

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

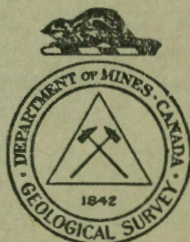
GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report, 1927, Part C

CONTENTS

	PAGE
LAKE DAVID AREA, CHIBOUGAMAU DISTRICT, QUEBEC: J. B. MAWDSLEY.....	1
EAGLE RIVER AREA, ABITIBI TERRITORY, QUEBEC: J. B. MAWDSLEY.....	23
ZINC-LEAD FIELD OF CENTRAL GASPE, QUEBEC: F. J. ALCOCK.....	27
THE GEOLOGY OF NORTH MOUNTAIN, CAPE BRETON: T. D. GUERNSEY.....	47
CUMBERLAND SOUND AREA, BAFFIN ISLAND: L. J. WEEKS.....	83
SOME PROBLEMS OF PEAT INVESTIGATION IN CANADA: VAINO AUER.....	96
DEEP BORINGS IN ONTARIO AND MARITIME PROVINCES: E. D. INGALL.....	112
OTHER FIELD WORK.....	116
INDEX.....	121



OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928

No. 2171

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ZINC-LEAD FIELD OF CENTRAL GASPE, QUEBEC: F. J. ALCOCK.....	27
THE GEOLOGY OF NORTH MOUNTAIN, CAPE BRETON: T. D. GUERNSEY.....	47
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LAKE DAVID AREA, CHIBOUGAMAU DISTRICT, QUEBEC

By J. B. Mawdsley

CONTENTS

	PAGE
Introduction.....	1
Previous work.....	2
Topography of Chibougamau district.....	3
General geology.....	4
Economic geology.....	14

Illustration

Map 2175. 222 A. Lake David area, Abitibi territory, Que.....In pocket

INTRODUCTION

The writer was instructed to visit, during the field season of 1927, Chibougamau region, Quebec, and to report on the mineral discoveries made since 1911. It was deemed advisable to obtain information regarding the rocks underlying the area in the vicinity of these recent discoveries and accordingly an area, the Lake David map-area, 60 square miles in extent, was mapped. Outcrops were studied along the watercourses and bush traverses spaced at half-mile intervals. The completion of the rest of the summer's program allowed only three weeks for this work. It is from the necessarily cursory survey of this small mapped area that the material for this report was obtained. The writer was ably assisted in the field by J. A. Retty and R. M. Williams. Various prospectors in the area helped in many ways to expedite the work.

Lake David map-area lies in the vaguely defined region generally known as Chibougamau district, which has an area of approximately 1,000 square miles and derives its name from the largest lake within it. Lake David map-area comprises a strip of country 15 miles east and west and for the most part 6 miles north and south, and lies immediately west of lake Chibougamau. The north boundary is about 10 miles south of latitude 50 degrees and the meridian of longitude 74°30' passes through the centre of the area. The map-area is approximately half-way between lake St. John and James bay, is 150 miles north of the Canadian National railway, 220 miles east of the Quebec-Ontario boundary, and 40 miles south of Mistassini lake.

Before the building of the Canadian National Transcontinental line, Chibougamau area was entered with difficulty, but since then it has become more accessible. The old route was from St. Felecion, lake St. John, by the Ashuapmuchuan River route, a difficult and arduous route taking skilled canoemen two weeks to make the 180 miles. Now a much easier summer route leads from Oskelaneo River station on the Canadian National railway; it is nearly 50 miles shorter and can be travelled

in just half the time by experienced canoemen. The Quebec Government spent some money on this route in the summer of 1927 and improved it considerably. A winter trail is now available for dog or light sleigh traffic from St. Felicien on lake St. John to lake Chibougamau.

The cost of transporting supplies over the summer route from Oske-laneo River station to Chibougamau lake is approximately 20 to 25 cents a pound. The route is well marked and well travelled. It is best negotiated by the 18-foot freighter type of canoe with small out-board motor. There are twenty-five portages along this route; one is 1½ miles long, the others are well under a mile in length and with a couple of exceptions are dry and afford good travelling. The cost of winter transportation from lake St. John to the south end of lake Chibougamau is approximately 15 cents a pound; sleighs used are either dog sleds or single horse sleighs.

The country is dotted with lakes, and transportation and exploration by airplane are feasible.

PREVIOUS WORK

During the seventeenth and eighteenth centuries fur traders, missionaries, and explorers seeking a route from lake St. John to James bay traversed parts of Chibougamau region. By the end of the eighteenth century the Ashuapmuchuan River route into Chibougamau and Mistassini lakes was well known. An interesting account of this early unsystematic exploratory work is to be found in the report of the Chibougamau Commission.

James Richardson, in 1870, did the first systematic work in the region. In 1884 the Bignell-Low Mistassini expedition did further work. In 1892 and 1905 A. P. Low did further geological exploration in the vicinity of Chibougamau lake. The geological results obtained by these members of the Geological Survey were published in Annual Reports of the Geological Survey for the years 1870-71, 1885, and 1892-93, and in Publication No. 923, published in 1906. In 1903 Mr. Peter McKenzie discovered what were believed to be valuable deposits of asbestos, copper, and gold; as a result of these finds Mr. J. Obalski made a report on this region in 1904 and in 1908 Professor E. Dulieux made an extensive examination of the known deposits of Chibougamau region. This work for the Quebec Government was published in the 1904 and 1908 reports on mining operations, province of Quebec.

Topographic work was done in the region by Mr. Henry O'Sullivan in 1898, by Mr. C. E. Lemoine in 1899, Mr. C. S. Lepage in 1906, Mr. J. H. Sullivan in 1907.

The finds Mr. McKenzie made in 1903, and subsequent official and private reports aroused great interest in the possibilities of the region and the Quebec Government was pressed to build a railway for the exploitation of the gold, copper, and asbestos deposits of the area. It was finally decided to have an unbiased and authoritative report on the mineral occurrences and economic possibilities of the area. Accordingly the Chibougamau Commission was appointed composed of Dr. A. E. Barlow of the Geological Survey, as chairman, Mr. E. R. Faribault,

also of the Survey, and Professor J. C. Gwillim, professor of Mining at Queens University. The commissioners, with a large party, entered the region in the summer of 1910 by the arduous Ashuapmucuan River route. The report of the Commission was published in 1911. It was a long and able report with a reconnaissance geological map representing 1,100 square miles of territory. The report was not optimistic and the building of a railway into the area was not recommended. It was pointed out that there were no asbestos deposits of economic importance and that, although the country gave promise of reward to the prospector, none of the gold or copper deposits so far found was commercially valuable even if railway facilities were available. This authoritative report killed interest in this region for many years.

The completion of the Canadian National railway from Quebec to Cochrane, has since made the region more accessible and the rich finds in Rouyn area, Quebec, once more turned the attention of the prospector to Chibougamau region. Since the publication of the Commission's report in 1911, other discoveries of sulphides carrying copper and gold values have been made.

TOPOGRAPHY OF CHIBOUGAMAU DISTRICT

Chibougamau district consists of a central hilly section and two more or less flat, low-lying sections respectively north and south of the upland area. The hilly section is 5 to 6 miles wide and is known to extend in an east and west direction for at least 15 miles. This section skirts the north shores of Chibougamau lake and lakes Dorés, David, and Simon, which lie west of lake Chibougamau. The south boundary of this hilly section forms, approximately, the north boundary of Lake David map-area. One hill in this section rises 725 feet above lake Chibougamau, or 1,950 feet above the sea-level, and many others have elevations of 1,525 feet to 1,825 feet. Their outlines are usually rounded, but cliff faces are not uncommon. The trend of the hills is, on the whole, irregular, and the drainage system has no definite pattern.

One-third to one-half of the low area south of the hilly or mountainous section is water. In this low section lies most of Lake David map-area. The bodies of water trend north-northeast, and most of the lakes contain many islands and many points trending in the same general direction. The largest of these bodies of water is lake Chibougamau with a rectangular outline and an area of 90 square miles. The lake is dotted with numerous small islands and its shores are irregular, with many long points. It drains west into lake Dorés, approximately 12 miles long, and, on an average, barely 2 miles wide. Lake Dorés discharges by a circuitous route embracing lakes David, Simon, and Asinitchibastat. Lake Chibougamau is approximately 1,230 feet above sea-level and Asinitchibastat is 43 feet lower. The waters eventually flow into Chibougamau river and finally find their way to James bay by way of Nottaway river. The country surrounding these lakes and to the south of them, is comparatively low and is largely drift covered, so that rock outcrops are few.

North of the central hilly belt is another area of low country. This was not visited by the writer. Lakes are fewer in the northern belt.

The two largest are Rush and Wakonichi. The former is about 8 miles long and 2 miles wide, and drains westward into Chibougamau river. Wakonichi lake is 20 miles long and averages 3 miles in width; it drains northward into lake Mistassini. The trend of these lakes is also north-northeast. Although this northern area is generally low some high hills occur along the shores of Wakonichi lake and are composed of flat-lying conglomerates of presumably late Precambrian age.

GENERAL GEOLOGY

Lake David area is underlain by Precambrian rocks covered in great measure by Pleistocene glacial deposits which are especially prevalent in the lower district forming the southern part of the map-area. The oldest of the Precambrian rocks are volcanic flows, chiefly andesite. These volcanic rocks are intruded by a series of related intrusives that are divisible with difficulty into three general types that in order of intrusion are: oligoclase granite, and oligoclase syenite, oligoclase anorthosite, and albite-oligoclase granite. A small area of fairly fresh gabbro was found within the map-area. A small area of conglomerate and fine sediments, younger than the volcanics, lies east of the map-area. They have suffered folding with the older volcanics.

Table of Formations

Recent and Pleistocene.....	Peat, sand, gravel, boulders, and unsorted morainic material
Precambrian.....	Conglomerate and fine sediments
	Gabbro
	Albite-oligoclase-granite
	Oligoclase anorthosite
	Oligoclase granite and syenite
	Volcanic flows, chiefly andesite

VOLCANICS

The volcanics extend across the northern part of the map-area from lake Asinitchibastat to a mile west of lake Dorés. They are well exposed in the high hills along the north boundary of the area and except for some hills adjacent to lake Dorés, the hilly region mapped is composed of these rocks. The volcanics are in contact with intrusives to the south and the line of contact is comparatively straight, follows an east-west course, and lies $\frac{1}{2}$ to $1\frac{1}{4}$ miles south of the east-west boundary line between McKenzie and Obalski townships. Approaching lake Dorés the contact turns north-east and then east to intersect the lake shore half a mile east of Cedar bay. The volcanics outcrop on lake Dorés east of this point.

Outside the map-area the volcanics are known to cover a large area to the north, having a width of at least 8 miles. This belt extends at least 10 miles northwest of the area and 15 miles northeast. A belt of volcanics probably equally extensive has been partly explored south of the map-area. The northern contact of this southern mass has a west-northwest trend and lies approximately 8 miles south of the southern contact of the northern area.

Within the map-area the volcanics have an east and west strike, vertical dip, and face north. An excellent determination of the attitude of an assemblage consisting of four flows was obtained on a cliff face three-fourths mile north of Cedar bay. These flows are andesites varying slightly in composition and at this point have an east-west strike, and a dip of 80 degrees north. The 40-foot cliff has a north and south strike, a length of 120 feet, and faces west. At the south end of the cliff, is exposed 15 feet of a fine-grained flow irregularly varying in grain and colour-banding. This is followed northward by the chilled edge of a flow 35 feet thick. This chilled edge grades within a few inches into massive, medium-grained material composing the bulk of the flow. The upper $4\frac{1}{2}$ feet is composed from south to north of 3 feet of amygdaloidal lava, 1 foot exhibiting pillow-like structures measuring 6 inches by 2 inches and elongated parallel to the surface of the flow, and 6 inches of fine-grained, light-coloured, rhyolitic material. This is followed by the narrow, chilled bottom edge of a flow 40 feet thick. The upper 15 feet of this third flow has a faint colour banding parallel to the top of the flow and the uppermost 3 feet is scoriaceous in appearance. This is followed by the narrow, chilled bottom edge of a medium-grained flow that is visible for a distance of 20 feet to where the exposure and the cliff end.

The volcanics of the Lake David map-area are predominantly andesites. Minor amounts of rhyolite, basalt, and volcanic fragmentals were noted. In general characteristics these volcanics resemble the greenstones termed Keewatin in western Quebec. They are usually massive, but locally are strongly sheared. The colours of the outcrops are generally various shades of greyish green; the colours of freshly broken surfaces are similar but darker. On a weathered surface the massive flows show minor structures such as: flow banding; ropy, scoriaceous, and fragmental tops; and amygdules. Pillows of various sizes and degrees of perfection are common in the andesites. Various textures can also be clearly seen, such as porphyritic and spherulitic. The grain varies from very fine to as coarse as one centimetre.

Usually the original minerals of the volcanics have been altered to products such as actinolite, chlorite, epidote, zoisite, and carbonate, but in some, fairly fresh plagioclase is visible. One porphyritic flow seen on lake Asinitchibastat, is composed of chloritized and epidotized phenocrysts of plagioclase one centimetre in diameter, irregular areas of about the same diameter of chlorite containing epidote particles and probably representing original ferromagnesian minerals, scattered in a fine-grained groundmass consisting of a felt of oligoclase-andesine ($\text{Ab}_{70}\text{An}_{30}$) crystals not more than one millimetre long.

A coarse-grained, granitoid rock was found a few hundred feet north of mile-posts XI and XII on the township line north of David lake. The mass extends east and west for a distance of $1\frac{1}{2}$ miles. Judging from the traverses across it, it is a band having a width of less than 400 feet. The rock is a light greyish green, soapy looking, altered rock with a grain of 1 centimetre. Irregular feathery crystals of colourless actinolite having a diameter up to 1 centimetre form 30 per cent of the rock. This mineral

is secondary and is itself going over to chlorite which is developed in a patchy pattern throughout the crystals. A few recognizable crystals of highly altered feldspar are present and are either acid oligoclase or albite. The rest of the rock is a fine-grained mosaic of zoisite with low double refraction, accompanied by a small percentage of small feathery crystals of actinolite and chlorite. These minerals very probably replaced original feldspar. If the alteration were not largely due to the addition of calcium from an outside source, the calcium-rich zoisite indicates that the original feldspar was a basic plagioclase. A few grains of reddish titanite are scattered through the rock.

It was impossible to determine the relationship of this rock to the adjacent volcanics and it has been mapped with them. It might be a coarse flow or, more probably, a dyke of fairly basic composition related either to some of the intrusives found to the south, or to an older intrusive.

GRANITIC INTRUSIVES

To the south of the volcanics and extending south of Lake David map-area, is a belt of intrusive rocks having an average width of 8 miles. A width of 3 to 5 miles of the northern part of this belt is shown on the map.

Except the area immediately northwest of Dorés lake and in the vicinity of Caché lake, the country underlain by these rocks is low and drift covered. Considerable areas contain no rock outcrops and where rock outcrops are present they are, in many cases, small, making it difficult to obtain information regarding the relationships existing between the various rock types. At least three main types of intrusive rocks, with intruded remnants of greenstone, are present. Each of the three types varies in composition and on the ground the variations in many cases occur within short distances.

End phases of each type resemble end phases of the other types, making it difficult to map separately the various rocks. All three types show certain petrographic peculiarities which lead the writer strongly to suspect that all originated from a common magma and are of about the same age; that is, the parent magma seems to have been capable of rather rapid and extreme differentiation.

For want of better names the three rock types in order of age have been called oligoclase granite and oligoclase syenite, oligoclase anorthosite, and albite-oligoclase granite. The three types have the common characteristic that no other feldspar than an acid, soda-lime plagioclase is present, this feldspar usually being an oligoclase close to the albite line. Where quartz is present it is usually opalescent, resembling in colour and lustre the precious opal; in thin section the quartz is seen to be filled with dust-like inclusions and cavities. Practically all the rocks have suffered alteration, usually to zoisite, epidote, chlorite, and talcose material. It is possible that some of the calcium-rich epidote, zoisite, and carbonate formed from the regrouping of the constituents of the original feldspars which, under this supposition, would be more calcic than the ones now present. It might be, therefore, that the original rocks were much more basic than the present feldspars indicate; they may have been diorites, typical

anorthosites, and quartz diorites. Alteration due to the addition or subtraction of material has, however, definitely taken place on a large scale and obscured the true nature of the original rocks. Though the names applied to the different rock types have been rather arbitrarily chosen, it is felt they are probably better than any that might be based on speculations as to the original compositions as indicated by the part of their present content of alteration products that might be attributed to the alteration of the original constituents. Further field and petrographic work is necessary before these rocks can be satisfactorily classified.

OLIGOCLEASE GRANITE AND OLIGOCLEASE SYENITE

Small areas of greenstone and of albite-oligoclase granite have been mapped with the dark, dioritic-looking oligoclase granite and oligoclase syenite. In the low, drift-covered area bordering Simon lake, in the southwest part of the map-area, the rock outcrops are confined to the lake shore and here, fragments of greenstone intruded by oligoclase granite are common and many show contact alterations. In the northwestern part of this area albite-oligoclase granite cuts a dark phase of the oligoclase granite. The point in the southern part of lake David, projecting north from the south boundary of the map-area, is underlain by greenstones, dark feldspathic dykes probably oligoclase syenite, and lighter-coloured, fine-grained granite dykes. In a schistose part of the greenstone are quartz stringers and disseminated pyrite and chalcopyrite. The small area on the north shore of David lake, represented on the map as occupied by oligoclase granite and syenite, is altered andesite cut by dykes, some related to the oligoclase granite but others being a coarse-grained feldspathic rock containing altered ferromagnesian minerals and probably related to the oligoclase anorthosite. The mass of oligoclase granite and syenite in the vicinity of Caché lake contains fragments of greenstone, some of which are altered to fine-grained hornblende rocks that in places carry some biotite. Dykes of granite probably related to the albite-oligoclase granite cut the dark oligoclase granite and greenstones. The small mass along the greenstone-anorthosite contact where, west of Dorés lake, it crosses the township line, is of dark granitic rocks that intrude the greenstone, but whose relation to the anorthosite is not known.

The oligoclase granite varies considerably and phases of it resemble the albite-oligoclase granite, but it usually has the appearance of a typical diorite or quartz diorite for which it was mistaken in the field. It is usually a dark green, medium-grained rock. In places it exhibits a porphyritic tendency and greenish feldspar crystals of 2 to 5 mm. are dispersed through a dark green groundmass. The granite is everywhere highly altered. The relative proportions of the constituent minerals vary. Plagioclase is the commonest and usually forms more than 50 per cent of the rock; it is much altered to epidote and zoisite with varying quantities of white mica or chlorite, but enough twinning is recognizable in some grains to determine them as being acid oligoclase. Zoning of these crystals was noticed. No orthoclase or microcline was found. Dark green hornblende, usually going over to chlorite, forms varying proportions of the dark min-

erals. Small interstitial flakes of biotite are present in some specimens. Part of the large quantity of secondary minerals such as epidote, zoisite, chlorite, carbonate, iron ore, and titanite, are presumably the alteration products of the original ferromagnesian minerals. Quartz is interstitial to the feldspars and forms from 10 to 50 per cent of the rock; it shows strain and is dusted with minute inclusions which very probably give it the opalescent look seen in some hand specimens. The accessory minerals, zircon, apatite, and iron ore, are sparingly present.

OLIGOCLEASE ANORTHOSITE

The name oligoclase anorthosite is applied to the feldspathic rocks of the map-area. The name in some ways is not satisfactory. Delesse proposed the name "anorthosite" for rocks almost wholly composed of plagioclase and the term was adopted by T. Sterry Hunt.¹ The name anorthosite has, however, been generally restricted to plagioclase rocks whose feldspar is basic and usually labradorite or, as in many cases, andesine or bytownite, the name being generally used for rocks of a gabbro or norite nature but deficient in dark ferromagnesian constituents. The plagioclase of the Lake David anorthosite is oligoclase, in many cases close to albite. The rocks are too acid to be considered as phases of gabbro. They are closer to syenite in composition and might be termed ferromagnesian-poor, oligoclase syenites or in the case of phases carrying quartz, oligoclase syenites. Certain minerals commonly associated with gabbroidal anorthosites are possibly not to be expected with the syenitic anorthosite of Lake David area.

A large mass of oligoclase anorthosite borders the northern part of lake Dorés. The rock is well exposed in the rocky hills forming the north-western shore of the lake. On the north and west the anorthosite is in contact with lavas, which it intrudes. A small mass of included greenstone lies less than one-half mile south of this northern contact and outcrops on Cedar bay. The anorthosite body towards the southwest is in contact with the area of oligoclase granite and included greenstones in the vicinity of Caché lake. A phase of the anorthosite carrying an appreciable amount of ferromagnesian minerals and quartz occurs on the north shore of David lake. On the west shore of David lake a normal phase is intruded by ferromagnesian-poor, albite-oligoclase granite dykes.

On the southeast shore of the same lake is a quartz-bearing phase which intrudes greenstone along the south shore of Berthe bay. Small areas of anorthosite were found about the south part of Simon lake and on Buckell lake (south of the map-area) on the route between lake David and lake Simon.

The outcrops of anorthosite weather white. When broken into, the rock has a greyish white, soapy look and is seen to contain chlorite in varying quantities. The feldspar crystals, many of which were originally 3 or 4 centimetres long, are crushed to grains of 2 centimetres or less, and greenish chloritic seams follow the irregular fracture planes. The rock is much altered and many of the alteration products were introduced by

¹ "Geology of Canada, 1863", p. 22.

solutions after the crushing of the rock. The feldspar fragments form the bulk of the rock and in some cases are completely altered, but usually traces of twinning and in some cases of zoning are noticeable and the feldspar is seen to be oligoclase, usually fairly acid. The alteration products differ in places, but are chiefly epidote and zoisite with varying amounts of chlorite, white mica or kaolin, carbonate, and quartz. Chlorite patches are common and with some of the epidote and zoisite, probably formed from the original ferromagnesian minerals. Iron ore and titanite occur and are probably largely secondary. A few grains of fresh oligoclase are found in some cases. Quartz is present in many instances and in extreme cases makes up as much as 15 per cent of the rock. It occurs both interstitially and as grains scattered through the other constituents. The quartz shows strain and crushing and contains dust-like inclusions. In some cases the quartz is intimately intergrown with zoisite.

Veinlets of quartz and veins of zoisite are common and are definitely later than at least some of the crushing suffered by the anorthosite. Much of the quartz, zoisite, and probably epidote, and many fresh oligoclase grains are probably due to solutions invading the rock after crushing.

ALBITE-OLIGOCLASE GRANITE

A belt of country underlain by albite-oligoclase granite extends for 7 miles from lake Asinitchibastat on the west to a point 1 mile northwest of Caché lake. The outcrops are comparatively few, especially at the western end of the belt. On the north the granite is in contact with the greenstones. On the south it extends into drift-covered country about lake Simon and lake David. On the west part of Simon lake it cuts the oligoclase granite. North and west of lake David it cuts a phase of the oligoclase anorthosite. It was noticed on an island just to the south of Knoll island in lake Dorés and here may be the northern margin of a mass extending south of the mapped area.

