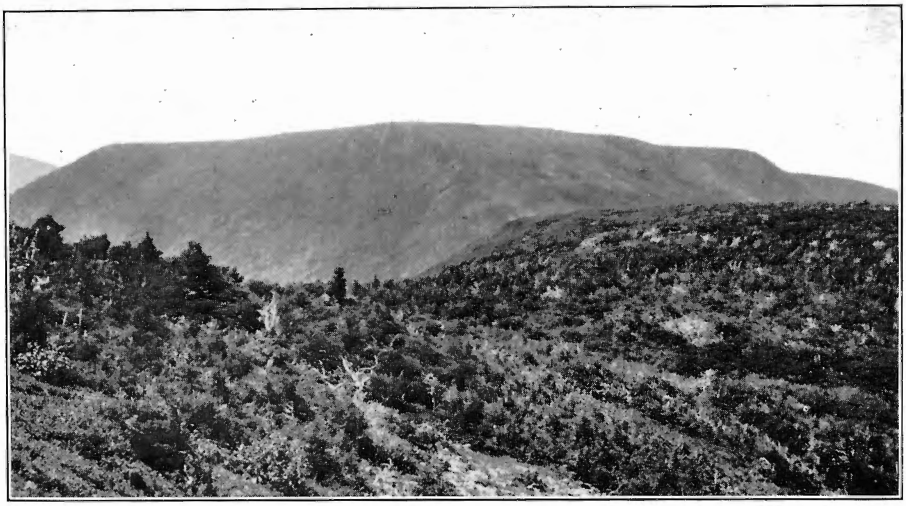
J. V. Butterworth, junior topographic engineer, was attached to Mr. Chipman's party.

S. C. McLean. Mr. McLean continued the primary control traverse of southwestern Nova Scotia. The work this year was carried along the Dominion Atlantic railway from Clementsport to Meteghan. Connexion by triangulation was made to the Geodetic triangulation station "Little River." Along the Halifax and Southwestern railway, the work was extended from Dalhousie siding to Bridgewater and to Caledonia. From Cherryfield, on the Caledonia branch, a traverse was carried to Aylesford, via the Cherryfield-Dalhousie and Dalhousie-Aylesford roads. From Caledonia, a traverse was carried to Annapolis Royal, via the Liverpool-Annapolis road. The total length of the traverses is about 190 miles.

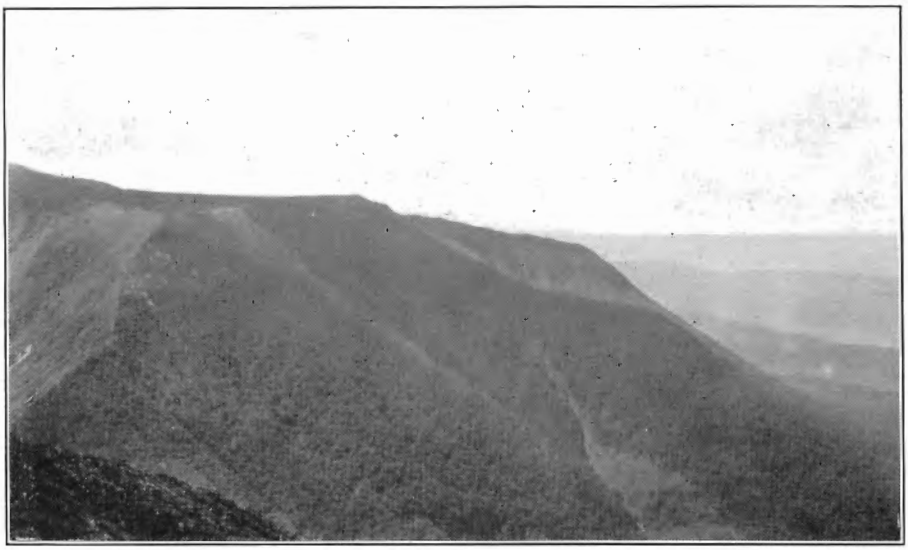
Throughout this work, points permanently marked on the ground by iron posts or brass plugs in concrete were established every 2 or 3 miles. In all seventy-five points were established. In addition to setting these points, other features were tied to the survey wherever possible; these include five precise level bench-marks of the Geodetic Survey, twenty timber and land corner posts, five county-line crossings, or posts, and a number of churches and lighthouses.

The accurate positions, on the North American datum, of all the above-mentioned points, are determined. These positions, together with descriptions and other information, are supplied to the government of the province of Nova Scotia, to the larger timber companies operating in the area, to the railway companies, and others interested. The results are available to anyone on request to this Department.