The albite-oligoclase granite is light-coloured, usually very low in dark ferromagnesian minerals, and conspicuous for its high content of opalescent quartz. Phases of it contain fair amounts of dark minerals and closely resemble the more acid phases of the oligoclase granite. The grain of the rock varies, but is commonly 2 to 3 millimetres. The granite has suffered much alteration. Quartz forms from 30 to 60 per cent of the rock and occurs in large grains, in small particles interstitial to the other minerals, and in round grains penetrating the plagioclase. Its boundary with the plagioclase is usually crenulated. The quartz is strained, and in many cases is crushed, and is full of dusty inclusions. Crystallization of the larger individuals was probably in the main contemporaneous with that of the plagioclase, but much of the quartz was later and is interstitial to the other minerals. Acid oligoclase or albite is the mineral next in abundance and forms with the quartz the bulk of the rock. It has not suffered strain or shattering to the same extent as the quartz. Some of the feldspar is little altered, but most of it is so changed that 50 or 80 per cent of each grain is an aggregate of zoisite, epidote, chlorite, and white mica, with minor amounts of carbonate and, possibly, quartz.

Minor amounts of green hornblende occur, usually feathery in habit and going over in places to chlorite. What apparently was biotite, but is now chlorite, small irregular patches of chlorite, and interstitial carbonate, occur sparingly. Small grains of the accessory minerals, apatite, zircon, iron ore, and fine-grained titanite are scattered throughout the rock. Some of the apatite grains were seen to be surrounded by pleochroic haloes.

AGE RELATION OF THE GRANITIC INTRUSIVES

The oligoclase granite in many places is cut by dykes of quartz-rich albite-oligoclase granite and, therefore, in part at least, is older than the albite-oligoclase granite. On an island in the south part of lake David and on the shore of Buckell lake on the route between lake David and lake Simon, what appeared to be phases of the oligoclase anorthosite cut the oligoclase granite. All granite dykes seen cutting the oligoclase anorthosite are albite-oligoclase granite. It is, therefore, at present felt that the oligoclase granite is probably in the main older than the anorthosite and the albite-oligoclase granite definitely younger than the oligoclase granite and anorthosite. Owing to petrographic similarities and the gradation of the three types into one another, it is believed that they are differentiates of the same magma and their successive intrusions occurred in the same general period of igneous activity.

GABBRO

A coarse-grained, comparatively fresh gabbro was found at one place within Lake David map-area. A body at least three-quarters of a mile long in a north and south direction and a third of a mile in width was mapped between Caché lake and Gladstone lake. The rock outcrops as high ridges surrounded by drift which obscures the contact with the surrounding oligoclase granite and included greenstone. The gabbro varies in appearance and texture in different outcrops.

The southern outcrops of the mass are of a gabbro having a granitoid texture and a grain of 5 millimetres. The weathered surfaces are a dark rusty brown. The freshly broken rock is greenish black and the shining faces of the fresh feldspar, which are slightly lighter than the rest of the rock, are easily recognizable. Feldspar forms 50 to 60 per cent of the rock and under the microscope is seen to be labradorite ($Ab_{45}An_{55}$) occurring in an interlocking mosaic of various-sized grains. The crystals are dusted, especially towards their centre, with minute inclusions, usually dark, having a maximum diameter of 0.01 millimetre. These inclusions are apparently primary. The feldspars show a slight alteration which generally occurs in irregular patches and consists of epidote, zoisite, and carbonate in fine grains. Secondary green hornblende in feathery aggregates traverses the crystals of feldspar along cracks and boundaries between crystals. Light sepia-coloured augite forms about 25 per cent of the rock. Occasional crystal faces are present, but on the whole it crystallized contemporaneously with the feldspar and in grains of like size. The augite crystals are dusted with stumpy dark schiller rods up to 0.1 millimetre in length, which within each crystal are orientated in the same direction. The augite

crystals around their edges have changed to a flaky, secondary, blue-green hornblende. Associated with this hornblende are grains of iron ore, probably magnetite. In some parts apatite in large grains forms 5 per cent of the rock.

Some of the northern outcrops of the mass contain fine as well as coarse-grained phases, grading into one another in short distances and without any definite arrangement. The coarse variety is 5 millimetres in grain and in this and its granitoid texture resembles the gabbro of the southern outcrops. The colour of the rocks of the northern outcrops is lighter and the feldspar more abundant than in the rocks in the southern outcrops. In the field the rock looks like the dioritic phase of a granite. This impression is heightened by the fine phases which form irregular patches of the rock. The feldspar has the same development as that of the rocks farther to the south, but is slightly more acid, and is a basic andesine ($Ab_{55}An_{45}$). It shows the same alteration, but to a greater extent since 50 per cent is affected. Secondary chlorite occurs in irregular patches and has replaced not only ferromagnesian minerals but also feldspar. Hornblende occurs both as the flaky green variety and as crystals that may or may not be secondary after augite. Accessory apatite and iron ore are scattered throughout the rock. A little quartz occurs and is generally associated with the chlorite. This rock gives the impression of having been altered by later solutions; the alteration resulting in the development of the chlorite, quartz, epidote, zoisite, carbonate, and some of the hornblende. The secondary chlorite and quartz may be the strongest evidence in favour of the action of later solutions. Although so much altered this rock is areally close to the gabbroidal rock previously described and in many ways resembles it. It is, therefore, at present considered as a phase of the same rock.

The relation of the whole gabbroidal mass to the adjacent rocks is not clear. The drift cover hindered the direct observation of the structural relations to the neighbouring rocks. Phases of the mass are fresh as the later gabbro dykes common throughout western Quebec, but texturally it does not closely resemble them. The alteration that the northern part of the gabbro mass has suffered may have been due to the metamorphic action of a later intrusive; or the altered northern gabbro and its fresh southern phase may be a part of the neighbouring body of oligoclase granite and oligoclase syenite which has suffered much greater but similar mineralogical alterations.

CONGLOMERATE AND FINE SEDIMENTS

East of Lake David map-area, on the north shore of Chibougamau lake in McKenzie bay and Contact bay, are beds of steeply tilted conglomerate and finer sediments. These sediments were mapped by the Chibougamau Commission and like the similar, but flat-lying, sediments to the north on Wakonichi lake, were tentatively correlated with the Lower Huronian or Cobalt of northeastern Ontario.¹ Lithologically the rocks are similar to the Cobalt and are coarse conglomerates carrying boulders

¹ Chibougamau Mining Commission Report, 1911, p. 134.

and pebbles of granite, and finer sediments such as sandstones, slates, and shales. On lake Wakonichi remnants of the series rest upon an eroded granite surface and on the same lake and on McKenzie bay remnants rest upon an eroded surface of lavas. This series both on McKenzie bay and lake Wakonichi is cut by quartz veins.¹ A vein near Conglomerate point on McKenzie bay is 4 feet thick, flat-lying, and can be traced for some hundreds of feet. The quartz is white, glassy, and contains a little tourmaline.

It is possible that an intrusive of the same age as one of the mapped intrusives in Lake David area is responsible for the quartz veins cutting the sediments on McKenzie bay and Wakonichi lake. On Wakonichi lake these sediments rest on an eroded granite surface.² The veins can not, therefore, be attributed to the underlying granite. They are due to a later intrusive which, so far, has not been recognized.

The steeply tilted attitude of the sediments on McKenzie bay indicates strong folding since their deposition. As these upturned sediments are north of a known east-west belt of northward facing, older volcanic flows, it is reasonable to assume, tentatively, that they lie in a synclinal trough of folded volcanics. The slates mentioned by the Commission³ as occurring at the outlet of lake Bourdeau and near the southwest end of lake Gwillim, 8 and 16 miles west of McKenzie bay, may also be of the same age and lie in the same synclinal trough. The establishment of the age of these sediments relative to that of the folding suffered by the volcanics and to the time of intrusion of the acid intrusives of the region will clarify some of the major geological problems of the area. It may be mentioned that Low in 1905 suspected that the granites in the area⁴ were of at least two ages.

STRUCTURE

As previously stated the belt of volcanics along the northern boundary of the area strikes east and west, dips vertically, and faces north. The synclinal axis of these folded volcanics must, therefore, lie to the north in the hilly belt. The steeply dipping sediments on McKenzie bay may lie infolded in this syncline. The slates in the vicinity of Bourdeau and Gwillim lakes may also lie in this syncline. The 6 to 8-mile wide intrusive belt to the south of these volcanics and sediments was presumably intruded along an east and west anticlinal axis paralleling the postulated syncline.

Remnants of volcanics have been found at points across the northern half of this intrusive belt. The greenstone areas may be considered as roof pendants, remnants of the once overlying rocks that erosion has since swept away. The distribution of these greenstone remnants indicates a flat roof to the intrusive rocks. The three types of intrusives in this belt may be considered as successive products of crystallization at the top of the intruding magmatic mass. The irregular areal distribution of the various intrusives is possibly due to the thinness of the successive shells of solidified

¹ Chibougamau Mining Commission Report, 1911, p. 53.

² Chibougamau Mining Commission Report, 1911, p. 136.

³ Chibougamau Mining Commission Report, 1911, p. 136.

⁴ Geol. Surv., Canada, Pub. 923, p. 36.

differentiates, to the irregular intrusion of the younger types into the older, and to the truncation of the intrusive assemblage by erosion.

Shearing is common throughout the area. In certain sections the volcanics are strongly sheared. Just within the southern border of the volcanics and extending for approximately 8 miles in an east-west direction from lake Asinitchibastat to a point 2 miles northwest of Caché lake a strong shear zone is present. The strike of the shearing varies slightly from point to point along this distance, but is approximately east-west and has a vertical dip. The width of this zone in places exceeds 1,000 feet. At a point three-quarters of a mile north of David lake the granite immediately in contact with the greenstone has suffered the same shearing. A short distance south of this sheared granite the rock is massive. Another strongly sheared zone lies north of Cedar bay on the north shore of Dorés lake immediately north of the anorthosite contact. Owing to lack of outcrops this shear zone was only traced for a short distance. It has a width of at least 300 feet, a strike of 20 degrees south of east, and a steep dip to the north. Very probably it is much wider and persists along its strike, but is hidden by drift. Shearing on a much smaller scale was observed in other parts of the volcanic area. An east-west shearing with vertical dip was seen on the township line a mile east of lake Asinitchibastat. Shearing, striking 80 degrees east of north and having a vertical dip, was seen half a mile east of mile-post IX and also in the vicinity of mile-post VIII where it strikes 30 degrees south of east and dips 30 degrees to the north.

The strongly sheared zones in the volcanics show much alteration due to mineral solutions. In these shear zones small quartz veins are found, also considerable carbonate and minor quantities of magnetite, pyrite, and chalcopryrite. A mile north of David lake in the long east-west shear zone, a 1½-inch stringer of light-coloured sphalerite with disseminated pyrite occurs. Similar mineralization was observed in some cases within areas of volcanics showing much less shearing.

The anorthosite generally shows a shattered and crushed structure, and in places is strongly sheared. A good example of this is to be seen on the north side of Merrill island on the Blake showings. The shear here has a width of 30 feet, strikes northwest-southeast, dips vertically, and is heavily mineralized with quartz, carbonate, pyrrhotite, pyrite, and chalcopryrite. Opposite Merrill island, on the north shore of lake Dorés, half a mile northwest of the above shearing, two small prospect pits disclose shearing having the same strike, dip, and mineralization. The shearing on the island and north shore are probably related. A similarly mineralized shear having a strike of 20 degrees south of east and vertical dip occurs in the anorthosite on the McKenzie showings on the point on the southwest part of McKenzie bay.

The east-west regional structure is believed to be closely related in time of origin, with the period of intrusion of the east-west trending belt of intrusive feldspathic rocks. The shear zones in the area are certainly younger than the greater part of the feldspathic intrusives and are presumably younger, though influenced in many cases by the east-west regional structure.

RECENT AND PLEISTOCENE

The effects of Pleistocene glaciation are evident throughout Chibougamau area. Erosion since the retreat of the ice has done little to modify the Pleistocene deposits. The hilly country shows the effects of glaciation in the rounded surfaces of the hills and the moraine-covered slopes and valleys. The lower areas are covered by a mantle of morainal material, usually unassorted. Comparatively low, rolling areas are floored with sand and gravel, probably deposited as outwash material from the melting and retreating ice. The direction of flow of the last ice-sheet is indicated by southwesterly striking glacial striæ and by the similar trend of the lakes that fill glacially formed channels. The points and ridges of morainal material that form the crenulated shores of the lakes show in their configuration the influence of the southwesterly moving ice-sheet.

Areas of poorly drained muskeg country, an irregular drainage pattern, and minor recent adjustments of this drainage indicate a very youthful stage in the present cycle of erosion, the start of which was at the end of the glacial period. The peaty material in some of the muskegs and the delta deposits at the mouths of some of the streams are the only deposits of post-Pleistocene age in the area.

ECONOMIC GEOLOGY

Examination of the mineralized showings was confined to the few sulphide discoveries made since the Commission's survey of the region and to the collection of specimens from Asbestos island in McKenzie bay, Chibougamau lake. In most cases the properties so thoroughly reported upon by the Commission are not now easily examined owing to caving of workings and growth of vegetation. The writer's work on Asbestos island corroborates the finding by the Commission that no promise exists of an economic deposit of asbestos on the island. Although deflexion of the compass needle indicated its presence in the locality, it was not known until the writer left the field, that a titaniferous iron deposit had been discovered on block D of the holdings of the Blake Development Company, Limited, on the northwest shore of lake Dorés.

STEELE AND FORTUNE CLAIMS

Two miles northeast of the northeast corner of the map-area, at a locality a mile north of Proulx bay at the northeast end of lake Dorés, a block of eleven claims were staked in 1926 by T. A. Steele and T. Fortune. The area in which the claims lie is hilly and heavy moraine hinders the prospecting of the lower parts. The composition of the bulk of the volcanics that underlie the claims is basic andesite. Near the northeast part of the group on claim Q1393 is a mineralized zone which has been prospected intermittently for 500 feet by pits and strippings. The exposed part of the zone strikes north and south, dips vertically, and starts 500 feet northwest of the southeast corner post of the claim. The southernmost pit shows a zone 8 feet wide composed of ramifying, glassy quartz veinlets

cutting across the basic volcanics and including fragments of them. Quartz forms 50 per cent of this zone; calcite and some pyrrhotite and chalcopryrite occur. One hundred feet farther north, stripping discloses 2½ feet of a north and south striking mineralized zone similar to the last. Sphalerite is present in small quantities, in addition to chalcopryrite and pyrrhotite. One hundred and fifty feet farther north, the same minerals occur in a single, branching vein 18 inches wide. One hundred feet farther on, small, irregular masses of barren quartz involve fragments of the country rock. Two pits in the next hundred feet disclose narrow stringers and sugary replacement quartz carrying small amounts of sulphides. One hundred and fifty feet west of the last outcrop, an east-west striking quartz vein 1 foot wide cuts a gossan-covered outcrop. On an outcrop 500 feet northeast of the last-mentioned outcrop, near the northeast corner of the claim, a 2-foot zone striking a little south of east and dipping steeply, is composed of granular, white, and cherty quartz, containing small amounts of chalcopryrite, pyrite, and pyrrhotite. On the southeasternmost claim, Q1402, 2,000 feet south of the south pit on the 500-foot zone described above, a north and south trench 25 feet long cuts across a gossan-covered outcrop. The southern 10 feet is a basic andesite containing a small percentage of pyrite. This gives place to a vertically-dipping bed of volcanic fragmental, 5 feet wide, striking a little north of west. The matrix of the fragments is replaced by fine-grained pyrite, forming 30 to 70 per cent of the total rock mass. The rest of the trench shows partly drift-covered gossan-stained rock. A few calcite stringers and what appear to be fine, silicified stringers cut the outcrop.

The mineralization on this group of claims is not heavy, but it is widespread. If substantial gold values are shown by the assays of the mineralization now exposed, further exploration for greater concentration of mineralization is justified. The thorough exploration of the north and south mineralized zone may show it to be made up of a series of veins rather than one continuous vein. The relationship of these veins to the east-west striking veins should also be studied. As the magnetic mineral pyrrhotite forms an appreciable amount of the mineralization, a dip-needle or magnetometer survey of the claims might help in locating mineral zones.

MCKENZIE SHOWING, CEDAR BAY

The Chibougamau McKenzie Mining Corporation holds a number of claims in the vicinity of Cedar bay on the north shore of lake Doré. In 1922 mineralization was uncovered on the point at the southwest extremity of Cedar bay, on claim number Q581. Work that year and subsequent years resulted in stripping, 50 feet of rock trenching, and in sinking of a 19-foot prospect shaft.

Stripping and trenching have exposed bedrock over an area of more than 200 feet east and west and 130 feet north and south. At the north edge of the stripped area the rock is believed to be a rhyolitic volcanic, engulfed in the anorthosite at a place three-quarters of a mile south of the anorthosite-greenstone contact. The rhyolite is exposed for a width of 15 feet. It is porphyritic with 3 millimetre phenocrysts of

quartz in a fine-grained, altered groundmass. The phenocrysts have smooth, rounded edges and many contain inclusions of the groundmass. The groundmass is not uniform in composition and there is a suggestion that areas of secondary minerals may represent completely altered feldspar phenocrysts. In places about 50 per cent of the groundmass is a fine-grained mosaic of quartz grains with intricate outlines, in other parts the quartz forms a much lower percentage. About equal quantities of chlorite and white mica, in minute flakes and small aggregates, compose the rest of the groundmass. Dust-like, black particles of what is probably iron oxide occur through the section. Minute veinlets composed of equal amounts of quartz and chlorite in fine grains traverse the rock. A few grains of pyrite were seen in an area rich in mica. The rhyolite on the south side is in contact with a dark, sheared rock intruded by a large number of narrow, dark quartz veins. The strike of the shearing and of the veins, south 65 degrees east, corresponds to the strike of the rhyolite contact; their dip is vertical. The width of this dark rock is approximately 40 feet. In appearance it closely resembles basalt or tuff, but thin sections show it to be a completely altered, sheared anorthosite, probably the oligoclase anorthosite. The rock is composed of aggregates in many cases with fairly regular boundaries, and veinlets of light-coloured, blue, polarizing chlorite; of patches composed almost entirely of fine, flaky white mica; and of areas of the two minerals intimately mixed. A small percentage of fine-grained carbonate is irregularly scattered throughout. A lace-like yellow crystal 2 millimetres in diameter was seen in one section and is believed to be titanite. The alteration exhibited is attributed to mineralizing solutions that were associated with the dark quartz veins and disseminated sulphides. The sulphides are pyrite and chalcopyrite. A little cobalt bloom was collected, but the cobalt or cobalt nickel mineral of which it is a weathering product has not been identified. In two zones, respectively 7 feet and 3 feet wide, the quartz veins form 40 to 60 per cent of the rock mass, but in other parts the quartz veins form a much smaller proportion. In the 7-foot zone the sulphides form about 10 per cent of the mass, but in places form as much as 50 per cent. The mineralization is usually closely associated with the dark vein quartz which often shows shattering. Fine stringers of sulphide and disseminated particles are also found in the dark chloritized country rock. The sulphides are in places largely pyrite and in other places largely chalcopyrite. Evidence gathered from a study of polished sections is somewhat conflicting, but it is believed that the quartz and sulphide mineralization is contemporaneous. One specimen shows a vein of pyrite one inch wide cutting across dark quartz. The pyrite and quartz are shattered and dark quartz fills the cracks in the pyrite. A little chalcopyrite is scattered in grains within the crystals of pyrite composing the vein and is also associated with the quartz filling the cracks in the pyrite. Chalcopyrite and pyrite are found along the fracture zones in the adjacent dark quartz. Another specimen is composed of equal amounts of dark quartz and finely disseminated sulphides. The pyrite occurs in grains of 4 mm. in diameter down to minute particles. Most of the pyrite apparently crystallized at the same time as the quartz, some of it slightly later. The chalcopyrite is

closely associated with the quartz crystallization and appears to be later than some of the pyrite.

South of the 40-foot band of highly altered anorthosite occurs a light green, soapy, shattered anorthosite having a breadth of 70 feet. A section of a specimen taken near the edge of the 40-foot mineralized zone shows chlorite veinlets with a small percentage of what is probably untwinned acid plagioclase. Carbonate is absent from the rock or in minute quantities. Scattered minute flakes of white mica are present. The rest of the shattered rock is a felt of minute, white mica flakes with a very low amount of associated chlorite. Within this rock, 50 feet south of its north edge, is a prospect shaft sunk on a mineralized zone 70 feet long, striking north 80 degrees east and dipping vertically. The width of this zone varies from nothing to 6 feet. Although some shearing continues from the two extremities of the zone the mineralization does not extend into the immediately adjacent rock.

The mineralization is roughly banded. In the shaft, within a few feet of the surface, the mineralization consists of 2 feet of dark, glossy quartz containing up to 80 per cent of chalcopyrite, followed on the north by 3 feet of black, chloritized, sheared anorthosite holding disseminated pyrite and chalcopyrite. When visited, the shaft was filled with water to within 8 feet of the surface. Down to water-level the mineralized zone was seen to widen slightly. From information of a reliable nature it is understood that this slight widening continues to the bottom of the 26-foot shaft where the width is stated to be approximately $6\frac{1}{2}$ feet. Polished sections of material from the shaft show that the relationships of the sulphide minerals and the dark vein quartz are much the same as in the mineralized zones to the north. The pyrite, chalcopyrite, and quartz are essentially contemporaneous, although the chalcopyrite is probably slightly the latest.

No statements of exact assay values are available, but it is known that encouraging assays in gold and copper were obtained from the mineralized zones north of and in the shaft, and that silver values were also obtained. The amount of mineralization already exposed on this property is encouraging and warrants careful prospecting along the present known zones and on their flanks in search of further zones.

CEDAR BAY

Northeast of the McKenzie showing, half-way up the east side of Cedar bay, is a greenstone area exposed in a 120-foot trench along the water's edge. This stripping was done in 1926 by Mr. Austin Dumonde. The greenstone is a fragment engulfed in the anorthosite and lies one-half mile south of the contact of the anorthosite with the main area of greenstones to the north. In the north part of the trench is a fine-grained, altered diabase that to the south gives place to a much weathered rock that is possibly a spherulitic andesitic flow. Half-way along the trench, in the diabasic greenstone, is a mineralized zone 6 feet wide, striking 35 degrees south of east, with an apparent dip of 75 degrees southwest. The zone is somewhat sheared and the mineralization is imperfectly banded. Sulphides form from 10 to 50 per cent of the rock

and average 20 per cent. The sulphides apparently replaced the sheared greenstone and are associated with quartz, calcite, and siderite. The banded mineralization is composed of carbonates, chloritic material, glassy quartz, and varying amounts of pyrite, magnetite, and chalcopyrite. The pyrite and magnetite are contemporaneous, the quartz and chalcopyrite finished crystallizing shortly after the other two. A 4-inch, glassy, white quartz vein strikes along the zone. The vein carries equal amounts of pyrite and chalcopyrite, which, combined, form about 15 per cent of the vein. The pyrite does not show a euhedral form and the chalcopyrite has a dendritic habit. The quartz and the two sulphides were closely contemporaneous in time of crystallization.

Similar mineralization is found on the west shore of Cedar bay on the strike of this showing. During the latter part of the summer of 1927, The Consolidated Mining and Smelting Company of Canada, Limited, did some systematic exploration west of the shore, the extent or results obtained are not known.

Three-fifths of a mile north of the showings just described, 1,000 feet north of the bottom of Cedar bay and 500 feet north of the greenstone-anorthosite contact, a few sheared, rusty outcrops are found. The shearing strikes 20 degrees south of east and dips vertically. Along this shearing narrow quartz veins cut carbonated and rusty weathering greenstones. This mineralized zone is hidden along its strike by drift, but it must be at least a few hundred feet long and 300 feet wide. No work has been done to ascertain the extent or nature of the mineralization in this zone.

BLAKE SHOWING, MERRILL ISLAND

The Blake Development Company, Limited, hold under mining concession 136, four claims on the shore of Dorés lake. Block C is on the east end of Merrill island and has an area of a little over 100 acres. At the extreme northwest corner of the block, on the shore, mineralization was discovered and subsequently trenched and examined. The exposed rock on this property is a soapy, altered anorthosite resembling the anorthosite in the vicinity of the prospect shaft on the McKenzie showing. It is part of the large mass of anorthosite found in the north part of Dorés lake.

Trenching on the north side of the island within a width of 30 feet and a length of 250 feet in a southeasterly direction from the shore, discloses a mineralized shear zone. This shear has a strike of south 40 degrees east and a vertical dip. At the northwest end of this trenched area, on the shore, a trench 25 feet long across the shear discloses strong shearing and banded mineralization. The 12 feet in the southwest part of this trench is heavily mineralized with quartz, pyrrhotite, chalcopyrite, and some fine and coarse pyrite. The sulphides form from 30 to 50 per cent of this zone. The next 6 feet to the northeast is similarly mineralized, but not so heavily, and the sheared, altered anorthosite forms a greater part of the material. Study of a thin section showed a rock irregularly composed of a felt of white mica, lesser amounts of chlorite, zoisite, and untwinned plagioclase in about equal quantities, and a small amount of quartz in fine grains and dendritic crystals. The feldspar in many cases

formed crystals 3 millimetres in diameter full of other products. Farther to the northeast the trench discloses sheared anorthosite and disseminated sulphides.

In the various rock trenches found for 250 feet southeast of the lake shore, there is, away from the lake, a progressive decrease in the intensity of shearing and mineralization. In the trench 250 feet from the lake, mineralization is scarce and the country rock merely shows a blocky shattering.

The sulphides and the quartz are believed to have been deposited at the same general time and in this way the mineralization resembles that seen on the McKenzie showing. In the specimens studied the pyrite is earliest, the quartz crystallized and was shattered before the deposition of the greater part of the pyrrhotite and chalcopyrite which are contemporaneous, the period of crystallization of the chalcopyrite continuing slightly longer than that of the pyrrhotite. The relative amounts of the sulphides vary, chalcopyrite and pyrrhotite predominate, and pyrite is usually subordinate.

Small mineralized shears having the same strike and dip occur on the strike of the one just mentioned half a mile to the northwest on the north shore of lake Dorés. Two small prospect pits on these shears disclose the same type of mineralization as that in the sheared zone on Merrill island.

Substantial values were found in the mineralized trenches near the lake. The report of J. G. Ross, of Milton Hersey, of Montreal, notes values in one case over a width of $31\frac{1}{2}$ feet as being 4.3 per cent copper and \$14.03 in gold.¹ Greater values over shorter lengths were obtained in other trenches. If further work is done on this property, it should be directed to ascertain the value and persistence of the mineralization under the waters of the lake, for indications point to a probable increase in mineralization in that direction and the possible existence of a commercial ore-body.

Other Mineralized Showings. Sulphite mineralization in anorthosite is known to occur on block B held by the Blake Development Company, Limited, but was not examined by the writer. This block is 2 miles west of Cedar bay, on the north shore of lake Dorés. One-quarter mile north of the northwest corner of the block, stripping done during 1927 under the direction of Mr. R. T. Gilman, disclosed pyrite-quartz mineralization associated with an altered quartz oligoclase feldspar porphyry intruding greenstones near the greenstone-anorthosite contact.

Pits at various points in the anorthosite on the north shore of Dorés lake and at the east end of the portage from Dorés lake into the north end of Caché lake, show small amounts of sulphide mineralization: pyrite, chalcopyrite, and, in places, pyrrhotite and sphalerite. On Knoll island off the southwest end of Merrill island an irregular mass of glassy quartz is present, having a length of 50 feet and a maximum width of 12 feet. The country rock is a sheared, chloritized dark granite. South of Knoll island the rock outcrops are granite and to the north anorthosite. A little pyrite

¹ Mineral Resources, Canadian National Rys., 1926, p. 32.

and chalcopyrite, and tourmaline are associated with the quartz. Although an unpromising-looking showing, assays by three independent parties have shown high values in gold.¹

Two large fragments of mineralized, glassy, white quartz float lie on the north shore of a small island in range V, Obalski township, near the west shore of lake Dorés. The sulphide mineralization consists of scattered masses of chalcopyrite and a little pyrite. The fragments of quartz are 40 feet apart and 8 and 10 feet in diameter. In their vicinity at least six other pieces more than a foot in diameter were seen. The number of pieces of this mineralized float in the one locality makes it very probable that the float is not far from its source. The south-southwesterly moving Pleistocene ice-sheet probably plucked these pieces from a vein now covered by water and less than half a mile to the north-northeast. The mineralization is not particularly rich, but it is notable that such mineralization should be found in the centre of the intrusive belt.

Quartz sulphide mineralization is found in sheared greenstone and dioritic looking rocks at the north end of the long point on the south shore of lake David, and on the point on the west side of the entrance into lake Simon, just southwest of Deschênes island.

Carbonization and, at points, pyrite and chalcopyrite mineralization, are to be found in the 8-mile shear extending east from lake Asinitchibastat to a point $1\frac{1}{2}$ miles northwest of the north end of Caché lake. In this shear, in the greenstone just north of the granite contact, at a point a mile north of the northeast corner of David lake and half a mile east of the stream flowing into the north end of David lake, the sheared greenstone is strongly carbonated and disseminated pyrite is sparingly present. The stripping of some moss disclosed a $1\frac{1}{2}$ -inch vein striking with the shearing at 10 degrees north of west. The vein is composed of about 2 per cent of cubical pyrite up to 2 millimetres in size, 70 per cent of light-coloured sphalerite containing minute particles of chalcopyrite, and the rest white granular quartz.

CONCLUSIONS

All the rocks of the area, except the gabbro, are much altered. The original constituents have been largely replaced by minerals such as chlorite, white mica, zoisite, epidote, and carbonate, and, possibly, acid plagioclase and quartz. In various thin sections veinlets carrying quartz, epidote, and zoisite were seen cutting altered anorthosite. Chloritized parting planes in the crushed anorthosite are structurally similar. Although these minerals are, no doubt, largely due to the regrouping of the original constituents of the rocks, it is probable that at least some material going into their formation was derived from an outside mineralizing source. The minerals of the rocks composing the sulphide-bearing zones are usually the same as those in the otherwise altered rocks. Small amounts of sulphide are found throughout the area mapped. It seems, therefore, that the available evidence points to the greater part of the area having been pervaded by solutions capable of producing the alteration minerals mentioned and

¹ Chibougamau Mining Commission Report, 1911, p. 210.
Mineral Resources, Can. Nat. res., 1926, p. 32.

of depositing, at a certain stage and under favourable conditions, quantities of the sulphides.

The sulphide mineralization occurs as sulphide-bearing quartz veins cutting massive country rocks, or as sulphide replacements in shear zones. Mineral solutions can travel comparatively easily along shear zones and owing to the crushed nature of the country rock, replacement is facilitated. When prospecting for sulphide deposits special attention should be paid to shear zones containing carbonates, chlorite, or quartz veins.

The introduction of the material forming the secondary minerals in the rocks and of that which gave rise to the sulphide-quartz mineralization, was probably not all contemporaneous, but, very probably, in many cases took place along the same channels. The chlorite and associated minerals were probably caused by solutions earlier than those giving rise to the sulphides and quartz, but nevertheless all the solutions may have been genetically related. Further work in the area may show that the altered chloritized rocks were more favourable to the deposition of sulphides than rocks not so altered. The sulphides are pyrite, magnetite, pyrrhotite, chalcopyrite, and sphalerite. Although in no one place are all found together, their distribution and relationships strongly suggest a common, contemporaneous origin. As no acid intrusive later than the albite-oligoclase granite and capable of producing quartz-sulphide mineralization is known, it is probable that the albite-oligoclase granite is the source of the presumably single period of mineralization and that the mineralization took place shortly after the consolidation of this granite.

As previously pointed out the regional structure seems to be closely related to the intrusion of the three acid feldspathic rock types of which the albite-oligoclase granite is the youngest. Most of the shearing also seems closely related to the folding. The presumed single period of mineralization is believed to have occurred after or near the end of this period of folding which involved the volcanics, younger sediments, oligoclase granite, and anorthosite. This folding probably ended with the intrusion of the albite-oligoclase granite. All the rocks older than the albite-oligoclase granite may, therefore, have been the country rock in which sulphide mineralization took place, and should be carefully prospected, especially along carbonated, chloritized, or quartz-bearing shear zones.

At or near the northern edge of the intrusive belt are found many of the mineralized showings and it is reasonable to expect that similar conditions and equally favourable prospecting ground are to be found along the southern edge of this, lying 2 to 5 miles south of the map-area (See Notaway Sheet, Geol. Surv., Canada, No. 190A). Prospecting there will be hampered by extensive areas of drift. The remnants of greenstone, and the areas of anorthosite and of dark oligoclase syenites and granites in the central part of this presumably flat-roofed intrusive belt, should be carefully prospected. The McKenzie and Blake showings on Merrill island lie in this intrusive belt and the mineralization on Knoll island is half-way across it.

Although little is known of conditions in the region north of Lake David area, it would be surprising if in this comparatively large area of greenstones, acid intrusives and related mineralization are wholly absent.

As the magnetic minerals, magnetite and pyrrhotite, in many cases form part of the mineralization, dip-needle or magnetometer surveys of suitable ground may help to quickly locate some of the mineral zones. It must be remembered that such surveys will not indicate the presence of the non-magnetic minerals, pyrite, chalcopyrite, or sphalerite if unaccompanied by the magnetic minerals. Adequate electrical surveys will also be of value, but will not indicate the presence of the non-conducting mineral, sphalerite.

EAGLE RIVER AREA, ABITIBI TERRITORY, QUEBEC

By *J. B. Mawdsley*

CONTENTS

	PAGE
Introduction.....	23
Means of access.....	23
General geology.....	24
Economic geology.....	25

INTRODUCTION

During the field season of 1927 geological exploration and mapping were carried on in Eagle River area, the chief part of which is between latitudes 49° 00' and 49° 30', and the longitudes 74° 30' and 75° 30'. A small northern extension lies along the series of lakes drained by Opawika river. The area has an east-west length of 45 miles, a width of 35 miles, and an area of approximately 1,600 square miles. The southern boundary is 60 miles north of the Canadian National railway, and the west boundary 180 miles east of the Ontario-Quebec boundary. The northeast corner of the area lies 20 miles southwest of lake Chibougamau. At least a third of the area is covered with water and large parts of the rest of it by forests of good pulp wood.

A track survey of Opawika river was made for the Quebec Government in 1898 by Henry O'Sullivan. H. C. Cooke¹ made a geological reconnaissance of this river in 1916. The mapping in 1927 was confined to the water courses, except in the vicinity of Little Nemenjish and Kaopotina lakes where bush traverses were made. Able assistance in the field was rendered by Messrs. J. A. Retty and R. M. Williams.

Further topographic mapping, by the Quebec Government, is now in progress and, therefore, a geological map will not be published until this information is available. As it is difficult to discuss the geology in detail without an accompanying geological map, in this report only a generalized account is given.

MEANS OF ACCESS

Eagle River area may be entered by three main canoe routes, two of which traverse the area. The routes to the area are shown on the 3-mile to the inch Saint-Maurice sheet issued by the Quebec Department of Lands and Forests.

The area may be entered from the west by a well-travelled, fairly easy route, that begins at the Canadian National railway about 4 miles west of Monet station and follows Susie river and Cedar lake to Megiscane

¹ Cooke, H. C.: "Some Stratigraphic and Structural Features of the Pre-Cambrian of Northern Quebec"; Jour. of Geol., vol. XXVI, pp. 180-188 (1919).

river and down that stream to the mouth of St. Cyr river. The latter river, which has no rapids, is ascended for 30 miles to lake Bailly in Bailly township, nearly 80 miles by water from the railway and close to the south boundary of Eagle River area. From lake Bailly a portage leads to the headwaters of Eagle river, a north-flowing river that traverses the western part of the area and empties into the northeast part of Father lake.

The other two routes, which may be termed, respectively, the central and the eastern route, begin at Oskelaneo River station on the Canadian National railways and are followed north for 40 miles to lake Obiduan. The central route, which is the more difficult, follows north for 30 miles up a stream to lac Baptiste on the south boundary of Eagle River area, 15 miles from its southeastern corner. From this lake the route is north to Kaopotina lake. The eastern route is along the usual canoe route to lake Chibougamau. From lake Obiduan the route swings northeasterly through a series of lakes to Verreau and Clearwater lakes, whence the well-travelled route is followed north to Lynxeye and Gabriel lakes. These lakes form the headwaters of Opawika river. Gabriel lake is on the east boundary of the area 12 miles from its northeast corner.

Canoes larger than 18-foot freighters are troublesome on these routes as there are many portages. Small out-board motors are useful and economically justifiable. With motors and average loads any of the three routes can be covered in four to six days. The area is dotted with lakes and may be easily explored by airplane.

GENERAL GEOLOGY

The bedrock of the area consists of Precambrian volcanics, sediments, and intrusives. These rocks are very largely covered by glacial deposits, and large, shallow lakes and muskegs.

The oldest Precambrian rocks in the area are volcanics, predominantly andesites which in many places show pillow and other volcanic structures. Rhyolites, basalts, and volcanic fragmentals are present in minor amounts. A thick series of sediment and interbedded volcanics, the Nemenjish series as named by H. C. Cooke, evidently younger than the first-mentioned volcanic series and in contact with them, forms an important proportion of the rocks mapped. The Nemenjish series consists in part of beds of conglomerate, arkose, and slate. Where metamorphism due to a later granite has occurred, the sediments and interbedded volcanics have been converted into hornblende and biotite schists. Intruding the Nemenjish and the older, volcanic, series are large bodies of granite and related syenites. Amphibolites and biotite and hornblende schists occur within the granite areas and are considered to be metamorphosed remnants of the volcanic and sedimentary rocks. Cutting all these rocks are a few dykes of perfectly fresh gabbro closely resembling the new gabbro of Rouyn district, Quebec.

The Nottaway map-sheet (No. 190A, Geol. Surv., Canada) gives a general idea of the geology and drainage features of the northern part of Eagle River area. Opawika river and its tributaries drain most of this region north of the height of land.

On Lac du Bras Coupé which lies a few miles north of the middle of the north boundary of Eagle River area, the rocks are granite. South of this granite is a belt of volcanics, about 5 miles wide and extending, apparently continuously, through the north part of Eagle River area from the northwest part of Father lake on the west, eastward through Windy lake. The volcanics face south.

South of the volcanics is a belt of the Nemenjish series. These rocks are overturned to the south and apparently lie in a synclinal trough whose axis strikes a little south of east. The width of the belt is from $2\frac{1}{2}$ to 5 miles. These rocks outcrop on the south shore and to the south of Kaopotina lake and extend on eastward where in the vicinity of Nemenjish lake are hornblende and biotite schists that are believed to be the metamorphosed equivalents of the sediments. The Nemenjish rocks are intruded by granite which forms a very large mass that extends southward beyond the south boundary of Eagle River map-area. The granite holds small masses of amphibolite and schists which are altered fragments of the intruded volcanics and sediments.

Glacial deposits in places almost completely cover the Precambrian rocks and have greatly influenced the drainage pattern of the region. The lakes in the hilly granite country in the southeast are irregular in shape and trend. They lie in a country marked by ridges and areas of morainic materials. These ridges have steep, north-facing, slopes of fairly regular outline. To the west and northwest of the hilly area is a low district that includes Kaopotina lake and is not more than 30 feet above it. The points and bays of the lakes in this district definitely trend south-southwest parallel with the glacial striæ in this part of the country. The shores of the lakes are composed mostly of wave-washed, rounded boulders and shingle derived from morainal deposits.

Some long sinuous points in the lakes and crooked ridges in other localities, are very probably eskers. These points and ridges of gravel, sand, and small boulders trend generally south-southwest, are narrow, steep-sided, and sinuous. In many places they have a height of 20 or 30 feet above the surrounding moraine-covered country and their tops, which show no evidence of modification by recent erosion, are undulating.

ECONOMIC GEOLOGY

Little prospecting had been done in Eagle River area and the little done has been confined almost wholly to the vicinity of Opawika river and a few of its tributaries. No claims are being held, no assessment work has so far been done, and no economic deposits have been found.

The northern and southern granite masses underlie two-thirds of the area and give no evidence of containing commercial concentrations of feldspar or other minerals such as are in some cases associated with granites.

Part of the greenstone area in the north, especially in the vicinity of Windy lake, is well exposed and there a few, small, glassy, unmineralized quartz veins and several unmineralized shear zones were noted. South of this, especially in the vicinity of Kaopotina lake, outcrops are few.

In this part unpromising quartz veins and shear zones were also seen. South of Kaopotina lake, scattered outcrops of greenstone and sediment give place to outcrops of the large southern mass of granite.

The extensive drift and moss cover will greatly hamper prospecting. Although the area of greenstone and sediments is of considerable size and may possibly contain economically valuable mineral deposits, it is not at present considered as favourable prospecting territory as some adjacent areas of volcanics and sediments.

ZINC-LEAD FIELD OF CENTRAL GASPE, QUEBEC

By F. J. Alcock

CONTENTS

	PAGE
Introduction.....	27
History.....	28
General character of the district.....	29
General geology.....	32
Economic geology.....	36

Illustration

Map 2129. 210 A. Part of Lemieux township, Gaspé county, Quebec.....In pocket

INTRODUCTION

The zinc-lead field of central Gaspé has been described in Memoir 144 which is accompanied by a geological and topographical map of the area. This report, issued in 1926, was based on field work carried on during 1921, 1923, and 1924. No new discoveries were made nor any new developments carried out on the old showings during 1922, 1923, and 1924. In the summer of 1925, however, a new interest began to be taken in the area. Additional veins were uncovered on the Federal and Lyall and Beidelman holdings, the Pioneer Mining Corporation of Canada entered the field and staked claims for themselves, and, in the following year, a block for the Huronian Belt. In 1925, also, Gaspé Mines, Limited, took up a block of claims. During the same year the Federal Zinc and Lead Company carried out a diamond drilling campaign. Prospecting proceeded in 1926 and in the autumn of that year the National Smelting Company of London took an option on the Federal holdings and in January of 1927 proceeded to do diamond drilling. Other companies entered the field and some 30 to 40 square miles of country were soon staked solid. In response to a request from several sources for a more detailed map of the mineral belt and for a report covering the newer discoveries, the writer was sent again into the area. The present report contains the results of this investigation.

An area of some 20 square miles covering the more important mineral holdings was mapped on a scale of 800 feet to an inch and contoured with intervals of 50 feet. Surveying was by means of chain, compass, and barometer traverses, with elevations checked against the readings of a camp barometer. Streams and claim lines were followed and intermediate traverses made at suitable intervals. Ties were made to two township lines cut across the area during the same season by a provincial survey party. Assistance in the field was rendered by E. B. Gillanders, J. G. W. Moore, E. F. Creelman, and O. I. Fetterly. During the writer's absence for a part of the summer the party was under the charge of Mr. Gillanders.

The writer is indebted to the officials of the Federal Zinc and Lead Company and of the Pioneer Mining Corporation of Canada for many courtesies. To Mr. J. Beidelman, Vice-President and General Manager of the former company, he wishes to extend his thanks for the use of the Federal camp buildings and for the maps and plans which were placed at his disposal. To Dr. J. MacIntosh Bell, Managing Director of the Pioneer Mining Corporation, he is indebted for the plans of that company's holdings, prepared by their surveyor, Mr. L. G. Djingheuzian.

The area lies in Lemieux township, Gaspé county, in the interior of Gaspé peninsula. It is drained by Brandy brook and the north branch of Berry Mountain brook, two headwater tributaries of Cascapedia river. It is reached by the road up Cascapedia valley from Cascapedia station on the Quebec Oriental railway which runs eastward along the north shore of Chaleur bay from Matapédia on the Canadian National railway. The road from Cascapedia to the Federal mine is 45 miles long. It follows the east bank of the Cascapedia for 35 miles as far as Berry Mountain camp and the west side of Berry Mountain brook for the remaining 10 miles. The road is well graded and for part of the summer season motor cars and trucks can be driven over it to the Federal mine. Owing to the lack of a gravel top and to poor drainage, it became so cut up during the summer of 1927 that it was impassable for cars and during the latter part of the season wagons had to be used. A trip by wagon from Cascapedia ordinarily occupies two days.

From the Federal camp a trail $3\frac{1}{2}$ miles long leads to the Pioneer camp. Other trains follow the main valleys. During the summer of 1927, in order to facilitate travel within the mineralized belt, the provincial government built several wood roads, the longest of which leads to lake Ste. Anne. Though not graded, these roads are sufficiently good to take a wagon over and are an important help in opening up the country for the prospector.

HISTORY

Interest in the region as a possible mineral producer was aroused in 1909 with the finding of pieces of galena float on a hill near Berry Mountain brook, on the site of the present Federal mine. In the following year James McKinley staked the hill and proceeded to search for the deposit from which the fragments had come. A company, known as the New Richmond Prospecting and Mining Company, was organized to develop the claims. In 1915 Messrs. Lyall and Beidelman entered the field and leased blocks "D" and "E" from this company. They also staked other claims and formed a company known as the Federal Zinc and Lead Company. Another company, the North American Mining Company, was organized with blocks "L" "O" "P" "Q" "R" "S" "T" as their holdings.