H. N. Spence, junior topographical engineer, was attached to this party.



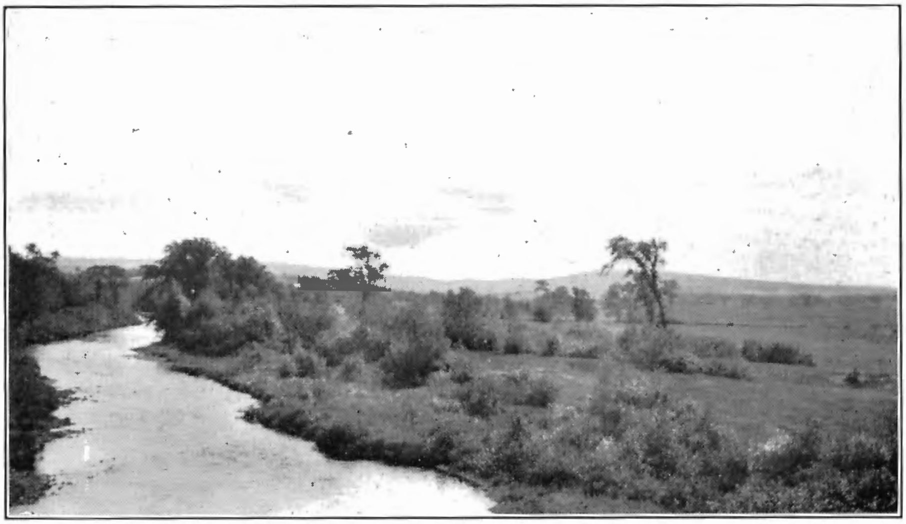
A. Mount Collins from Mount Matawees, showing the flat character of the higher plateau. (Page 129.)



B. Looking west from mount Pembroke, showing the abrupt descent from the high plateau surface to the lower plateau country. (Page 129.)

A. Looking west from the summit of mount Logan. Mount Matawees in the middle, and Bayfield in the distance. (Page 129.)

B. Cirque between mount Logan and mount Pembroke. (Page 129.)



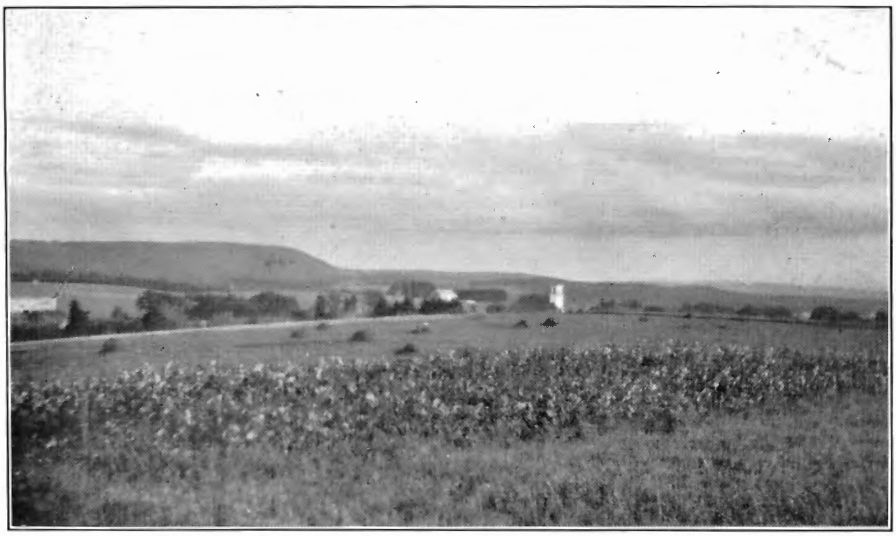
A. Waugh River valley, with the Cobequids in the background. (Page 143.)

B. Coarse phase of the Millsville conglomerate on West branch river John. (Pages 143, 148, 161.)

A. The Millsville conglomerate at The Falls, Waugh river. (Page 161.)

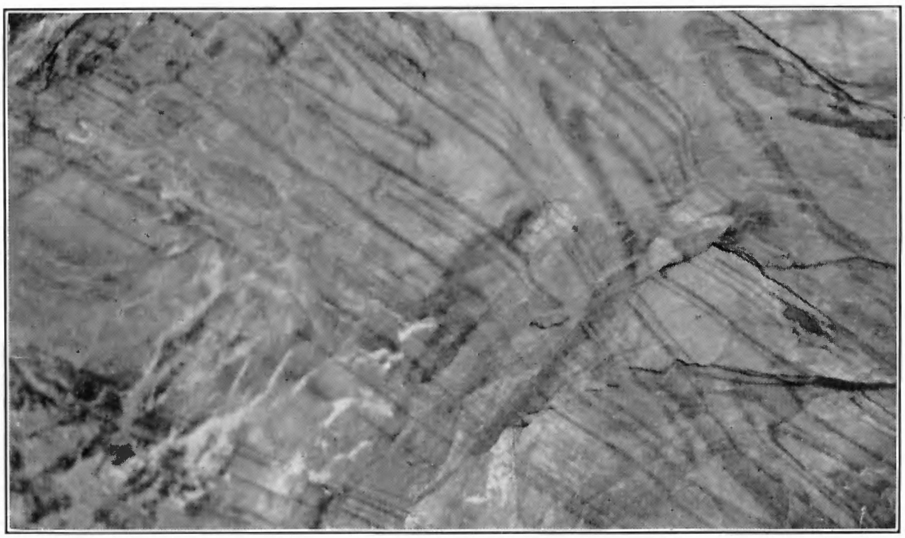
B. Unconformable contact of New Glasgow conglomerate upon Lismore formation, Blackwood brook, New Glasgow. The hammer lies upon a plane of jointing. (Pages 147, 166, 171.)