The Federal Zinc and Lead company in succeeding years carried out a considerable amount of development on their property and some work was also done by the North American. Interest then lagged for several years until 1925, when new holdings were taken up by the Pioneer Mining Corporation of Canada and the Gaspé Mines, Limited. The taking of an option on the Federal holdings by the National Smelting Company of

London in 1926 led to an additional interest in the region and other companies entered the field and took up blocks, viz., Phelps-Dodge, Mining Corporation of Canada, Harvie Mines, Limited, M. J. O'Brien, Limited, Minerals Exploration Company, Cascapedia Mines, and others. During the past summer prospecting operations were carried out by all these companies.

The following publications contain descriptions of, or references to, the area, its geology and ore deposits:

- Alcock, F. J.: "Geology of Lemieux Township, Gaspé County, Quebec"; Geol. Surv., Canada, Sum. Rept. 1921, pt. D, pp. 71-96.
 "Across Gaspé"; Geog. Rev., April, 1924.
 "The Mineral Deposits of Gaspé"; Can. Min. Jour., October 10, 1924.
 "Shickshock Mountains, Central Gaspé, Quebec"; Geol. Surv., Canada, Sum. Rept. 1924, pt. C.
 "Mount Albert Map-area, Quebec"; Geol. Surv., Canada, Mem. 144.
 "Recent Developments in Gaspé Peninsula"; Bull. Can. Inst. Min. and Met., March, 1928.
- Beidelman, J. C.: "The Zinc and Lead Deposits of Gaspesia"; Address to Society of Chemical Industry of Canada, Montreal, November 21, 1919.
 "Developing Zinc and Lead Deposits in Gaspé Peninsula"; Bull. Min. Inst. Canada, March, 1924.
- Coleman, A. P.: "The Gaspé Peninsula: A study of the Geology of the Region and Its Influence on the Inhabitants"; Roy. Soc., Canada, Presidential Address, May, 1921.
 "Physiography and Glacial Geology of Gaspé"; Geol. Surv., Canada, Mus. Bull. 34.
- Mailhot, Adhemar: "Geological Reconnaissance in the Gaspé District"; Rept. on Mining Operations in the Province of Quebec during the Year 1917, Dept. of Colonization, Mines, and Fisheries, p. 117.
 "Geology of a Portion of the Projected Township of Lemieux, County of Gaspé, P.Q."; Report on Mining Operations of the Province of Quebec for the Year 1918, p. 134.

GENERAL CHARACTER OF THE DISTRICT

The interior of Gaspé is a plateau dissected by deep, steep-sided valleys. The highest part of the plateau is a belt of country lying north of the medial line of the peninsula and known as Shickshock mountains. It is developed on a zone of hard rocks consisting of volcanics, serpentine, and granite. The summits reach elevations varying up to 4,200 feet which is the approximate height of the highest dome on Tabletop mountain. The mountain summits show broad, flat surfaces. Mount Albert, which has an elevation of over 3,700 feet, has for a length of $3\frac{1}{2}$ miles and a width of $1\frac{1}{2}$ miles, a surface almost as flat as the western prairies. Tabletop has a length of over 15 miles and a width of about 5 miles. It shows a rolling mature surface dotted with lakes and ponds.

East of the granite mass of Tabletop, the upland surface is about 1,000 feet lower, and both north and south of the Shickshocks there is a similar rather abrupt descent to a lower plateau region. North of the mountain belt this lower plateau is developed largely on shales and slates, whereas to the south it is formed mainly on limestones and sandstones.

The drainage in the Shickshock belt presents a number of interesting features. For example, the Ste. Anne and Cap-Chat rivers rise south

of the mountains and flow through narrow gorges in them to reach the St. Lawrence; the Matane rises north of the mountains, flows southward through them, turns westward along the foot of the belt, and in a northward swing cuts once more across the range to reach the St. Lawrence. The headwater drainage also shows a large number of examples of stream piracy.

The suggested explanation for these topographic features is as follows: As a result of the folding and deformation in late Devonian time a range of mountains was produced down the middle of Gaspé south of the present Shickshocks. Two sets of consequent streams resulted, one flowing northward to the St. Lawrence trough and one southward to Chaleur Bay basin. In time the region was reduced to base-level. The summits of the present Shickshocks are remnants of this old erosion surface. During the base-levelling process subsequent streams flowing along east and west lines parallel to the strike of the rocks, carved broad valleys, so that this type of drainage became more important than the consequent type. With uplift the streams were rejuvenated and valley-cutting began again. In this new period of base-levelling the limestone rocks on the divide, however, were more easily eroded away than the belt of hard volcanics, serpentines, and granites to the north. With the lowering of the limestone and shale belts, this band of hard rocks began to stand up above the surrounding region. After the softer rocks had been reduced to base-level, there came another period of uplift and once again rapid down-cutting took place. The present deep valleys date from this period of down-cutting. Numerous cases of stream capture took place where streams eating headward along softer rocks like limestone tapped other streams whose courses followed harder rocks. It was such piracy that produced the abnormal features of drainage such as the Matane exhibits.

The zinc-lead belt of Lemieux township lies south of Shickshock mountains. The characteristic topography consists of broad, flat-topped, interfluvial areas separated by deep valleys. The elevation of the upland surface varies from about 1,800 to 2,800 feet, with a general slope to the south towards where the streams converge to join the Cascapédia. To the immediate northeast of the area rises mount Lyall, 3,100 feet high, the most conspicuous topographic feature visible from the Federal belt. It is really an outlier of Tabletop mountain.

The area is drained by the north branch of Berry Mountain brook, Brandy brook, and North Brandy brook. The valleys of these streams and their tributaries are entrenched to depths as great as 1,000 feet below the plateau surface. The valley sides are commonly steep and the change from the flat plateau summit to the valley slopes is abrupt. The degrees of steepness of the valley sides depend to a considerable extent on the character of the bedrock. Hard volcanics commonly give very steep cliffs, as do commonly also horizontally-lying limestones. Folded shales give gentler slopes. Locally the streams have cut narrow gorges and in places there is a tendency for them to disappear underground for short distances.

The mineralized belt of Lemieux township was overridden by glaciers during the Pleistocene. Evidence of this is abundant in the form of erratics scattered over the region. The easiest and best place to observe

these is on the Federal hill where a large area of land has been cleared and some of it ploughed. Numerous boulders of porphyry, basic volcanics, granite, and syenite are to be seen where the underlying rock consists of argillite. In the creek south of the Federal hill is an erratic 10 feet long, 8 feet wide, and 6 feet thick, consisting of a basic rock belonging to the peridotite series of mount Albert; about 2 miles north of the Federal another large boulder of similar rock was observed on a valley slope. Near one of the trenches on the Pioneer property a boulder of banded amphibolite was found and the only locality known to the writer where this rock occurs in place is along the border of the serpentine mass of mount Albert, more than 6 miles to the north.

The smoothed character of certain rock surfaces is also suggestive of glacial action. On the Federal hill north of the staff house, the outcrop of a syenite dyke shows a rounded, smoothed appearance. No striations are present, but the general appearance is most suggestive of glacial scouring. Similar surfaces were observed elsewhere.

In connexion with the glaciation two features are to be noted. The first is that apparently the ice only lightly touched the region, disturbing to only a minor extent the old overburden. Nearly everywhere the character of the rock fragments indicates the variety of the bedrock underneath; if there is more than one kind of rock represented in the loose material the dominant variety is usually the same as the bedrock. This fact is most useful in mapping formations where outcrops are scarce or absent, and to the prospector in searching for mineral deposits. If, for example, a piece of galena float is located it usually happens that the vein from which it came is nearby and, usually, a matter of trenching uphill locates it.

The second point is that though glacially-carried boulders are fairly common not one was observed to be composed of rock that does not occur in place in Gaspé peninsula. In other words, no erratics consisting of Precambrian gneiss or other rocks from the north side of the St. Lawrence have been found. This means either one of two things: (1) that the glaciers which transported the erratics were of local origin spreading out from a central gathering ground in the high interior region of Gaspé; or (2) that if the boulders were carried to their present position by the continental ice-sheet that spread out from the centre of Labrador the ice cover brought little or no material with it.

Local glaciers were present in the high country of the Shickshocks. On the flanks of the higher mountains, such as Tabletop, mount Albert, mount Logan, mount Lyall, and others, cirques exist which were clearly the result of individual glaciers. These show the characteristic amphitheatre forms with steep, in places vertical, walls, and commonly with lakes in the basin bottoms. North of the Shickshocks, also, are huge erratics consisting of granite, which were carried down from Tabletop. Since the direction in which they moved is northward, they must represent the work of local glaciers and not of the southerly moving continental ice-sheet.

The high summits of the Shickshocks present an unglaciated appearance. They are covered with blocks of rock of the same character as the underlying bedrock. Along geological contacts there is little mixing of the

loose fragments of the two adjacent varieties. There is an absence of smoothed, polished, and striated surfaces and many small irregularities of bedrock project which would certainly have been worn down had an ice-sheet passed over. From these facts Coleman, who studied the glacial features of the peninsula, concluded that the Labrador ice-sheet did not override Gaspé and that the erratics to which reference has been made were carried to their present position by local glaciers that had their gathering ground in the mountain belt.

There is, however, an alternative possibility. Coleman has more recently collected evidence that eastern Canada and Newfoundland suffered two periods of glaciation in Pleistocene time, separated by a long interglacial period. It is possible that the first of these advances from the centre of Labrador did extend over the top of the Shickshock range, removed the old residual soil, and scattered local erratics. Little or no morainal material from Labrador, however, was carried far inland into Gaspé. Since this period of early glaciation there has been enough time for the surface rocks to weather, destroying the glaciated surfaces, and for frost action to produce the broken blocks of rock which strew the higher surfaces. The later period of glaciation brought morainal material from the north shore of the St. Lawrence and scattered it along the northern part of Gaspé. The ice, however, was not thick enough to override the Shickshocks, so that during this period the only glaciers in the high interior were of local origin.

GENERAL GEOLOGY

An outline of the general geology of Gaspé peninsula is given in Memoir 144. The following description is limited to the rocks of the map-area.

Table of Formations

Upper or Middle Devonian.....	Veins Porphyry Syenite
Middle Devonian.....	Sandstone
Middle or Lower Devonian.....	Volcanic rocks
Lower Devonian.....	Limestone, argillite, quartzite, volcanic tuffs

LOWER DEVONIAN

The greater part of the map-area is underlain by Lower Devonian sediments with some tuffs. The more important finds of ore were made in this series and in the recent period of staking it was the belt of these rocks that was taken up first. Later claims were taken up on volcanic and sandstone country.

Outcrops of this series occur at abrupt changes of slope and, in places, in the beds of streams. They are so few, however, that it was impossible to work out a succession or establish structure. The rocks are highly tilted

and have been faulted and brecciated so that strikes and dips are very irregular. The following is a description of the main varieties of rock included in the series.

Limestone is an important variety in this series. It varies from light grey to dark bluish grey, occurs in beds ranging from thin to thick, and is locally fossiliferous. Fossils from several localities in the map-area indicate that the series is of Lower Devonian age and that it probably corresponds to the Bon Ami and the Grand Greve limestones, subdivisions of Logan's Gaspé Limestone series. With the limestone are associated argillaceous and sandy beds.

Argillaceous rocks are also common in this series. They vary from shales to hard argillites. On a fresh surface they are commonly black, but weathered fragments are usually grey. Interbedded with them are limestone and calcareous bands, and, in places, also sandy phases. The black limestone associated with these rocks occasionally contains abundant crinoid stems. In some places breccias composed of angular fragments of all sizes and shapes have formed; in other places the beds are finely jointed, and locally a cleavage is developed across the bedding planes.

On some of the claims in the northern part of the map-area, a considerable amount of loose fragments of quartzite occurs. Outcrops of this rock were observed on claims 1849 and 1853. The rock is made up of small, well-rounded quartz grains well cemented by silica. The scarcity of rock exposures makes it difficult to be certain of the stratigraphic position of these beds, but the fact that they occur in the limestone belt makes it probable that they are horizons in the Lower Devonian series.

Associated with the limestones and argillaceous rocks are beds containing a considerable amount of tuffaceous material. The best place to study these varieties is the Federal mine itself, though good exposures occur also on the upper part of Little Lake river northeast of the map-area. The rocks at the Federal mine are very hard and are finely banded. The banded effect is brought out to the best advantage on the weathered surface. The colour bands are extremely narrow and ordinarily no pyroclastic material can be made out with the naked eye or with the lens. In examining the cores from drill-holes at the Federal mine fresh specimens were obtained for study. These include hard, black, argillaceous limestones, dense grey rocks too fine-grained to make out individual fragments with a lens, and hard, massive rocks in which angular fragments, suggestive of volcanic material, can be seen with the unaided eye. Thin sections of these various types were cut for microscopic study. One variety, a dense grey rock, in thin section was seen to consist of ash material composed largely of glass. A certain amount of secondary quartz, sericite, and calcite was also present. In other sections angular fragments of altered rock were present in the same type of matrix. Other sections showed a carbonate matrix in which were numerous fragments of quartz and some ash material. Apparently volcanic activity took place while the limestone and shale sediments were accumulating.

MIDDLE OR LOWER DEVONIAN

Overlying the Lower Devonian sediments is a thick series of dark-coloured volcanic rocks. They occupy the southern part of the map-area. Outcrops are fairly abundant in streams and on valley slopes. In places they give rise to steep cliffs.

The rocks vary from dense, massive types to porphyritic varieties showing lath-shaped crystals in a dense matrix. Amygdaloidal varieties are to be seen in a number of places. The amygdules consist of calcite and quartz. Some have a greenish border of delessite and some of the smaller amygdules are completely filled with this mineral. In thin sections the rocks show a range of types varying in composition from intermediate to basic. A common variety shows phenocrysts of labradorite in a groundmass of augite penetrated in all directions by laths of labradorite. Olivine is present in one section studied. Other sections show a typical ophitic texture with no phenocrysts and with nearly all the augite altered to a pale green chlorite. In some specimens quartz occurs in minor amounts and the types may be said to range from andesites to olivine basalts.

These basic rocks are locally mineralized. In the amygdaloidal variety at the narrows of Berry Mountain brook about 2 miles below the Federal mine, cubes of galena occur in the calcite amygdules in places. At other places small calcite veins cut these rocks, but as yet no strong vein of commercial possibilities has been found.

MIDDLE DEVONIAN

A small part of the map-area is underlain by a clastic formation equivalent to Logan's Gaspé Sandstone series. In this area it rests on a thick mass of the basic volcanic rocks previously described. During 1927 some claims were taken up on this belt, but as yet nothing of interest has been located on them. The rock varies from grey to buff, in some cases with a greenish or reddish tinge. Associated with the sandstone are shaly and, in places, conglomeratic beds.

The series covers wide areas in the interior of Gaspé. The best sections are along the eastern coast where it was first studied by Sir William Logan. The series there rests on the Gaspé limestone and is almost conformable with it, the difference of dip being at most only a few degrees. According to Logan the series shows a thickness of 7,036 feet, but Ells, who later studied it, was of the opinion that this amount is too great, owing to the probability of repetition of parts of the series through faulting.

The series contains an interesting flora of Devonian age. The commonest plant is *Psilophyton* which locally occurs in great abundance. Specimens can be collected along the road leading to the Federal mine about 2½ miles south of the property. Petrified trunks of the giant alga, *Prototaxites*, also occur locally. Specimens of this were obtained during the past summer from a sandstone exposure on the Gaspé coast near Cross point, opposite Campbellton. Other species have also been described by Dawson. Marine invertebrates have also been found in the series. The forms are Middle Devonian, including some survivals of an early Devonian fauna.

The best exposures of the series in the region of the map-area are along the road leading to the Federal property. There the beds are hori-

zontal. Locally, the series contains shale and limestone pebbles, thus suggesting a break between their deposition and that of the underlying Gaspé limestones. In most cases, however, throughout Gaspé, the sandstones are folded, showing that the main period of deformation was after their deposition.

Though the series contains some marine horizons it is believed that most of it was deposited under continental conditions. It is probable that it represents a huge delta whose material was derived from an ancient land mass to the east.

UPPER OR MIDDLE DEVONIAN

Throughout the map-area are small areas of dense, light-coloured igneous rocks that are locally porphyritic. They furnish good outcrops on the steep slopes of the valley sides, but it is rare that exact contacts can be located without trenching, or that they can be followed by actual exposures for any considerable distance. Some of the bodies are intrusives clearly cutting Lower Devonian sediments, others are volcanic flows of the same general age as the basic volcanics.

The best evidence of the surface origin of some of these rocks occurs near the northwest corner of location 1806. Most of this claim is underlain by basic volcanics, but near its northern border trenching carried out by the Federal Zinc and Lead Company during 1927 uncovered the contact between these rocks and an underlying, light-coloured acid volcanic. Associated with the latter is a breccia made up of angular fragments of volcanic material in a dense volcanic matrix. The angular fragments are largely of the light-coloured acid volcanic, but some darker material is also present. The intrusives in the map-area consist of two varieties, porphyry and syenite. Both are considered to be differentiates of the granite that outcrops north of the map-area in Tabletop and Hogsback mountains. These mountains are formed from the upper part of a batholith that apparently underlies the middle of the peninsula.

The syenite forms dykes and stocks. The rock on weathered surfaces is in many cases reddish, owing to the presence of orthoclase feldspar. Fresh specimens show pink orthoclase crystals in a dark grey ground. Individual crystals of feldspar reach a length of over one inch. Most of them are long and lath-shaped. There is a gradual increase in coarseness of grain as one goes from the edge of the intrusion inward. This is excellently shown in one of the diamond-drill cores that penetrates an intrusion.

In thin sections these rocks are seen to consist of orthoclase, a little albite and oligoclase, some quartz, and hornblende, but which in most of the sections is largely altered to chlorite. A few narrow dykes are finer grained and darker in colour. In thin section they are seen to consist of feldspar, mostly orthoclase, with hornblende largely altered to chlorite. Pyrite crystals are locally abundant.

The largest area of porphyry lies in block R and adjoining claims about $1\frac{1}{2}$ miles north of the Federal mine. Another large area extends northwest from claim 959 crossing block B and the northeast corner of block A to claim 965. The rocks vary in colour from grey to pink and reddish.

They are dense and hard, with phenocrysts of pink feldspar and, in places, quartz. In thin section the rocks are seen to consist of a microcryst-

stalline groundmass of quartz and orthoclase, with phenocrysts of the same two minerals. Some of the quartz phenocrysts show crystal outlines, others corroded borders. Pale green hornblende, secondary after either hornblende or biotite, is present and also some iron ore. In the vicinity of some of the porphyry intrusions, pyrite, chalcopyrite, and specular hematite mineralization is present, but nowhere yet has proved to be of economic importance.

ECONOMIC GEOLOGY

The minerals of economic importance in the area are sphalerite and galena. A little chalcopyrite has also been found in places, but nothing of sufficient importance to lead to the belief that the camp will ever be a copper producer. Precious values also are so low that the deposits must be mined for the zinc and lead content alone.

CHARACTER OF THE DEPOSITS

The deposits lie in the Lower Devonian series of argillites, limestones, and tuffs. These rocks are intruded by numerous dykes and stocks of syenite and porphyry. The deposits are veins and breccia zones. In some places the veins show sharp contact with the enclosing rock, in other places there is a more or less gradual transition from massive vein material through a brecciated zone into barren country rock. Fragments of country rock of all sizes and shapes lie in the veins. These are marked by sharp angles and borders, and many are entirely separated from their neighbours by vein material.

The deposits apparently follow fault and brecciation planes, with mineralization to a less extent along joint planes. Some of the larger veins strike northeast, others strike north and northwest. Their dip is for the most part steep, usually over 70 degrees. There has also been movement after the period of mineralization. One fault parallels the west wall of the Federal vein. The same vein, 180 feet north of the north crosscut, is cut off on the 100-foot level by another fault.

The veins are younger than the syenite intrusives and in places cut them or follow the contact between the syenite and the intruded sediment. Some of the strongest and richest veins of the area follow such contacts.

MINERALOGY OF DEPOSITS

The vein minerals are sphalerite and galena in a gangue of quartz and carbonate. Pyrite, marcasite, and chalcopyrite are present in minor amounts. The sphalerite is for the most part light yellow varying locally to a reddish brown and is almost free from iron. An analysis (made by J. T. Donald and Company, Montreal, for the Federal Zinc and Lead Company) of a sample of ore gave the following results:

	Per cent
Insoluble and silica.....	0.35
Iron oxide.....	0.82
Aluminium.....	0.10
Sulphur.....	32.46
Zinc.....	66.00
Lead.....	Traces
Lime.....	None detected
Magnesia.....	None detected
Cadmium.....	None detected

HOMER ZINN
VIA RAIL

In the surface exposures and to a certain extent in the upper parts of the veins, sphalerite has been leached out by surface waters. Some of the surface specimens have a white coating of an intimate mixture of smithsonite, calamine, and hydrazincite. A soft, white kaolin mineral is also found on the 100-foot level, and even on the 250-foot level, but only in small amounts. On the 250-foot level a greenish yellow mineral belonging to the kaolinite group was also found.

The galena, as a rule, is less abundant than the sphalerite, but in places occurs in large masses. Some of the masses show strain effects produced by movement after the period of mineralization.

The most abundant gangue mineral is quartz of two varieties, white and amethystine. In places the quartz is banded and commonly there is good comb structure. Where the latter structure is shown, the centre almost always consists of the amethystine variety. In some places the central bands consist of amethystine quartz and the outer of white quartz. Carbonate gangue consisting of dolomite and a light yellow ankerite is also fairly abundant. It is intimately associated with the white quartz and usually accompanies the sphalerite and galena mineralization.

Movements took place during the period of mineralization. In places along the walls of the veins are parallel sets of quartz bands with central comb structure showing that reopening took place a number of times. In other places the vein material has been fractured and is recemented by later quartz. Small, narrow stringers of carbonate can also be found traversing the quartz.

ORIGIN OF THE DEPOSITS

The deposits are believed to be genetically related to the deep-seated intrusive rocks of the area. The syenite and porphyry dykes and masses represent early differentiates of the granite batholith which outcrops north of the map-area and which undoubtedly extends below it. During the late stages of crystallization of the magma, siliceous sulphide-bearing solutions escaping from the still molten intrusion travelled along lines of fracture for considerable distances and deposited their sulphide and silica content along these fracture planes and brecciated zones. Fractures along which dykes had been intruded were reopened in places and formed channels of access. Earth movements continued during the period of mineralization. The veins were repeatedly reopened and even after vein deposition ceased further faulting took place. Practically all the deposits have been formed by the filling of cavities. At one place, however, an example of replacement was found. In the middle of block A, in a trench opened during 1927 to trace the extension of a newly discovered vein, the limestone along the contact with a syenite dyke shows small, detached masses of sphalerite of irregular shapes and not accompanied by quartz or carbonate.

FEDERAL ZINC AND LEAD COMPANY PROPERTIES

The Federal Zinc and Lead Company owns blocks C, F, G, H, K, J, M, N, and have under lease blocks D and E. Their main camp is on block H and most of their underground development work has been on it.

Block H. Numerous vein showings can be observed on the Federal hill in the northeast corner of block H. The one on which most work has been done is the No. 1 or Federal vein. This vein has a known length of over 600 feet and an average width of 8 feet. In places it is considerably wider and, locally, it is bordered by mineralized breccia. Several veins intersect it. No. 1 shaft was sunk on it to a depth of 257 feet. A description of the underground workings is given in Summary Report, 1921, Part D. The amount of horizontal work is as follows:

	Feet
North drift (100-foot level).....	657.3
Drift from No. 1 west crosscut north (100-foot level).....	34.2
South drift (No. 1 level).....	360.8
Drift around Federal shaft (100-foot level).....	73.8
	<hr/> 1,126.1
No. 1 west crosscut north (100-foot level).....	180.4
No. 2 west crosscut north (100-foot level).....	164.0
No. 1 east crosscut north (100-foot level).....	30.9
No. 1 west crosscut south (100-foot level).....	48.0
Adit (100-foot level).....	126.8
Adit (250-foot level).....	104.0
West crosscut (250-foot level).....	165.0
East crosscut (250-foot level).....	61.0
	<hr/> 880.1

The McKinley or vein No. 16 forms a large outcrop on Federal hill 900 feet southwest of No. 1 shaft. The length of this vein has not been determined, but it is exposed in the road east of the main outcrop. The vein shows a width of 60 feet which includes, however, a horse of country rock. It carries galena and sphalerite and is bordered on the north by a breccia zone.

In the spring and summer of 1925 the Federal Zinc and Lead Company drilled six holes from the underground workings on block H. The results of this drilling may be summarized as follows:

D.D.H. No. 1

Location: 250-foot level, 146 feet west of shaft and 20 feet from west face
 Direction: Easterly with drift
 Dip: 55 degrees. At 300 feet and 595 feet, 60 degrees
 Length: 596 feet
 Log: 0-51 feet, argillites
 51-88 feet, syenite
 88-596 feet, argillites

D.D.H. No. 2

Location: 250-foot level. Face of west crosscut, 166 feet west of shaft
 Direction: West with drift
 Dip: Horizontal
 Length: 416 feet
 Log: 0-416 feet, tuffs, argillites, limestones
 124 to 126 vein of quartz carrying sulphides

D.D.H. No. 3

Location: 250-foot level, 12 feet from face of west crosscut, 154 feet west from shaft
 Direction: West, directly under D.D.H. No. 2
 Dip: 26 degrees
 Length: 520 feet
 Log: 0-520, tuffs, argillites, limestones

D.D.H. No. 4

Location: 250-foot level, east crosscut facing south opposite north face of vein
 Direction: 43 degrees west of south magnetic
 Dip: 17 degrees
 Length: 620 feet
 Log: 0-198 feet, tuffs, argillites, etc.
 198-486½ feet, syenite
 486½-609 feet, argillites
 609-620 feet, syenite
 17 to 21½ vein of quartz carrying sphalerite
 90½ to 96½ vein of quartz carrying sphalerite and galena

D.D.H. No. 5

Location: 250-foot level; face of east drift; same setup as No. 4
 Direction: East magnetic
 Dip: Horizontal
 Length: 590 feet
 Log: 0-154½ feet, argillites, tuffs, etc.
 154½-329 feet, syenite
 329-445½ feet, argillites
 445½-590 feet, syenite

D.D.H. No. 6

Location: 100-foot level; north drift 475 feet north of the shaft
 Direction: Northwest with drift
 Dip: Horizontal
 Length: 60 feet
 Log: 0-23½ feet, altered syenite porphyry
 23½-60 feet, argillites

Block C. In September, 1926, discoveries of heavy float were made in the northeastern part of block C, near the head of a valley leading to Brandy brook. Trenching was carried out for a distance of 500 feet and vein material, in places showing widths of from 12 to 20 feet, located. In the winter of 1927 one drill-hole was put down in a northeast direction at an angle of 40 degrees to the horizontal. Its length was 399 feet. A few narrow seams of quartz were encountered, but no strong vein was located. The dip of this vein was, however, unknown at the time the hole was drilled.

Block J. In the southeastern corner of block J two veins have been located. The more westerly of the two strikes north 28 degrees east magnetic, and has been traced for 300 feet. It shows quartz and galena, but the width of the veins has not been proved, although one exposure of 20 feet has been uncovered. The eastern vein strikes approximately north 15 degrees east magnetic, and shows a width of from 10 to 40 feet of quartz with ore in places. To the south it crosses to block N, to the northeast to block T of the North American Mining Company, and has been traced for over 500 feet by trenches.

LYALL AND BEIDELMAN PROPERTIES

Lyall and Beidelman hold four patented blocks, A, B, W (1467A), X (1467B), and a large number of other holdings. The latter include blocks U, V, Y, Z, 6 (1477), and location numbers 662-666, 956-958, 1806-1810, and 2429-2436.

Block A. In July and August of 1926 discoveries were made and work done on block A, and in 1927 important further discoveries were made. The first finds were made in the southern part of the block south of the trail which leads to Brandy brook, commonly called the Pioneer trail. A vein was traced, by six trenches, up the bank on the south side of the creek for a distance of about 400 feet. This vein strikes northeast and, judging from the material taken from the trenches, has good values. Definite information about the width of the vein was difficult to obtain at the time of the writer's visit owing to the condition of the trenches, but in places it apparently exceeds 20 feet.

In the summer of 1927 a vein was located in the middle of the southern half of the block, north of the Pioneer trail. This vein lies on the slope facing Brandy brook along the lower contact of a syenite dyke. The finding of quartz and large masses of galena float led to its discovery and stripping uncovered a vein from which were taken solid pieces of galena weighing up to 200 pounds. This vein is commonly referred to as the lead vein. The contact between the syenite and argillites was exposed by a series of trenches, and galena and sphalerite mineralization was found to continue for over a thousand feet. The strike of the vein zone is northeast. It lines up with the other vein on block A mentioned above and the two may be parts of one continuous vein. It closely follows the syenite contact, but in places lies entirely in the sediments, whereas in other places quartz veins and stringers cut the syenite. The largest exposure is the southwest end where the richest galena specimens were obtained. Owing to the exposure being on the side of a hill and along a dyke, it is difficult to say how thick the vein is at this point. Vein widths of over 12 feet occur in some of the trenches and at the discovery trench a considerably greater thickness is present. The mineralization consists of galena and sphalerite with pyrite and chalcopyrite in a gangue of quartz and carbonate. Barite also occurs in one trench. Another trench shows, near the vein, limestone containing small, irregular masses of sphalerite, evidently a result of replacement.

Block B. In the summer of 1926 discoveries of quartz were made at several places near the middle of block B. Towards the centre of the block, at elevation 1,550, two trenches exposed a vein with a width of from 12 to 15 feet striking a little east of north. Galena and sphalerite are both present with the quartz. This vein is on the same line of strike as the Lead vein of block A, and if continuous with it, must be a very strong vein zone crossing the two blocks.

Several other veins have been picked up on block B paralleling the Lead vein, but little has been done as yet to trace them.

Block 6 (1477). In the summer of 1925 vein showings were discovered in Brandy Brook region on blocks 6, X, and W, and since that time this locality has attracted more attention than block H. The rocks are argillaceous sediments cut by syenite.

A series of trenches has opened up what is known as the Big vein. This strikes northeast across the extreme northwest corner of block W and the eastern part of block 6. It follows closely the lower or northern

border of the syenite intrusion, in places, however, cutting it. The vein has been traced for a distance of about 1,000 feet. It shows widths from 10 to 35 feet, with good sphalerite and galena values.

Three diamond-drill holes, Nos. 2, 4, and 5 respectively, were drilled to intersect this vein. They were located on the slope below the vein outcrops and directly southeast. No. 2 was put down at an angle of 12 degrees to the horizontal for a distance of 428 feet. From 338 to 350 feet quartz with good zinc and lead values was encountered. Hole No. 4 was located about 200 feet southwest of No. 2. It was put down at an angle of 25 degrees to the horizontal for a distance of 392 feet. Breccia and vein material was passed through between 346 and 363 feet; from 350 to 363 solid vein matter carrying 18.57 per cent zinc and 4.13 per cent lead was obtained. Hole No. 5 was located approximately 180 feet southwest of No. 4. It was put down at an angle of 15 degrees to the horizontal for a length of 479 feet. Two veins, 6 and 7 feet thick respectively, and separated by 5 feet of argillites, were encountered from 224 to 231 feet and from 236 to 244 feet. These holes show that the vein dips from 64 to 77 degrees to the southeast and that for a length of 400 feet at least the vein maintains a width of about 13 feet with good sulphide values.

In the west bank of the brook, opposite the cabins of Brandy Brook camp, a vein outcrops. It shows 6 feet of quartz and ore in a wider crushed zone. A number of other trenches were opened up in the vicinity to trace the vein and other quartz showings were located. During 1927, however, little could be observed in these trenches. A diamond-drill hole No. 8 was put down in a northwest direction to cut this zone. The length of the hole was 399 feet and the angle to the horizontal 47 degrees. It cut three veins at the following distances: 256 to 272 feet, 305 to 317 feet, and 353 to 364 feet.

Block W. Besides the Big vein to which reference has already been made and which cuts across the northwest corner of block W, several other veins are exposed along the northern border of the block, along the west bank of the valley leading to Berry Mountain brook. Outcrops of what appear to be several veins occur in a series of trenches along the southern margin of the syenite dyke. Diamond-drill hole No. 3 was put down in a southeast direction to cut this zone. The length of the hole is 376 feet and its angle to the horizontal 20 degrees. It began in syenite, but at a distance of 90 feet it passed into argillites. At the following places it traversed quartz veins, 98 to 102 feet, 119 to 120 feet, 155 to 158 feet, 221 to 240 feet.

Claim 961. In October, 1926, an iron-stained zone was found on claim 961 and a series of trenches was opened for 500 feet along a northward-trending line, down to the brook that crosses the claim and up the north slope. The iron-stained zone is from 50 to 75 feet wide. It consists of broken argillites mineralized with quartz, siderite, calcite, barite, hematite, pyrite, chalcopyrite, and tennantite. Masses of secondary malachite occur with the chalcopyrite, and tennantite. Diamond-drill hole No. 10 was put down in a direction north 70 degrees east astronomic, to cut this zone. The length of the hole was 549 feet and the angle to the horizontal 50 degrees. The hole traversed argillites for the entire distance. In a few places seams of quartz with pyrite and hematite were found, but no strong mineralized zone was penetrated.

Claim 965. Mineralization consisting of quartz and specular iron occurs in the southeast corner of claim 965. Chalcopyrite also is to be found on the steep slope near the north boundary of claim A. In the narrow part of the claim between block A and claim 364 of the Pioneer main block, a series of trenches opened showings of quartz along the border of a syenite dyke. The showings in some of these trenches have promising widths of vein material. The mineralization consists of quartz, carbonate, and barite, with chalcopyrite, galena, and sphalerite.

THE NEW RICHMOND MINING COMPANY PROPERTIES

The New Richmond Mining Company owns blocks D and E. These are under lease to the Federal Zinc and Lead Company.

Block D. A series of trenches in the eastern part of block D has traced a vein known as No. 14. This lines up with the vein at shaft No. 3 on block E. Altogether on this line of strike there are quartz showings for a distance of over 2,000 feet.

In the southeastern corner of D is located shaft No. 2 which has a depth of 18 feet, sunk on a vein wider than the shaft.

Block E. On block E, shaft No. 3 was sunk to a depth of 64 feet on the Bois or No. 14 vein. This vein shows a maximum width of 18 feet. It strikes northeast and, as has been mentioned above, continues over on to block D. Northeast of the shaft a series of trenches has traced what is probably a continuation of the vein on the valley slope facing Berry Mountain brook. At one place the vein follows the lower contact of a syenite dyke. This vein shows the usual mineralization with, locally, more chalcopyrite than is present in the Federal vein.

During the summer of 1927 trenching was performed on two newly discovered veins on block E, about 500 feet north of shaft No. 3. These two veins lie about 200 feet apart and strike northeast. Both show good sphalerite and galena mineralization with widths of from 8 feet to at least 15 feet.

A vein was also discovered on block E near its western border, on the trail from Federal hill to Berry Mountain brook. A trench across the trail has exposed a vein about 10 feet wide carrying good zinc and lead mineralization. A syenite dyke is exposed immediately to the north.

PIONEER MINING CORPORATION OF CANADA, PROPERTIES

The Pioneer Mining Corporation holds two blocks of claims, and their associated company, the Huronian Belt, one block. The Pioneer main block lies west of and adjoins the Federal, and the Lyall and Beidelman holdings. It consists of thirty-six claims, Nos. 359 to 378, 1542 to 1547, 1685 to 1689, and 1711 to 1715. The north block lies north of the Mineral Explorations holdings and consists of fourteen claims, Nos. 1690 to 1703, inclusive. The Huronian Belt block lies east of the Pioneer north block and the Minerals Exploration block, and north of the Lyall and Beidelman holdings. It consists of thirty-five claims, Nos. 1548 to 1567, 1680 to 1684, and 1723 to 1732, inclusive.

Active prospecting was commenced by the company in 1926. Their cook-house was built the same year, and in the early months of 1927 their other camp buildings were erected and mining machinery brought in. Work was continued until November, 1927. It consisted of surface examination, mapping, trenching, and exploratory tunnels. It was concentrated largely near their main camp on North Brandy brook and the claims adjacent to their camp on Brandy brook.

Many mineral showings were located on the claims. The one which received most attention is what is known as the Pioneer "Big Vein". This is a mineralized zone that crosses claims 374 and 1686 in a northwest direction and which was traced by trenches, spaced at an average distance apart of about 120 feet, for a length of 2,300 feet. The zone is on a flat summit where the overburden is deep, so that the trenches do not show fresh rock or vein material. The vein zone was traced by the iron-stain character of the overburden. The trenches show loose, crumbly quartz, iron-stain quartz with sphalerite, galena, and marcasite, rounded masses of galena with an iron-stain coating, and chambered quartz with malachite and chalcopryrite. This iron-stain zone reaches widths up to 100 feet. At the north end it tapers down to 8 feet. At the south end, in trench No. 18, it has a width of about 30 feet. This trench shows some large blocks of galena with minor amounts of chalcopryrite. The average width of the stain-zone is about 30 feet. Just what widths of vein below this actually represents, is impossible to say. Between trenches No. 6 and No. 8, is an offset of about 50 feet suggesting a fault.

Two shafts were sunk on the zone in an effort to get through the weathered material into the fresh, unaltered vein. The north shaft was sunk 73 feet and the south one 39 feet. In the north shaft the vein zone appears to have a dip to the west of 65 degrees. A crosscut 25 feet long from the bottom of the south shaft indicates that here the vein zone has a westerly dip of 52 degrees. Owing to trouble with water, work was discontinued without obtaining definite information about the widths of the vein zone.

The largest single piece of work carried out by the Pioneer was the driving of a tunnel, No. 3, from a point in the valley above the main camp. It was expected that this tunnel would serve several purposes. It was driven in an easterly direction in order to reach eventually the "Big Vein" which it would tap 400 feet vertically below the surface trenches. It could thus be used as a working tunnel for the extraction of ore should the vein prove of workable value. It was also designed as an exploratory tunnel in the hopes that other veins might be picked up. The tunnel was driven for 530 feet and two side-drifts, 175 feet and 80 feet long, respectively, were opened from it. In order to reach the "Big Vein" zone it is still necessary to carry the tunnel forward about 1,000 feet.

The tunnel traverses almost horizontal shales. One hundred feet from the portal, vein A, 5 feet wide, was encountered and drifted on to the south for 175 feet. For the first 106 feet of the drift the average values were found to be 5.78 per cent zinc, and 0.73 per cent lead across a width of 65 inches. From near the end of the drift a crosscut to the west for a distance of 20 feet shows a mineralized zone 12 feet wide. Two narrow

veins, B and C, were cut in the main tunnel at distances of 10 feet and 40 feet respectively from vein A. They show steep dips to the east. Two hundred feet from the portal a shatter zone was encountered which continues for a distance of 130 feet. Thirty feet of this, which shows better mineralization than the rest, is known as vein D. For a distance of 42 feet along this part of the tunnel eastward from where drift No. 4 branches off, the values averaged 0.96 per cent zinc. Drift No. 4 was driven along the shatter zone for a distance of 80 feet. Sixty feet along it a vein 54 inches wide with a dip of 60 degrees to the east was cut. The remaining part of the tunnel shows two narrow veins, F and G, but otherwise no mineralization.

Work was also carried out at a number of other places. Tunnel No. 1 was driven from a point farther up the valley in an easterly direction parallel to No. 3, for a distance of 80 feet. Near the face it intersected a narrow vein. Tunnel No. 2 follows vein No. 18 for a distance of 8 feet. This vein has been traced by 10 trenches above for a distance of about 700 feet. Vein No. 14 is exposed in two trenches, in one of which 18 inches of solid galena was found in an oxidized zone.

In the eastern part of the block, mineral showings were located on claims 364, 365, 366, 368, 369, and 372, and a considerable amount of surface work was done. A few exposures show quantities of chalcopyrite. The overburden here is also very heavy and makes it very difficult to trace and prove veins by surface work alone. The result was that, though encouraging finds were made, nothing of proved importance was opened.

NORTH AMERICAN MINING COMPANY PROPERTIES

The North American Mining Company owns blocks L, O, P, Q, R, S, T.

Block L. Earlier work consisted in the sinking of a shaft 30 feet deep, and the opening of some trenches on block L. Quartz with sphalerite and galena mineralization was found, but the amount of work done was insufficient to enable any statement to be made about the possibilities at this place.

A small amount of work has recently been done near the eastern boundary line of block L. Here some trenches show mineralization of quartz, as vein and breccia, carrying sphalerite and galena over a width of 22 feet. Nearby on block N of the Federal Zinc and Lead Company, mineralization has been found at the contact of syenite and shales. At the boundary between L and H, 670 feet from the eastern border of L, a trench 66 feet long shows 8 feet of quartz carrying good values of sphalerite.

Block T. During the summer of 1927 work was carried out on block T. Immediately east of the boundary between it and block J of the Federal Zinc and Lead Company some large pieces of galena float were discovered. Trenching located two veins 5 feet and 10 feet wide, respectively, separated by 30 feet of shales. It is probable that these are the continuation of the two veins that cross the southeast corner of block J in a northeast direction.

Six hundred feet northeast of the trench in which these two veins were exposed, on the same general strike, other mineralized quartz discoveries were made. These are along the lower or northwest flank of a syenite dyke. At the time of the writer's visit work had just commenced on this vein. Good galena specimens were exposed and it looked as if an attractive vein might be opened up.

A considerable amount of work was also done on another discovery on block T, known as vein No. 45. A mineralized vein and breccia zone was uncovered, but owing to the heavy overburden definite results concerning the size and character were not obtained.

GASPE MINES, LIMITED, PROPERTIES

Gaspe Mines, Limited, is controlled by Honourable John Hall Kelly. During the summer of 1927 prospecting was carried out on some of the claims and a number of veins were located.

Vein No. 1 lies in the northwest corner of Location No. 647. It shows a large exposure of quartz, 12 feet across, mineralized with sphalerite and galena, but not enough work had been done at the time of the writer's visit to trace it under the heavy overburden. At a distance of about 200 feet southeast of this find is a vein from 2 to 2½ feet wide called the Crooked vein. It strikes in a northwest direction.

Vein No. 2 lies near the middle of claim 647. It strikes about north and south, following at its northern end the border of an intrusive mass of syenite. It has been traced for a distance of 600 feet. In places it shows a width of quartz of 7 feet and in one trench the width of the mineralized zone, consisting of vein and breccia, is 20 feet.

No. 3 vein lies in claim 648, on the wood road built in 1927 and crossing the claim. The one place where it is exposed shows less than a foot of quartz. Vein No. 4 lies in the northeast corner of claim 650. It has been traced by trenches for a distance of over 300 feet in a northwest direction. It shows good sphalerite and galena values and varies in width up to over 12 feet.

Vein No. 5 lies in the northwestern part of claim 647. It has been traced by trenches for a distance of over 700 feet. It shows a vein and breccia zone in places 25 feet wide. It lies on the same line of strike as No. 2 vein, and is probably a continuation of it. To the north it crosses to claim 646. On the latter claim, 250 feet to the northwest of where the vein crosses the claim line, another quartz vein was uncovered in a trench.

Vein No. 6 lies to the southeast of No. 5. In one trench a 2-foot vein of quartz with sphalerite, galena, and chalcopyrite is exposed. In a second trench there is considerable iron-stain in the overburden, with sphalerite and galena masses in the weathered rock. A third trench shows black argillites cut by narrow quartz stringers.

PROPERTIES OF OTHER COMPANIES

During the summer of 1927 prospecting was carried out by a number of other companies on their respective claims. These companies include the Phelps-Dodge, Mining Corporation of Canada, Harvie, M. J. O'Brien, Minerals Exploration, and others. No finds were reported by any of these.

SUMMARY

Prospecting during the past summer may be said on the whole to have yielded encouraging results. The finds made on the Federal, the Lyall and Beidelman, the Pioneer, the Gaspé, and the North American properties show a wide mineralized belt. The lack of discoveries on the claims of other companies is not proof that deposits do not exist on their holdings. The difficulties of prospecting, to which reference has already been made, such as the heavy overburden and the scarcity of roads and trails, which always makes the problem of travel and supplies a serious one, render it a long and tedious matter to investigate the country properly. More work is required to test some of the larger veins, such as the one on block 6 and the one located during the past summer on block A.

THE GEOLOGY OF NORTH MOUNTAIN, CAPE BRETON

By T. D. Guernsey

CONTENTS

	PAGE
Introduction.....	47
General character of the district.....	48
General geology.....	50
Physiography.....	69
Mineral resources.....	77

Illustration

Map 2177. 223A. North Mountain area, Inverness county, N.S.....In pocket

INTRODUCTION

North mountain lies about 10 miles northeast of the strait of Canso and borders the northwest shore of West bay, one of the arms of Bras d'Or lake. The mountain is roughly 15 miles long and $3\frac{1}{2}$ to 4 miles wide. The Canadian National railway skirts the northwest flank and the area is readily accessible from three stations on this railway; namely, West Bay Road, River Denys, and Orangedale.

Field work was carried on during the summer of 1926. The writer was assisted by R. M. Williams. Mr. W. A. Bell and Mr. M. E. Wilson of the Geological Survey visited the writer in the field.

Their advice and helpful criticisms are gratefully acknowledged. Special thanks are due to the many residents of the district who in so many ways facilitated the progress of the field work.

This report was prepared under the guidance of the Department of Geology, Columbia University. The writer gratefully acknowledges the friendly counsel and advice received from the late Professor J. F. Kemp, Professor C. P. Berkey, Professor D. W. Johnson, and Professor R. J. Colony.