A. Green hill in left background is underlain by New Glasgow conglomerate. Foreground valley of West river is on the Lismore formation. (Page 166.)

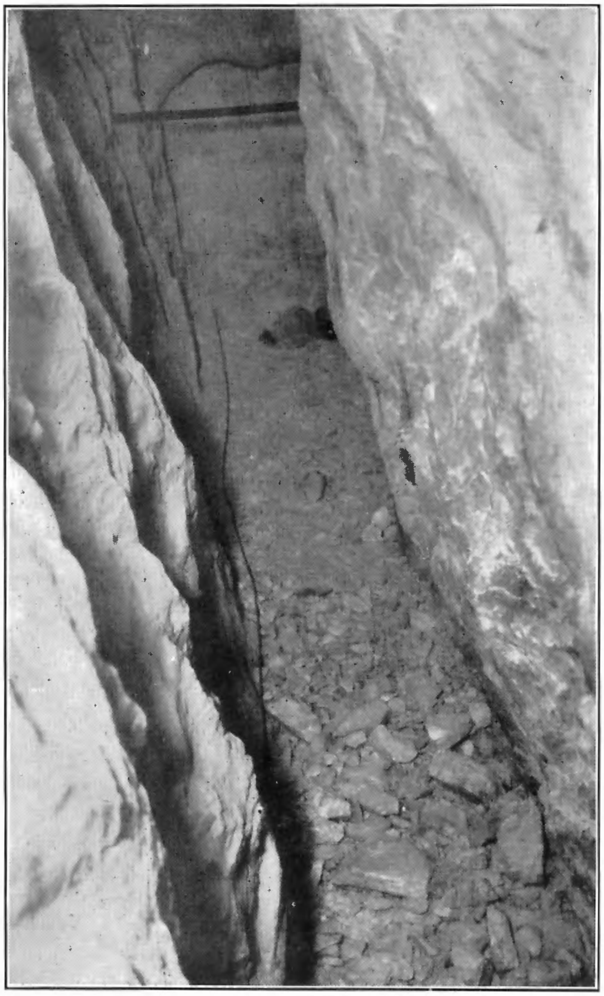


B. New Glasgow conglomerate, Green hill. (Pages 143, 147, 172.)

A. Bed of freshwater limestone in Pictou series, Malagash point. A few limestone casts of Stigmariæ may be seen beneath the limestone bed at a. (Page 174.)

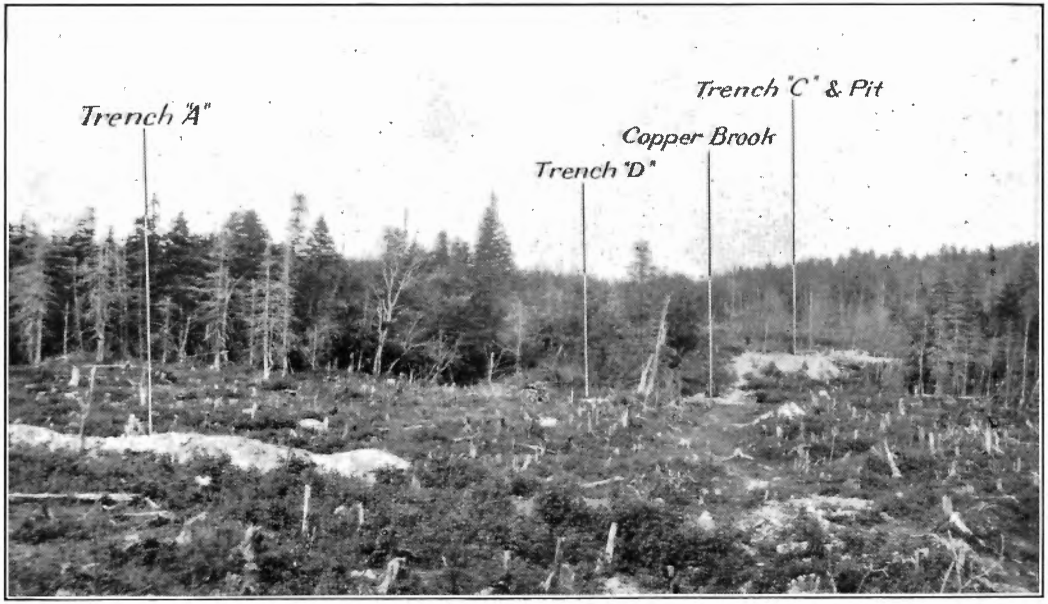


B. Illustrating bedding and deformation of Malagash salt. (Page 183.)



Stope with broken-down salt in steeply inclined beds, Malagash salt mine. (Page 182.)

Plate VIII



Stirling property, October, 1924, Cape Breton. (Page 210.)

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The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are three parts, A, B, and C. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of mines.