The mountain is formed of pre-Carboniferous rocks and there is a pronounced topographic boundary between the area occupied by these rocks and that underlain by the Carboniferous strata that flank the mountain. Rock outcrops are fairly abundant on the mountain in the immediate vicinity of streams, but away from the streams, exposures, except in special cases, are rare and, generally, small.

The many records of Cape Breton geology contain few references to North mountain. Sir William Dawson, in his classical work, "Acadian Geology", mentioned

"The syenite and porphyry extensively developed . . . in the irregular tract at the sources of the Inhabitants river and River Denys."¹

Prior to the year 1855, the Reverend David Honeyman noted the occurrence of marble on North mountain,² and commencing in 1875 the reports

¹ Dawson, J. W.: "Acadian Geology"; 1st Edition, Edinburgh, 1855, 384 pp., p. 323.

² Honeyman, D.: "Record of Observations on Nova Scotian Geology Since 1855"; N.S. Inst. Nat. Sc., Pr. Tr. 3, pp. 6-18, 18-40 (1873-74).

of the Nova Scotia Department of Mines record a lime-burning industry at Marble Mountain.

The geologic surveys of the eastern part of Nova Scotia, commenced by Charles Robb and completed by Hugh Fletcher, covered the whole of Cape Breton island. Fletcher's report on the counties of Richmond, Inverness, Guysborough, and Antigonish, published in the Report of Progress for 1879-80, contains the only systematic work relating to the geology of North mountain. Fletcher mapped the crystalline rocks, and, following a classification made in an area farther to the east, divided them into two groups, Carboniferous and Precambrian. He divided Precambrian into the George River Limestone, and a group defined as consisting of syenitic, gneissoid, and other feldspathic rocks. Fletcher believed the George River limestone to be unconformable upon the underlying igneous rocks.

This early work was summarized by Young¹ in 1913 in a description of the type locality of the George River limestone.

The following quotation shows some divergence from Fletcher's interpretation.

"Recent examinations made of some typical sections of the George River series indicate, however, that the granites unmistakably cut and are younger than the George River series. The correlation on lithologic grounds of the George River series with the Laurentian (Grenville-Hastings) of distant Quebec is perhaps no longer justifiable. But the various points of resemblance existing between the Precambrian of Cape Breton and the original Laurentian, are worthy of note."²

It follows, therefore, that one of the major problems to be determined in this re-examination of the ground was that of the true structural relations of the principal formations.

GENERAL CHARACTER OF THE DISTRICT

TOPOGRAPHY

Cape Breton is characterized by a series of upland areas separated by broad lowland valleys, or by the arms of Bras d'Or lake. According to Goldthwait³ the uplands are remnants of an extensive plain, once lying nearly at sea-level and resulting from the long-continued action of sub-aerial erosive processes. Movement of a regional nature lifted the plain above sea-level and tilted it to the south, so that today at Cape North, the most northerly point in Cape Breton, the ancient plain stands at an altitude of about 1,200 feet above sea-level, whereas at Madame island, to the south, the plain disappears beneath the Atlantic ocean. Since the time of uplift, erosion has etched the broad lowland valleys out of the softer rocks, leaving the more resistant rocks as upland ridges. The western part of the island contains four such ridges, not all of the same size, but preserving the same general trend, and characterized by a remarkable evenness of the summits.

¹ Young, G. A.: "George River"; 12th Int. Geol. Cong., Guide Book 1, pt. II, pp. 266-276 (1913).

² Young, G. A.: *Op. cit.*, p. 267.

³ Goldthwait, J. W.: "Physiography of Nova Scotia"; Geol. Surv., Canada, Mem. 140, 179 pp., p. 4 (1924).

North mountain is the second largest of the four uplands in western Cape Breton. It rises about 700 feet above West bay which flanks it on the southeast and is an arm of Bras d'Or lake whose surface is at sea-level. The lowland to the north and northwest is occupied by a partly drowned river valley known as Denys basin and by the basins of two rivers, known as Denys river and Inhabitants river.

The mountain is about 15 miles long, $3\frac{1}{2}$ miles to 4 miles broad, and extends northeast-southwest. It rises abruptly from the lowland areas, the northwest and southeast slopes being fairly steep. The northeastern end is slightly lower than the central part; at the southwestern end, in the vicinity of West Bay Road, the relative elevation of the upland is not nearly so pronounced because the bordering lowland there also attains an appreciable elevation. The top of the mountain is nearly flat, with a gentle, downward inclination to the northwest, and the transition from the flat top to the steep slopes is abrupt.

The drainage of the mountain is mainly to the northwest by several large and numerous smaller streams flowing in valleys cut deeply into the resistant rocks. A number of the streams rise in small, shallow, swamp-fringed lakes. The gradients of the northward-flowing streams are, as a rule, uniform, although falls occur on several of the streams close to where they issue from the highland. The southward flowing drainage is relatively short and is characterized by the steepness of the stream gradients. In most instances the valleys have not been cut back to the headwaters of the streams, which in their upper courses flow over the upland through swampy, poorly drained areas, many of which are, doubtless, ancient lakes that have become filled through the growth of vegetation. In many of the southward-flowing streams the change in gradient at the scarp of the mountain is pronounced. They are at first sluggish and deep, flowing through a succession of swampy areas, but on nearing the south scarp the gradient increases and the waters finally plunge downward by a series of cataracts. At the eastern end of the mountain the even contour of the upland is broken by two embayments of the lowland, one of which projects east along the valleys of McKenzie brook and the other west along a brook flowing into Little harbour. The valleys of these two streams unite at their heads to form a notch.

The lowlands are rolling and are well drained by streams that have cut wide valleys into the general lowland level. Denys river, the master stream of the lowland to the north, rises in Craguish hills, another upland ridge about 10 miles northwest of North mountain. Big brook, flowing along the northwest base of North mountain, is an important tributary to Denys river.

Small alluvial fans are numerous along the base of the upland and are especially noticeable in the valley of Big brook. They are built up at the mouths of the deep upland valleys where the decreased gradient on the lowland permits only the finer material to be carried by stream currents.

West bay and Denys basin are arms of Bras d'Or lake. The water is saline and supports a marine fauna, but the tides, of only a few inches, are variable, and are considerably affected by winds. Denys basin is

shallow with a narrow, tortuous entrance and is now seldom used by vessels of deep draught. West bay is navigable for vessels of all draughts.

POPULATION AND INDUSTRIES

The population of the district is mainly of the descendants of Scotch settlers who came to Cape Breton during the first half of the nineteenth century. Gaelic is spoken by many and is still the only tongue of a few. A few Indian families are resident at a government reserve on Malaga-watchkt peninsula.

Farming is the chief industry; hay, oats, potatoes, and vegetables being the common crops. At one or two places on the south side of the mountain, small fruits, especially strawberries, are grown to advantage. Although the best farms are on the lowlands, the northeast, southeast, and southwest slopes of the mountain are cultivated to some extent, although at the present time not all of the holdings are occupied. Fishing, though important, does not reach the status of an industry. A few oysters and lobsters are exported and a considerable number of codfish are taken and dried for local use. Previous to the year 1922 the Dominion Iron and Steel Company worked an extensive limestone quarry at Marble Mountain. The abandonment of the quarry, which employed several hundred men, removed an important economic industry from the community.

Where not farmed, the country is covered with a thick growth of hardwoods and conifers. These are mainly of second growth, as a violent gale in August, 1873, destroyed a large part of the timber standing at that time. The trees grow to good size on the well-drained slopes, but the swampy, poorly drained areas on the top of the mountain support only a stunted growth of conifers. The soft woods are cut in a small way for lumber to be used locally, and as pitprops for the coal mines. When market conditions are favourable, considerable spruce is cut and exported as pulpwood to the United States.

Four villages are included in the area of the map sheet. They are: River Denys, West Bay Road, West Bay, and Marble Mountain. River Denys and West Bay Road are each about 8 miles from the Victoria highway, the main automobile road through Cape Breton. The road encircling North mountain is suitable for automobile traffic, but the roads across the mountain have difficult grades and are seldom used.

GENERAL GEOLOGY

OUTLINE

The rock formations of North mountain are readily grouped into three main divisions, namely:

- (1) A complex, pre-Carboniferous basement.
- (2) A thick series of Carboniferous sediments which rest with marked unconformity upon the older basement.
- (3) Unconsolidated material of glacial and fluvial origin.

The pre-Carboniferous basement consists of ancient sedimentary and volcanic rocks that have been intruded and metamorphosed by granite. Granite makes up the greater part of North mountain, whereas the intruded group occurs as a rather narrow belt serving to divide the granitic mass into two nearly equal areas.

The Carboniferous sediments rest upon an erosion surface carved on the pre-Carboniferous complex. For the most part the Carboniferous sediments occupy the valley lowlands. Their upturned edges were noted along the lower slopes of North mountain.

Glacial debris lies upon the surface of all the preceding formations and in the valleys is augmented by stratified sands, gravels, and clays.

Table of Formations

Quaternary.....	Boulder clay, sand, gravel, and clay
Palaeozoic.....	Pennsylvanian (?).....	Sandstone and shale
	Mississippian: Windsor series.....	Conglomerate, limestone, gypsum, shale
Pre-Mississippian, probably Precambrian	Igneous intrusives.....	Basic and acid dykes
		Granite, and, or, granodiorite
	George River series.....	Volcanics, quartzite, limestone, greywacke

GEORGE RIVER SERIES

The primary classification of the Precambrian rocks in Cape Breton was accomplished during the study of the Boisdale hills, an area lying south of St. Andrew channel.¹

The rocks were divided into two main groups. The lower group was described under the heading, "Syenitic,² gneissoid, and other feldspathic rocks," and the upper group under the name "George River Crystalline Limestone series." The George River series was believed to be younger than, and to rest unconformably upon, the underlying igneous rocks. Although the original work of Fletcher, and later that of Matthew,³ and others, has demonstrated that both groups are undoubtedly Precambrian, later work on sections of the George River series has shown that the igneous rocks are intrusive into the sediments, and that the sediments are, therefore, the older of the two groups.

The name George River is taken from a small stream of that name which flows along the trend of the Boisdale hills, and enters St. Andrew channel near its northeastern extremity. The name as applied to the older sedimentary rocks in this vicinity was first used by the Reverend David

¹ Fletcher, H.: "Report on Explorations and Surveys in Cape Breton, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1875-76, pp. 369-418.

² The word syenite, as used in early reports, indicated a rock composed principally of feldspar, hornblende, and quartz.

³ Matthew, G. F.: "Report on the Cambrian Rocks of Cape Breton"; Geol. Surv., Canada, Pub. No. 797, 1903, 246 pp.

Honeyman in 1873,¹ although the strata were not described in detail until 1876 when Fletcher published his report on this district. In its typical development the George River series is described as consisting of

"highly crystalline limestone and dolomite, containing talc, mica, tremolite, plum-bago, galena, hematite, magnetite, and other minerals, interstratified with felsite, syenite, diorite, mica schist, quartzite, and quartzose conglomerate; and dipping steeply to the south of east."²

No fossils are known to occur in this series and the exact succession of the strata is somewhat in doubt, but from sections described by Robb,³ the limestones are apparently interbedded with the quartzose strata which grade up into shales.

The descriptions of the rocks lying below the George River series indicate that they are mainly plutonic, but include "laminated felsites" which are apparently to be differentiated from both the George River series and the intrusive rocks. Speaking of the felsites as found in Craig-nish hills, Fletcher states:

"The distribution of the . . . felsites here lends strength to the assumption that they belong to the syenite series and are older than the crystalline series which appears at no great distance from them and distinctly overlies the syenite into which these felsites insensibly merge."⁴

Describing the George River series as found on North mountain, Fletcher refers to the felsites as follows:

"The opinion already expressed that this (George River series) forms an over-lying unconformable group of Precambrian age is greatly strengthened by the results of recent investigations, the limestones in every case capping the felsites, with which, however, they often seem to blend near the contacts as if by a common metamorphism. . . . That the felsites were subsequently intruded or contemporaneous volcanic deposits seems less probable."⁴

Gilpin, in 1886, summarized this problem in a paper delivered to the Geological Society.

"Two divisions have been recognized in these measures. The lower consists of laminated felsites and interstratified porphyry and syenite and gneissoid rocks; the upper is characterized by the addition of great beds of limestone. Mr. Fletcher, speaking of the lower division, gives it as a result of his experience that both the felsite and syenite strata are intimately associated as part of the same group of crystalline rocks, differing not so much in composition as in the degree of crystallization they have been subjected to, and that as no evidence has been found proving the higher position of the felsites, they may at present be considered together."⁵

The present writer recognized volcanic rocks on North mountain. They are poorly developed and not distinctly separable from the sedimentary George River strata. In spite of the fact that Fletcher reported a conglomerate or breccia containing fragments of felsite within the George River series in the type area, the writer is inclined to interpret the felsites as a part of the George River series which, for the North Mountain district, thus is made to include all sedimentary and associated rocks that have been intruded by granite.

¹ Honeyman, D.: "Notes on the Geology of Nova Scotia and Cape Breton"; N.S. Inst. Nat. So., Pr. Tr. III, pp. 193-202, p. 196 (1871-74).

² Fletcher, H.: Op. cit., p. 382.

³ Robb, C.: "Report on Explorations and Surveys in Cape Breton, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1874-75, pp. 166-266, pp. 252-257.

⁴ Fletcher, H.: "Report on Surveys in Richmond, Inverness, Guysborough, and Antigonish Counties, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1879-80, pt. F, 125 pp., p. 12 F.

⁵ Gilpin, E.: "The Geology of Cape Breton Island, Nova Scotia"; Quart. Jour. Geol. Soc., vol. 42, pp. 515-526, p. 516 (1886).

On North mountain the George River series has its chief development in a band that extends southwest along the south scarp of the mountain from Little Harbour to Lime Hill and from there westward across the mountain to River Denys.

Owing to the complexity of this group, and insufficient exposures, the relations between its several members are not well known. The members are described in the following order, namely: Volcanic member, Limestone member, Quartzite-greywacke member.

Volcanic Member

The volcanics are believed to be the oldest rocks exposed, and do not appear to be of very great extent. They may be seen to good advantage on the bare hill northwest of Little Harbour, locally known as "The Creigan", and they extend southwestward along the scarp of the mountain towards the head of Mill brook. No exposures of them were recognized between Mill brook and Lime Hill, but in the vicinity of Mill brook and inland similar rocks are strongly developed.

The volcanic rocks are generally soft, fine-grained, and dark green. Their exact nature, even under the microscope, is obscure, for the primary minerals have been converted into aggregates and pseudomorphs of amphibole, chlorite, carbonate, sericite, epidote, magnetite, and leucoxene. The feldspars, when discernible as such, are lath-shaped and have, apparently, small extinction angles.

Trachytic, porphyritic, and amygdaloidal structures were noted. Interstitial quartz is present in some specimens and small veinlets of carbonate cut the rocks. Staining by ferric oxide is very common.

At 'The Creigan' the rock carries specks of sulphite and close jointing is very prominent. What was taken to be pillow structure was observed on the weathered surface. The pillows are rather small, 1 foot to 18 inches long, and although not conspicuous, were accentuated by small arcuate areas that weather a lighter colour than the surrounding surfaces.

Near Lime Hill the rocks are massive and dense, with much ferric iron on the weathered surface. Pillow structures were not noted in this vicinity; the rocks are arranged in rude sheets, 15 to 20 feet thick and with a very steep dip.

Limestone Member

The limestones of the George River series may be traced in more or less isolated exposures over the entire length of the sedimentary belt. The best development is in the vicinity of Marble Mountain, between the village and Little Harbour, and northeast of Campbell brook in the southern part of the belt where it crosses the mountain.

The limestones are invariably crystalline and commonly of coarse texture, but where metamorphism is apparently at a minimum the texture is fine and banding prominent. They may be grey or white on the fresh surface, but weather bluish. Granite intrudes the limestones and the effects produced include the formation of opicalcites, dolomitic limestone, white massive marble, and occasionally the development of quartz, lime silicates, and abundant pale yellow mica. The intrusive nature of the

granite is very plain along the top of the south scarp of the mountain from the lakes at the head of Mill brook, westward to, and beyond, Sydenham brook. In this area there are many exposures of the limestones which so far as could be determined are wholly surrounded by granite. A contact between granite and limestone is visible on the Marble Mountain-Munroe Bridge road, and west of Sydenham brook the granite was observed to include blocks of limestone 4 to 6 feet long. At these points few structures are to be seen in the limestone which is white, coarse, and contains a considerable proportion of magnesium.

The relatively numerous exposures of the limestones may possibly give a false impression of their extent and thickness, for it is probable that they are to some extent interbedded with the quartzites and greywackes to be described next.

Quartzite-Greywacke Member

Quartzites outcrop at several places along the sedimentary belt. A very good section of these rocks is to be seen in the valley of Mill brook, and they may be traced southwestward along the scarp of the mountain where small exposures of limestone and quartzite are associated with granite. A considerable thickness is also exposed below the road at Marble Mountain. Near River Denys, the quartzites again appear. Lithologically the rocks range from a micaceous arkose to a nearly pure quartzite; a micaceous quartzite is the most common facies. They are thoroughly recrystallized and it is only occasionally that the original grain outlines can be distinguished.

The quartzites at Mill brook are mainly dark grey, well-banded rocks of fine grain. Under the microscope they are seen to be largely composed of quartz, with usually a strong development of biotite. Subordinate white mica is present and occasionally altered feldspar occurs as scattered grains or in distinct bands. Light green amphiboles in small, fresh, hypidiomorphic prisms, are very common in some specimens, with occasionally larger, incomplete crystals enclosing original quartz grains. Two of the slides examined contain small grains of unknown minerals of high relief. These grains are somewhat elongated, but rounded, and have pitted surfaces. They occur scattered amongst the quartz and biotite, or distributed along the foliation in lines. In the latter case they appear in greatest quantity with bands of altered feldspar. The most common of these undetermined minerals is analogous to zircon and the group as a whole is believed to be heavy minerals of the original sediment.

Quartzite is in contact with limestone in the quarry at Marble Mountain. It weathers rather dark red due to small flakes of hematite and abundant staining with ferric oxide. Below the limestone the first rock noted is an almost pure white quartzite, but as the exposures are traced towards the shore, biotite becomes more prominent and forms distinct bands, 1 to 4 millimetres thick. Ferric oxide along the banding gives a dark colour to the exposures.

Quartzites occur on the northwest slope of the mountain near River Denys. The rock outcropping nearest to the limestones of this locality is a red-weathering, well-banded arkose, but within 150 feet this gives place to an almost pure white quartzite.

At the shore, southwest of Little Harbour, and again in the valleys of Dallas and Campbell brooks, the rocks outcropping on the south side of the limestone zone differ markedly from any already described. They are dark, fine-grained, impure grits and greywackes, which by shearing pass into slates and schists. Banding is noticeable at some localities and where the rocks are least disturbed bedding is more or less prominent. Under the microscope quartz is seen to be the dominant mineral. It occurs in single and composite grains ranging in size from microscopic fragments up to grains $\frac{3}{4}$ of a millimetre in diameter; and it is accompanied by a few scattered grains of feldspar and occasionally a lithic fragment. Sericite is present in varying quantity and is associated with chlorite and small fragments of ferromagnesian minerals. Banding is not prominent in the thin sections examined and most commonly the quartz grains are scattered heterogeneously through the finer groundmass. They are equidimensional, but are not especially rounded, nor were they noted to be drawn out or sheared.

In the upper valley of Campbell brook the rocks are slates and shales, with some few thin beds of limestone. Extremely schistose graphitic shales occur a short distance below the upper forks and are again exposed above the bridge on the southeast branch. All the beds in this vicinity dip very steeply to the south and in the northern exposures they are much contorted. The beds are cut by veinlets of carbonate and quartz, the latter carrying iron and copper sulphides. These same conditions prevail along the road to Lime Hill and in the valley of Dallas brook. Here, however, limestone is exposed in greater quantity, is banded, contorted, and at places contains serpentinous material and brown mica. Judging from scattered outcrops the greatest width was between 250 and 300 feet.

Near the mouth of Dallas brook the rocks are much crumpled, although the original bedding can still be distinguished. Proceeding northeastward, between Lime Hill and Marble Mountain, two small quarries above the road again show limestone in contact with strata of the quartzite-greywacke member, which, in general, are schistose. At several outcrops along the shore, one or two thin beds of quartzite, and a thin bed of conglomerate or breccia were observed. Where schistose the rocks are very soft, chloritic, and hold lenses and stringers of carbonate.

The exposures farther northeast where the pre-Carboniferous rocks come to the shore to the southwest of Little Harbour, show the strata to be well bedded, very compact, and of extremely fine grain. Their stratigraphic position relative to neighbouring bodies of the limestone is indeterminable because of close folding and faulting. At one place, graphitic shales apparently underlie a well-bedded limestone.

The strata of the band of George River series are characterized by a general southwesterly strike. The dips are almost invariably steep, from 50 to 70 degrees, and close folding is pronounced at some localities. Conditions are such that the stratigraphical succession within the George River series has not been established. The limestone member forms a valuable key horizon, but its worth is somewhat impaired by the possibility of overturned folds. The volcanic rocks are thought to form the

base of the series on North mountain. They are mainly developed near the contact with the granite and only sparsely elsewhere. Their relations with the other members of the series are not established, but the presence of a volcanic rock interbedded with the micaceous quartzites at Mill brook, suggests that the quartzites succeed the volcanic member. The association of the micaceous quartzites with the limestones, and the limestones with the greywackes, also suggests that the limestones are an intermediate member separating the two quartzose formations. The possibility that the micaceous quartzites are, in part, metamorphosed equivalents of the greywackes, does not affect this conception.

The succession then as tentatively set forth, is, from the base upwards: (1) volcanics; (2) quartzites with a zone of thick, interbedded limestone, and grading up into; (3) greywackes.

IGNEOUS INTRUSIVES

Granite

Igneous rocks, mainly granitic in character, occupy the greater part of North mountain. As already stated, the granite is intrusive into the George River strata. It is not practicable to draw a sharp line of contact between the two groups, as they are generally mixed within an intervening zone of greater or less width. Variations in the character of the granite occur in many places between successive outcrops and there is a possibility that the granite is the result not of one intrusion but of a series of intrusions, although no evidence to this effect was obtained.

Typically the granite is pink, or grey, depending on the proportions of flesh-coloured and white feldspars. The texture varies from medium to coarse, but the grain is seldom even, being commonly hiatal and occasionally porphyritic. In some cases the grains range up to, and exceed, one centimetre in greatest dimension.

The rocks as indicated by the examination of thin sections, vary from a true granite to a quartz diorite, with granodiorite as perhaps the most common facies. Some doubt is felt as to whether the more basic examples are truly representative of any large mass of the rock, as it is thought that scattered inclusions of the sediments may occur more abundantly than were noted and thus cause rapid changes in composition.

In the slides examined the primary essential minerals, in order of abundance, are: feldspars, quartz, biotite, and, in some cases, hornblende. The proportions are, approximately: feldspars 50 per cent, quartz 40 per cent, biotite 10 per cent. The accessory minerals include: magnetite, ilmenite, apatite, zircon, and titanite.

The feldspars are chiefly plagioclases, but orthoclase, perthite, and microcline are not uncommon. The plagioclases show alteration, but appear to range between oligoclase and andesine. The orthoclase is also altered, but the microcline and perthite are commonly comparatively fresh. Sericite is the principal alteration product of the feldspars, but epidote is present as stringers and patches in the more altered individuals. Unaltered feldspar of a more acid type was noted to occur along the edges of, and in some instances to penetrate, the altered crystals. The quartz forms coarse

aggregates. The quartz individuals in some cases hold small crystals of feldspar, or penetrate or cut the feldspar clusters, or occur as small, rounded grains within crystals of feldspar. The quartz aggregates are crossed by lines of inclusions, and strain shadows are prominent in most of the slides examined.

The biotite is developed in small crystals that are inclined to be grouped. In some sections the biotite shows only slight alteration around the edges, but in others it is almost completely destroyed.

Green hornblende is present in some of the sections. Like the biotite it is developed in comparatively small crystals and shows only slight alteration.

The accessory minerals are not abundant. The iron ores are in greatest quantity and occur mostly with the ferromagnesian minerals. Zircon and apatite appear as inclusions in both the biotite and hornblende. Titanite was noted in only one section.

INTRUSIVE AND CONTACT PHENOMENA

Although mixed zones of the granite and George River strata are most strongly developed as a fringe bordering the sedimentary strata, there are areas removed from the sedimentary belt where inclusions of the sediments occur in the igneous rocks. Because of the limited number of exposures, the delimitation of the borders of the mixed zones, and especially of those removed from the main belt of sediments, could only be roughly approximated. Over most of the area, weathering of the granites does not appear to be deep, and characteristically the feldspars decay leaving the quartz aggregates projecting as knobby protuberances from the surface. In the western part of the area, and especially in the valley of the west fork of McLeod brook, the weathering is very deep and a fresh surface was unobtainable from any outcrop. The stream has cut a narrow gorge in the granite, from 10 to 30 feet deep, and from caves in the side of the gorge the rock may be scraped off with the bare hand.

Between Marble Mountain and Little Harbour, where volcanic rocks occur along the western edge of the band of George River strata and, therefore, are believed to be in direct contact with the granite, the granite of the intervening mixed zone is characterized by the presence of oval bodies. These are commonly not more than 3 or 4 feet long and may be as small as 8 inches. They are arranged with their long axes paralleling the length of North mountain, that is paralleling the structural trend of the district, and the line of contact. On the weathered surface they are easily distinguished by their colour which is slightly darker than that of the normal granite, but on fresh surfaces they are not clearly defined.

The rock of these oval bodies when examined under the microscope is seen to be of medium grain and to consist of plagioclase, biotite, hornblende, and quartz in the proportions of about 4-2-2-2. The accessory minerals include apatite, magnetite, and a little titanite. The plagioclases have an index which is slightly lower than the index of balsam and, from determination made on the twinning lamellæ, the composition is between oligoclase and andesine. The biotite and hornblende are closely

associated and in some cases are intergrown. Both show varying degrees of alteration to chlorite, and a little zoisite may also be present. The hornblende is light green, strongly pleochroic, and contains scattered patches of needle-like inclusions, probably rutile. The dark brown biotite is characterized by alteration products, occurring as lenticular masses between the folia, and for the most part appearing to be colourless epidote. The quartz occurs in very irregular shapes between the feldspars and generally exhibits rectilinear boundaries. It is unevenly distributed and in several cases a number of adjacent areas were noted to have the same optical orientation. It is evident that this rock differs from the granitic rocks in being more basic, and in carrying a higher proportion of hornblende, but it has no structures that seem to indicate that it has been derived from any part of the George River series.

Quartz-poor igneous rocks were noted on the road a few hundred yards east of Mill brook. They outcrop close to the sedimentary rocks, and are much darker than the typical granitic rocks. An abrupt variation from medium to coarse texture was observed in adjoining outcrops. In mineralogy and structure the medium-grained phase is somewhat similar to the rock of the oval bodies described above. The coarse variety is characterized by brown hornblende and large aggregates of secondary chlorite, leucoxene, epidote, and zoisite. Quartz is subordinate and interstitial, is much fractured, and carries radiating aggregates of a colourless mineral with the optical properties of epidote.

At Marble Mountain where the granite is in contact with limestones and quartzites, oval bodies such as those already described were not noted, but instead the passage from the granite area of the band of George River strata consists of an alteration of bands and patches of sediment and granite. In places the mixed zone is of considerable width. It extends southwest along the scarp of the mountain towards the lake at the head of Sydenham brook, and where it is crossed by the Marble Mountain-Munroe bridge road the limestone, occurring within 10 feet of granite outcrop, is characterized by the differential weathering of metamorphic minerals developed along the bedding planes. The granite is not greatly affected close to the contact, although a slight decrease in the intensity of the colour is apparent and the texture is somewhat finer. At Sydenham brook the limestone, which, so far as could be seen, is entirely surrounded by granite, does not show the development of contact minerals, nor is banding present on the weathered surface. Near the scarp of the mountain the granite was observed to carry blocks of the limestone. The feldspars of the granite lack colour and are inclined to be idiomorphic and zonal. Quartz is present in some quantity and exhibits penetration effects against the feldspars, as well as slight evidences of straining. The rock shows only slight alteration.

Still farther southwest, in the neighbourhood of Lime Hill and in the valley of Campbell brook, the mixed zone on the whole is narrow. That part on the farm of Mr. Neil McMillan, on the Lime Hill-River Denys road, shows granitic rocks in close proximity to limestones and quartzites. Here the sedimentary rocks appear to be more profoundly affected than those observed farther east.

Four isolated mixed zones are shown on the accompanying map. Two at the northeastern end of the mountain are small and exhibit only slight evidences of the older rocks. The two larger areas near the southwestern end of the mountain contain a variety of rock types, and although remnants of the sedimentary rocks appear to be present in only small quantity, they are widely spread, and are believed to have exerted a profound influence on the character of the intrusive. Since the rocks in these two areas differ somewhat in general appearance, they will be described separately and in some detail.

The Lime Hill-Ross Brook Mixed Zone

The rocks of this zone are best seen in the valleys of Ross and McCuish brooks, and along the shoreline, where, although outcrops are few, the beach is made up of large boulders showing most of the rock types noted on the hillslope above.

The most abundant general rock type, called "diorite" in the field, shows gradations from granite to quartz-bearing gabbro. This general type is invariably grey, but the shade varies with the grain size and the content of ferromagnesian minerals, both of which are subject to rapid change. The texture is commonly equi-granular, but in places is slightly porphyritic. The variations exhibited by this general type are indicated by the following descriptions.

The rocks east of McCuish brook, near the road, are of variable grain size and various shades of grey. The dominant mineral is acid feldspar, mainly orthoclase, but with some acid plagioclase. Green hornblende is the most important constituent after feldspar.

Biotite occurs rather sparingly as a primary constituent. It is associated with the hornblende. A little quartz occurs interstitially and replaces the feldspar in part. Apatite, magnetite, and titanite are the accessory minerals.

The rock outcrop along the road between Ross and McCuish brooks is very dark, coarse, and consists mainly of hornblende in short, thick prisms. Feldspar and quartz are also present, and with the hornblende occur in the proportions of about 5-2-2. Pyroxene, magnetite, pyrite, titanite, epidote, and apatite make up the remainder. The hornblende, feldspar, and quartz act as hosts to each other and to the remaining constituents. The hornblende is brown and green, both varieties being noted in the same crystal. Some of the smaller grains are associated with a pale green pyroxene, close to diopside, and probably resulted from the alteration of that mineral. The feldspars are mainly untwinned plagioclases, with distinct zonal structures and between oligoclase and andesine in composition. The quartz occurs in rather large, irregular grains and exhibits more pronounced poikilitic structures than do the other minerals. Some of the grains show slight strain shadows.

A specimen from the small stream east of McCuish brook is from a locality where the granite apparently grades into the type under discussion. This specimen has a faintly developed porphyritic structure. The constituents in order of abundance are: feldspars, quartz, hornblende, and biotite, in the proportions of about 5-2-1-1. Magnetite, titanite, and

apatite are the accessory minerals. The feldspars are plagioclases, about andesine in composition, with distinct zonal structures. The hornblende is green. Brownish yellow biotite is associated with the hornblende.

Another example from the small stream east of McCuish brook is one of the darkest specimens of this general type. It is of medium grain and consists of labradorite, quartz, and alteration products in the proportions of about 5-3-2. The quartz does not appear to be primary, for although in considerable quantity in the slide, it is in largest part restricted to one rather large, lens-shaped area. Smaller interstitial patches of quartz show myrmekitic intergrowths with the plagioclase.

A variety from the east branch of McCuish brook is a medium-grained rock whose essential constituents are acid feldspar, and altered ferromagnesian mineral, and quartz, in the proportions of about 5-3-2. The structure is slightly porphyritic and there is a slight but obscure banding on a large scale. The feldspar appears to be dominantly orthoclase, with some little acid plagioclase. The ferromagnesian minerals are totally replaced by chlorite, leucoxene, a little feldspar, carbonate, and epidote, the original mineral is believed to have been biotite.

Another example from the east branch of McCuish brook is a medium-grained, grey rock, consisting of quartz, feldspar, hornblende, and biotite in the proportions of about 5-3-1-1. The quartz occurs in quite large grains which surround and enclose the feldspars. The feldspars are chiefly acid andesine, but also include a more acid plagioclase and a few comparatively large crystals of orthoclase. Some of the plagioclases are zonal. The hornblende is green and occurs in long, irregular prisms. It is associated with a little granular epidote, probably an alteration product. The biotite is in part an alteration product from the hornblende, but some of it is primary.

Associated with the above described rocks are others of widely different character. These include limestones, gneisses, and dark, coarse, badly altered granitic rocks. Dykes of aplitic character cut all the other rock types and in some places are very numerous.

The limestones occur abundantly in the lower part of Ross brook and were observed in rather thin bands in the upper part of McCuish brook, where they are somewhat crumpled. Although preserving their identity, they are much metamorphosed and exhibit pronounced differential weathering. Besides calcite, the chief constituents are micas, olivine, and serpentinous material, which combine to give the rock a grey colour. The micas are colourless and unaltered. They are grouped in aggregates of rounded grains. The serpentinous material is variable in amount. It occurs in more or less rounded aggregates believed to be pseudomorphic after the olivine.

The gneisses occur mainly along the north edge of the mixed zone. Good exposures may also be seen in the two small streams west of Dallas brook. Variations in the general appearance and in the amount of banding exhibited were taken to indicate that probably both orthogneisses and injection gneisses were present.

Rock classified as orthogneiss was found not far west of Lime Hill. It is of granitic habit and the foliation, due to the ferromagnesian minerals,

is rather coarse and interrupted. The principal constituents are quartz, acid feldspar, and biotite. The feldspars include orthoclase, acid plagioclase, microcline, and perthite.

The most common gneiss is a grey, medium-grained rock with a well-developed, rather fine foliation. The feldspars, in about equal proportions with quartz, include orthoclase, perthite, microcline, and a little plagioclase. Biotite is the principal ferromagnesian mineral and is developed in large crystals. Pale brown aggregates of secondary minerals are concentrated near the biotites. They consist of serpentinous material, pale green amphibole, colourless micas, ferric iron, and a little titanite. They are thought to be derived from olivine. Inclusions of zircon are present in the aggregates.

All the rocks of the above assemblage are cut and injected by small dykes and stringers of aplite. In places these are very numerous and they are especially abundant on the east branch of McCuish brook. In general the walls of the stringers where they cut the granitic rocks are not well defined, and there is a gradation from the light-coloured aplite to the darker enclosing granitic rock.

The aplite consists of orthoclase, microcline, perthite, and a little albite. Interstitial quartz is present in some specimens, but as a rule the rocks appear to be poor in this mineral. Ferromagnesian minerals are not present in any quantity, and in some examples are entirely lacking.

An example of a rock formed by lit-par-lit injection was found on the west branch of McCuish brook. This rock is darker and of finer grain than the gneisses described above. The different bands are 4 to 5 millimetres wide. The primary rock is foliated along planes parallel to the layers of injected material and consists of quartz grains set in an extremely fine, complex mass of alteration products, including colourless micas, leucoxene, carbonate, pyroxenes, saussurite, zoisite, and magnetite. In addition there are many elongated grains of rutile scattered along the foliation and large, clear grains of a colourless pyroxene form a distinct but thin band. The injected material consists of microcline, microperthite, pale brown biotite, and scattered grains of pyrite. The contact between the primary and injected material is zonal and the feldspars along the contact hold the original minerals in poikilitic structures. Shreds of pale green pyroxene, and a little carbonate are scattered through the feldspars and are evidently derived from the primary rock.

The West Bay Road-Big Brook Mixed Zone

This zone differs from the above described zone on the southwest side of the mountain, in that inclusions are more numerous within the igneous rocks, and the intruded sediments are recognizable at only a few places. The streams between Big Brook post office and West Bay Road afford the best opportunities for observing the rocks in this zone. Good exposures may also be seen along the road going southward across the mountain from Big Brook post office.

The most common type of rock is somewhat similar in mineralogy and structure to the grey granites, etc., of the Lime Hill-Ross Brook mixed zone. Here, however, the rocks are coarser and in places grade

into types very similar to, and in some instances more acid than, the granitic rocks. With the distinctly igneous rocks are darker rocks showing rapid variations in texture. Where the road going southward from Big Brook post office approaches the south boundary of the mixed zone as drawn on the map, the rocks along the road include fine-grained granite, gneissic granite, medium-grained diorite, and a coarse blotchy rock of dominant green colour. These same conditions prevail in some of the stream courses where dark, greenish, schistose rocks contain varying amounts of injected igneous material. Commonly the rock consists of a few irregular, pink feldspars in a dark groundmass. Inclusions are not discernible, and in general the rocks appear very similar to the nebulites of Sederholm¹ and Weinschenk.² At some places the greenish rocks contain no injected material, and in these cases are seen to be dark rocks with greenish feldspars and much chloritic mica. In places they are very schistose. All gradations of mixing between these rocks and the granites are to be seen, and the dark rocks may predominate over the granite in the proportion of about three to one.

Gneisses are commonly associated and intermixed with the dark rocks. From their appearance they are all injection gneisses and may be fine- or coarse-grained with varying degrees of banding. One specimen in thin section is seen to be a medium-grained rock consisting of quartz, andesine, and ferromagnesian minerals in the proportions of about 6-2-2. The ferromagnesian minerals are mainly green hornblende and biotite, but a colourless pyroxene is present in small quantity and is the mineral from which the hornblende is derived. The hornblende is arranged in aggregates of grains that contain many, small, irregular, and rounded inclusions of some colourless mineral, probably a feldspar. Intergrowths of feldspar with hornblende or pyroxene lie along the boundaries of many of the aggregates. The biotite is a very deep brown, and commonly holds large grains of magnetite. Rounded grains of quartz and feldspar are very prominent in one part of the thin section. The grains are very dusty and are enclosed and held in larger crystals of quartz.

Where distinct and recognizable xenoliths appear in the igneous rocks the latter are even-grained, but the shade of colour varies with the locality. Xenoliths are fairly numerous throughout the mixed zone, but are seen to best advantage along the roads crossing the mountain, where they are common in the igneous rocks, in this case granites.

The xenoliths are not large and are invariably rounded. They are darker and of finer grain than the enclosing rock, and are quite prominent even on fresh surfaces. In some cases they have a porphyritic structure, which is blasto-porphyritic, the blastocrysts being feldspars derived from the enclosing rock. The borders of the xenoliths in many cases contain abundant blastocrysts with a flecked appearance due to the inclusion of minerals from the xenolithic rock. The border blastocrysts are at times extensions of crystals from the coarse-grained granitic host.

¹ Sederholm, J. J.: "On Migmatites and Associated Pre-Cambrian Rocks of Southwestern Finland"; part 1, "The Pelling Region". Bull. de la Comm. Geol. de Finlande, 53, 153 pp., p. 120 (1923).

² Weinschenk, E.: "The Fundamental Principles of Petrology". Tr. A. Johannsen, McGraw-Hill, New York, 1916, 214 pp., p. 66.

A xenolith in the vicinity of the first stream east of West Bay Road is a rather fine-grained rock showing pink and green coloration. Microscopic examination shows that the rock is composed of dominant quartz occurring in small, rounded grains with some larger aggregates, and grains of very cloudy orthoclase. Between the grains is much dusty material, principally chlorite, sericite, leucoxene, carbonate, epidote, and finely divided quartz. Apatite prisms are present in the quartz grains and the orthoclase owes its cloudy appearance to iron oxide and vermicular chlorite. Slight shearing is noticeable in the thin section. Xenoliths occurring on the road going southward from Big Brook post office are medium-grained, acid rocks of orthophyric structure. They consist chiefly of orthoclase, with a little acid plagioclase, hornblende, and biotite. The feldspars are very much sericitized and are zonal with more or less unaltered feldspar around the edges. The hornblende occurs in elongated prisms. The biotite has been completely altered to chlorite. A little interstitial quartz is present, and magnetite and apatite are distributed through the section.

The host rock is a coarse-grained granite consisting of orthoclase, perthite, acid plagioclase, abundant quartz, and subordinate biotite and hornblende. The action of the granite on the xenolith may be seen at the boundary between the two where the larger feldspars of the granite penetrate into the xenolith and hold all the constituents in poikilitic structures. The feldspars of the granite show only slight alteration. Although they do not appear to actively corrode the xenolithic minerals, in one case small prisms of sericitized feldspar are present and in another the xenolithic feldspars are absent and only the ferromagnesian minerals remain.

Exposures of recognizable sediments are few. Small exposures of metamorphic limestone, associated with dark quartzose rocks, were noted at two places. The limestones are finer in grain than are the rocks on the south side of the mountain, and hold abundant pale mica, garnets, quartz, and occasionally graphite, and traces of iron and copper sulphides.

In some localities small quartz veins are numerous, but are not persistent. They appear cutting the above described rocks. Where the quartz parallels the foliation of the rock the original minerals have been profoundly altered, and a thin section shows interrupted bands of alteration aggregates in clear granular quartz.

Minor Intrusives

A number of dykes of varying composition cut the granite and members of the George River series.

The extent and persistence of the dykes are not known, for, although twenty exposures were noted, in no case was it possible to trace any one dyke for any distance along the strike. Mineralogically they may be divided into three groups: basic, intermediate, and acid.

The basic dykes are the largest and also probably the most numerous. They appear to be developed in two sets, striking on the average 58 degrees and 152 degrees (true). The widths range from 20 inches up to, in one case, 70 feet. Most are diabasic and some are slightly porphyritic. They consist of basic andesine, or labradorite, monoclinic pyroxene, and, in some

cases, biotite. The accessory constituents include magnetite, ilmenite, pyrite, and apatite. In most specimens examined the feldspars occur in idiomorphic or hypidiomorphic prisms with the pyroxene as interstitial filling. Some show a distinct zonal structure. The pyroxenes and biotite are much altered, and in some cases completely destroyed. Hornblende is a common alteration product, and is accompanied by aggregates of chlorite, epidote, carbonate, and leucoxene. Quartz was observed in a few specimens. It is small in amount and occurs interstitially with intimate penetration effects against, and in one case intergrowths with, the feldspars.

The largest basic dyke noted, outcrops on the Marble Mountain-Munroes Bridge road. It is a hornblende diorite, of coarse, granular texture, and consists of andesine and hornblende in the proportion of about 6, -3, accompanied by white mica and alteration products of sericite, fibrous hornblende, chlorite, and leucoxene.

Dykes of intermediate composition were noted at four exposures. Of these, one is referable to as bostonite, the others are lamprophyric in character. The bostonite is fine-grained, porphyritic, and consists mainly of acid feldspars heavily stained with iron oxide. Carlsbad twinning is present in the phenocrysts, but the feldspar rods of the groundmass exhibit little twinning of any character. No distinct ferromagnesian minerals are present, but the groundmass contains chlorite, sericite, and a little epidote, much of which is associated with the feldspars. The lamprophyres are porphyritic and approach vogesites in character. The dominant mineral is acid feldspar, probably almost wholly orthoclase. Pyroxene and biotite are present in some specimens, but not in great quantity. Quartz is generally subordinate and interstitial, but in one specimen made up about one-third of the rock and was intimately intergrown with the feldspars. The feldspars of the groundmass carry abundant ferric iron dust and are altered to a considerable extent to sericite, and are penetrated by mats of fresh, green, actinolite rods. The alteration of the ferromagnesian minerals produces fibrous amphibole, micas, chlorite, leucoxene, carbonate, sericite, and epidote which generally appear as pseudomorphic aggregates after the ferromagnesian phenocrysts. Zircon, magnetite, and in some cases titanite, occur as accessory minerals.

The strictly acid dykes, excepting the aplites of the Lime Hill-Ross Brook mixed zone, appear to be rather few. They include granophyres and coarse rocks of granitic character that in places are porphyritic. Ferromagnesian minerals are subordinate and where noted consist mainly of a little bleached biotite. Only one dyke of pegmatitic character was noted. It occurs in the stream east of McCuish brook, and is a coarse rock made up of quartz, feldspar, and a little green mica. The quartz is concentrated along the middle of the dyke, whereas the feldspar occurs along the walls. The mica projects from the walls into the feldspar.

CARBONIFEROUS

The lowlands surrounding North mountain are developed on Carboniferous rocks. In the vicinity of the mountain the Carboniferous beds for the most part are Mississippian and belong, largely, to the Windsor

series. Younger measures, of Pennsylvanian age, occur to the southwest, on the hill northwest of Big brook and in the valley of Inhabitants river.

The lowest exposed Carboniferous beds are conglomerates and rest on eroded surfaces of the crystalline rocks. The conglomerates are made up in greatest part of fragments from the underlying rocks, cemented by carbonate and finely comminuted material from the same rocks. All the pebbles are angular, with rounded edges, and, although in places the largest are about 2 inches in diameter, the usual size is less than 1 inch. The character of the conglomerate depends upon the neighbouring older rocks. Where these are the George River series, the pebbles are of limestone, schist, greywacke, and gneiss, mixed with small fragments of quartz and feldspar. Where granite is the underlying rock, the conglomerate is a coarse arkose barely distinguishable from the weathered rock beneath and the cement is dark green, limy material. Small, grey or grey-green lenses of sand are common even in the lowest part of the conglomerate and in some places carry obscure plant remains.

Exposures of conglomerate were observed at six widely spaced points around the base of the mountain. At no place did the exposed thickness exceed 15 feet, and at only one point were overlying strata seen in contact with the conglomerate.

In the valley of Campbell brook, a short distance below the lower forks, are isolated exposures of conglomerate which, so far as could be determined, are in place. This occurrence is well within the area of North mountain where the valley sides rise steeply for several hundred feet. Lower down the valley, near its mouth, large, detached blocks of grey conglomerate occur on the hillside northeast of the brook. An outcrop of conglomerate occurs in McKenzie Brook valley well within the area of North mountain, on the south side along the main tributary brook from the south. These conglomerates are possibly of pre-Windsor, Horton age. They are so situated as to indicate that Campbell Brook and McKenzie Brook valleys originated in early Mississippian time when North mountain must have been an upland area.

On the lowland northeast of the mountain in the general vicinity of Little Harbour and Big Harbour and on the bordering lowland on the northwest side from Denys basin inland to River Denys station, gypsiferous Windsor strata apparently closely adjoin the outer edge of the area of Precambrian rocks of North mountain and, in part, make their presence known by areas of low, swampy ground close to the abrupt slope of the mountain. Exposures of the rocks associated with the gypsum are not abundant, but dark, fetid, cavernous limestones, and buff, dolomitic limestones were noted at one or two places. On the hillside above the post office at Big Harbour, a dark, oolitic limestone, carrying micro-fossils, rests on granite with only a few inches of mixed granitic material and lime at the base. As exposed it is about 12 feet thick. This rock is undoubtedly a member of the Windsor series.¹ On the northwest side of the mountain, at the foot of the slope north of the mouth of McKenzie brook, fossiliferous limestone outcrops. This limestone, as stated in a succeeding paragraph, is of lower Windsor age.

¹ Bell, W. A.: Personal communication.
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On the southeast side of the mountain, Windsor strata in two places are to be seen lying on Precambrian rocks. At one locality, on the shore southwest from the entrance to Little harbour, fossiliferous, massive, grey limestone dips away from the mountain at an angle of 76 degrees and is separated from the Precambrian by a thin conglomerate. The second locality is a rocky point near the post office at Marshes where a dark, fine-grained, thin-bedded, fossiliferous limestone dips away from the mountain at an angle of 70 degrees and is underlain by conglomerate resting on Precambrian granite.

W. A. Bell, while visiting the writer in the field, made small collections of fossils from the above-mentioned limestones. Mr. Bell makes the following statements in regard to these rocks:

"The conglomerate, and the overlying limestone and gypsum are all referable to the Windsor series, as the limestone from Marshes post office yielded a small Windsor fauna that included *Leptodesma borealis* Beede, and *Pteronites gayensis* Dawson, two characteristic lower Windsor pelecypods. The limestones associated with the gypsum near the mouth of McKenzie brook yielded abundant specimens of *Cranaena*, of a species common in Lower Windsor strata of the type locality at Windsor, as well as specimens of *Dielasma davidsoni* (Hall and Clarke)."

The Carboniferous rocks at the southwestern end of North mountain are quite different from the strata to the northeast. In McLeod brook, dark, fine-grained limestones and limy shales strike about east and dip north at high angles. In Cameron brook, to the south, buff, grey, and green sandstones, in beds from 1 to 2 feet thick, overlie dark, thin-bedded shales carrying a fauna of ostracods and a species of *Leaia*. The sandstones are fine-grained, and carry abundant white mica. Ripple-marked surfaces were noted on loose blocks. The road between West Bay and West Bay Road, although rising to an elevation of about 300 feet, nevertheless runs wholly over Carboniferous rocks, which consist of chocolate and grey shales, and shaly sandstones, dipping southerly. The dip increases as the base of the mountain is approached, except in the vicinity of the road over the mountain to Big Brook where grey shales dip 10 degrees south. They are crumpled, contorted, broken by small faults, and show incipient slaty cleavage. The lithology of the above rocks, as well as their contained fauna, correlate them with some part of the Riversdale series of lower Pennsylvanian age.

The attitude of the formations, in the immediate vicinity of their contact with the older rocks, varies considerably. On the southeast side of the mountain, with the exception of the strata in the embayment at Little Harbour, the dips are very steep, in the neighbourhood of 70 degrees, and are in marked contrast with those on the northwest side of the mountain where the steepest dip noted was 28 degrees. Away from the base of the mountain the formations as a whole appear to be only gently inclined, and strata with low dips may be seen in the valley of Cameron brook, and in the neighbourhood of Denys basin.

The Carboniferous formations dip away on all sides of the pre-Carboniferous basement exposed in North mountain. Originally laid down with perhaps slight initial dips, and derived in largest part from the underlying rocks, they are now characterized by variable and in places very steep dips. Structures similar to these exist on the south side of Craignish

hills to the northwest and probably prevail also on the north side of Sporting mountain to the south.

The lowlands, then, represent structural basins lying between the older uplands. The synclinal nature of the structure is well shown on the hill northwest of Big brook where, as shown on Fletcher's map, the higher formations of the Carboniferous strata dip inwards on all sides of the hill. Although synclinal in general, the structures are not simple, as at many places on the lowland the strata are steeply folded.

Faulting was noted at several points within the pre-Carboniferous crystalline area. At McMillan's farm, on the Lime Hill-River Denys road, a basic dyke, striking about 70 degrees (true), has been displaced in a northerly direction by several closely spaced faults. In the first stream east of West Bay Road, another basic dyke has been involved in fault movement, and the granitic rocks which it cuts are brecciated and contain small fragments of the dyke. This fault appears to parallel the dyke which strikes 70 degrees (true).

Faults along the base of the mountain were observed near the mouth of McKenzie brook, near the cliffs southwest of Little Harbour, between Marble Mountain and Lime Hill, and in the lower part of the east branch of McLeod brook. The faults near McKenzie brook and Little Harbour dip outwards from the crystalline rocks, whereas the other two dip steeply inward. The fault between Marble Mountain and Lime Hill is a strike fault in the George River series.

The maps that accompany Fletcher's report on the western part of Cape Breton,¹ show a large fault along the southwest base of North mountain, close to the contact of the Carboniferous sediments with the older rocks. Undoubtedly this fault was determined from stratigraphic data obtained in the study of the sedimentary rocks of the lowlands southwest of North mountain, as well as by the attitude of the rocks in the vicinity of their contact with the pre-Carboniferous. The direct evidences of faulting along the south and southwest base of North mountain are the above-mentioned faults at Little Harbour, between Marble Mountain and Lime Hill, and in the valley of McLeod brook. The steep, almost vertical, attitude of the Carboniferous rocks in the immediate vicinity of their contact with the older complex is probably also indicative of faulting, but the total evidence appears rather insufficient to assign a major fault to the southeast base of the mountain.

The steep folding of the Carboniferous sediments, and at least some of the faulting along the base of the mountain, are probably referable to the movements that marked the close of the Palæozoic era.

PLEISTOCENE

The evidence of glaciation on North mountain consists of a mantle of glacial drift which, except in special cases, is rather thin. The drift, in largest part, consists of crystalline boulders mainly granitic, with only a slight admixture of Carboniferous sediments. Towards the western end

¹ Maps numbered 18, 19, 21, 22.

of the mountain the latter become more prominent. A typical boulder clay does not appear to be present on the mountain itself, but is the principal formation making up the islands of West bay.

The thickness of the drift on the top of the mountain is not great, and in many places it is entirely lacking, although a covering of moss and humus obscures the bedrock. This is well instanced along the roads that cross the mountain. These are not especially graded, yet traffic exposes areas of bare rock that in ordinary circumstances would be quite abnormal.

Although rounded surfaces of rock are not uncommon, in only one instance was anything resembling a glacial striation seen. This occurs on an exposure at McMillan's farm close to the road from Lime Hill to River Denys. The orientation of this mark was 135 degrees (true).

The rounded surfaces of the granitic rocks, even where covered with moss, are quite rough, and a thin veneer of cream-coloured, gritty material was commonly observed to lie between the moss and the solid granite. The roughness is due to the quartz grains which stand out on the surface as a result of decay or solution of the feldspars. When liberated from the parent rock these grains accumulate at the bottom of the outcrop as a coarse siliceous sand.

In the main, glacial action appears to have removed all the products of subaerial weathering, leaving the exposed surfaces in a fairly fresh condition. The deeply weathered zone in the western part of the mountain is restricted almost entirely to the west branch of McLeod brook.

On approaching the lowland from the crystalline area, the drift cover increases and, as seen in numerous road cuts, becomes sorted to a considerable extent. In places this sorted material may exceed the unsorted drift. Both are composed of essentially the same materials, namely; rounded boulders, pebbles, and sand of igneous rocks, mixed with fragments and particles of chocolate-coloured shale and sandstone. The colours are almost invariably shades of red, depending on the proportion of igneous material.

The sorted drift is developed to a considerable extent on the lowland to the west of Big Harbour, and in the valley of Big brook. A section exposed at the former place shows a 4-foot band of horizontally stratified, fine, brown sand, overlain by rather coarse gravel. In the valley of Big brook, sections cut by the stream consist of chocolate-coloured clays and sands, interstratified with coarse gravels. The clays are generally in beds from 1 to 3 inches thick, and rarely $\frac{1}{4}$ to $\frac{1}{2}$ inch. Fragments of wood and branches of trees are visible in some of the layers.

Near River Denys and again at West Bay Road, deposits of stratified gravel have been opened and used for railway ballast. At River Denys the deposit is at least 60 feet thick. It consists of a top layer of unstratified material a few feet in thickness, followed below by layers of gravel and coarse sand dipping steeply to the north and east. The deposit projects from the mouth of the valley of Campbell brook, and is apparently an outwash deposit built by that stream. At the present time the brook has cut deeply into the gravels and flows eastward from the mouth of the valley. The writer was informed by employees of the railway, who were working in the gravel pit, that shells were occasionally

found in the basal layers when the deposit was being actively worked. The top of the deposit has an elevation of about 130 feet above sea-level.

The gravels at West Bay Road, which is about 9 miles west of River Denys, have an exposed thickness of 70 feet. These beds also dip to the north and east and the top of the deposit has an elevation of over 250 feet.

The glacial desposits on the southwest side of the mountain are mainly boulder clays, built into oval, elongated hills with a rounded profile. They cover a large part of the lowland southwest of Big Harbour, and make up the irregular peninsulas and islands along the shore as far southwest as the village of West Bay. The hills apparently have their steepest major-axial slope to the east, although in most cases this feature was obscured by wave erosion. The orientation of the hills is variable through an arc of about 90 degrees, but the greater number have an elongation in a direction east of north.

Vigorous wave erosion on the ends and flanks of the hills and islands is exposing the contents to view, and building spits and bars from the eroded material. The hill at the base of Malagawatchkt point has been half cut away along its major axis, exposing a high, steep bank on the south side, and leaving a gentle, forested slope to the north. Magnus island, near the village of West Bay, has been almost entirely cut away, but its former extent may be seen by shoal water to the east of the island.

Of the materials making up the boulder clay the larger boulders are dominantly crystalline with only a few examples of sedimentary rock. The latter, however, increase in the smaller sizes, and the clayey matrix is generally brown or chocolate coloured. Striated boulders are common, and several small, striated pebbles of Carboniferous sandstone were collected from points about 30 feet above water-level on the end of George island.

Evidences of bedrock were obtained at only a few places within the area covered by the oval hills. On Militia peninsula a small outcrop of Carboniferous limestone was observed on the shore not far south of the entrance to Little Harbour, and an area of sink-holes, with limestone boulders, in the interior of the peninsula, was taken to indicate gypsiferous strata. Some of the islands show rather large blocks of gypsum projecting from the boulder clay near the water-level, but in no case was the gypsum actually determined to be in place.

There appears to be little doubt, from the shape, structure, and composition of these hills that they are drumlins, built up from material carried by glacial ice. The possibility that the gypsiferous rocks, observed on some of the islands, may actually be in place, does not materially affect the classification, as the gypsum occurs near the water-level and the wave erosion demonstrates that the greater part of the hills is of glacial origin.

PHYSIOGRAPHY

The physiographic features of Nova Scotia have been described at some length by several writers, notably R. A. Daly,¹ J. W. Goldthwait,² and D. W. Johnson.³ In its broadest features the province may be

¹ Daly, R. A.: "The Physiography of Acadia"; Harvard Univ. Mus. Comp. Zool., Bull. 38, No. 3, pp. 73-103 (1901).

² Goldthwait, J. W.: "Physiography of Nova Scotia"; Geol. Surv., Canada, Mem. 140, 159 pp. (1924).

³ Johnson, D. W.: "The New England-Acadian Shoreline"; J. Wiley and Sons, N.Y., 1926, 608 pp.

separated into two main divisions, an upland division, and a lowland division.

The upland division, called by Goldthwait, the 'Atlantic Upland'¹ forms the largest physiographic feature, and occupies all the southern half of the province, with extensions and detached areas to the north. It is underlain by resistant rocks of Devonian or pre-Devonian age, and is characterized by a surface of striking uniformity which bevels or cuts across the complex structure of the underlying rocks. Because of this feature it is believed to have originated through long-continued erosion that reduced a mountainous region to a plain.

At the present time the upland emerges from the Atlantic ocean along the southeast coast of Nova Scotia, and rises in altitude as it is traced northwest. The present tilted attitude of the surface is thought to be due to a general warping of the whole region, after erosion had produced a plain near sea-level.

The lowland areas have their chief development towards the northern part of the province, and are underlain by relatively soft rocks mainly of Carboniferous age. The lowlands are more or less deeply sunk below the uplands and owe their existence to erosion which followed the general upwarping of the whole region.

Both the Atlantic upland and the lowland areas are well developed in Cape Breton. The upland appears wherever the hard crystalline rocks come to the surface, and consists of a series of elongated irregular belts that trend northeast from the strait of Canso. The lowlands are the deep, wide valleys that separate the upland belts. They have been eroded principally in the areas of Carboniferous sediments.

In North Mountain district erosion surfaces of different ages are visible or indicated. The oldest are of early Carboniferous age and developed on the crystalline rocks; a younger surface truncates the Carboniferous sediments and the oldest erosion surface or surfaces; and the youngest is developed almost wholly on the Carboniferous sediments.

The Carboniferous sediments of Nova Scotia are dominantly of non-marine character, and are lenticular in nature with lateral gradation in many places. These and other factors demonstrate that parts of the region were in a state of movement, either positive or negative, during the whole period of sedimentation. In Cape Breton the base of the Carboniferous is a thick conglomerate series, which is well developed in the eastern part of the island and is of the age of the Horton series of the mainland.² This Horton assemblage occurs in the vicinity of Whycocomagh, at the eastern end of Craignish hills to the north of North mountain, and on Madame island to the south. The nature of the Horton strata and their relations to the older rocks indicate that the pre-Windsor topography consisted of valleys separated by areas of high land. Presumably North mountain was one of these areas of high land. The patch of Carboniferous conglomerate situated towards the centre of the mountain, on the relatively deep floor of Campbell brook, is evidence that at the time of deposition

¹ Goldthwait, J. W.: Op. cit., p. 4.

² For the data relating to the Carboniferous sedimentation in Nova Scotia and Cape Breton the writer is indebted to Mr. W. A. Bell of the Geological Survey.

of the conglomerate, the area had very considerable relief. This conglomerate may be of Horton age and possibly, therefore, by Windsor time continued erosion of the uplands and deposition on the lowlands may have reduced the region to an area of low relief.

In Nova Scotia the earliest deposit of the Windsor sea is commonly a finely laminated limestone. This earliest limestone was not seen at North mountain and, instead, at the few places where Windsor limestone may be seen resting on the crystalline rocks, the limestone is of a higher horizon, perhaps indicating that at North mountain the Windsor sea as it rose encroached upon an upland. The Windsor limestone and gypsum beds that floor at least the lower part of the valley in North mountain that opens on Little harbour, by their presence suggest that this valley was existing in Windsor time, but possibly the strata may owe their position to secondary folding along east-west axes and such folding may explain the attitude of the Windsor beds in the vicinity of Big Harbour post office. Thus, though the writer is inclined to believe that North mountain was an area of very considerable vertical relief during part or all of Windsor time, the available evidence is admittedly inconclusive and it may be that by Windsor time the uplands of Horton age had disappeared and that the general region was low and only gently undulatory. In any case it is not intended to suggest that the upland area of early Carboniferous time was necessarily as high or higher than that of today; nor to suggest that there has been no adjustment since Mississippian time. The dips of the sediments on both sides of the mountain certainly indicate strong movements since deposition.

After the close of Palæozoic sedimentation, the Carboniferous strata were folded and another cycle of erosion set in. During the Mesozoic era the greater part of the mainland of Nova Scotia and all of Cape Breton appear to have undergone erosion. The surface developed by this cycle is the Atlantic upland and is, by Goldthwait, correlated with a similar surface that is well developed along the Atlantic coast of the United States, where it is known as the "Cretaceous Peneplain". In Cape Breton, not only were the folded Carboniferous strata bevelled to a smooth surface, but the higher parts of the areas of crystalline rocks were also truncated, although on account of their resistant nature they may, perhaps, have projected above the general level.

North mountain, with its neighbours, Sporting mountain, Craignish hills, Mabou highland, and a small area on Madame island, are the remnants of the Atlantic upland in western Cape Breton. They rise more or less sharply from the lowlands surrounding them and increase in elevation from south to north. North mountain attains an elevation of a little more than 700 feet above sea-level, and its slightly undulating surface slopes gently to the north and west. A full view of the upland surface is generally masked by the thick forest growth, but where clearings give opportunity for wider vision the surface is seen to be monotonously regular, and to be unrelieved by any important elevations. From North mountain the Craignish hills to the north, and Sporting mountain to the south present even skylines, and it requires little imagination to visualize the original peneplain: the whole area near sea-level, the intervening valleys filled with

Carboniferous sediments, and a sluggish drainage system occupying the wide valleys of that time.

The drainage on the ancient surface has been fully discussed by Goldthwait,¹ but so far as North mountain is concerned, this area gives little if any clue to the ancient drainage development. There is no evidence that the harder rocks had more topographic relief than the areas of sediment, but doubtless at many places the crystalline areas acted to control the drainage courses.

After peneplanation had reached a development that must have been nearly a maximum, the region was uplifted and tilted to about its present position. This tilting extended over the whole region and appears to have taken place without any great dislocations. Because of the rising of the land surface the old drainage lines which were doubtless to the south and east and controlled no doubt by the areas of crystalline rock, were rejuvenated and commenced active erosion in their old channels. It is this third cycle of erosion that has formed the lowlands.

The effects of the third erosion cycle have been confined chiefly to the areas of Carboniferous strata that occupy the intervals between the crystalline areas. The later drainage has in these strata developed wide valleys which are accentuated by the resistant crystalline masses. The gradual erosion of the softer strata would also lead to erosion of the crystalline highlands.

The present lowland surfaces are more or less distinctly separated from each other by the crystalline hills. The lowlands may rise as much as 400 feet above sea-level. The rolling surface is in places interrupted by areas of strata which, through differing lithologic characters, are more resistant than usual and stand up as low hills.

The sinking of the surface, believed to have taken place before glaciation,² interrupted the normal erosive cycle in as far as the drowned parts of the country are concerned. Subsequent glaciation has modified the land surface and positive and negative movements of sea-level have taken place. In the vicinity of North mountain, the drowning of the former valleys is well illustrated in Denys basin and West bay, and the glacial modifications are shown by the hills of glacial till at the eastern end of the mountain, and along the south shore. The ice has also doubtless modified the lowland surface by smoothing the more elevated parts and filling in some of the valleys.

The melting and withdrawing of the ice-sheet in North America left large areas of country below the level of the sea and it was not until a considerable time had elapsed that the land regained in some measure its former position. Many authorities unite in stating that the line of zero post-Glacial uplift passes through Cape Breton. In the vicinity of North mountain, however, there are indications of a slight positive movement since the retreat of the ice. The clay at Eden siding, between River Denys and Orangedale, although not stratified, contains few pebbles, and may be water laid, as it is stated to overlie the glacial drift.³ The

¹ Goldthwait, J. W.: *Op. cit.*, pp. 40-48.

² Goldthwait, J. W.: *Op. cit.*, pp. 4-5.

³ Ries, H., and Keele, J.: "The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick"; *Geol. Surv., Canada, Mem.* 16, 164 pp., p. 64 (1911).

stratified clays and gravels, noted in the valley of Big brook, may also be of estuarine or marine origin, although no fossils were observed, and the shell layer, stated to lie near the bottom of the gravel deposit near River Denys, is also of value as evidence. The bottom of the gravel pit has an elevation of about 70 feet above sea-level.

THE SHORELINE¹

The shorelines of Bras d'Or lakes have been investigated by Tarr,² Woodman,^{3, 4} Goldthwait,⁵ and Johnson⁶. It appears to be well demonstrated that these lakes resulted from the drowning of former drainage systems, and that the irregular shore pattern is in the main due to original irregularities of the non-drowned surface rather than to erosion by marine agencies. According to Johnson,⁷ shorelines of submergence may be divided into two classes; (a) those formed by the partial drowning of a land mass that has been dissected by normal river valleys (the ria shoreline); and (b) those formed by the partial drowning of a region of glacial troughs (the fjord shoreline). Although Cape Breton has been intensely glaciated, glacial troughs, of the over-steepened type characteristic of mountain regions, are uncommon, and the shoreline of Bras d'Or lakes falls into the first class, namely, the ria shoreline.

The chief agents in the shaping of a shoreline are waves and currents of several varieties that are produced in different ways.⁸ In Bras d'Or lakes the connexion with the open sea is so restricted that ocean currents are non-existent, and, as the tidal range in the lakes is very small, currents caused by tides are negligible, except at the entrance where tidal currents in Great Bras d'Or channel may attain a velocity of 7 miles an hour. The shore forms produced are, therefore, the result of wave action, and of currents caused by wave action, and are thus indirectly controlled by the winds. At North mountain the greatest effects caused by wave action are to be seen at Malagawatchkt and Militia peninsulas and along the north shore of West bay where the expanse of open water is at a maximum. In Denys basin, wave-built forms are also developed, but since this water is more restricted, the forms are subordinate.

The greater part of the North Mountain shoreline is developed on the lowland areas which fringe the northeastern and southwestern ends of the crystalline area. Two groups of rocks occur on the lowlands, the sedimentary group of Carboniferous age, and the overlying unconsolidated deposits of glacial origin. Both of these groups take part in the shore forms developed, but the glacial deposits are by far the most important. The effect of the partly drowned glacial topography is to give an exceedingly irregular shoreline, with many bays, islands, peninsulas, and the dead

¹ Admiralty Chart, No. 2758, illustrates the features described in the following paragraphs.

² Tarr, R. S.: "Wave-Formed Cusped Forelands"; *Am. Geol.*, 22, pp. 1-12 (1898).

³ Woodman, J. E.: "Shore Development on the Bras d'Or Lakes"; *Am. Geol.*, 24, pp. 329-342 (1899).

⁴ Woodman, J. E.: "Forelands on the Bras d'Or Lakes"; *N.Y. Acad. Sc., Annals* 22, p. 351, Abst. (1913).

⁵ Goldthwait, J. W.: *Op. cit.*, pp. 104-107.

⁶ Johnson, D. W.: "The New England-Acadian Shoreline"; *J. Wiley and Sons, N.Y.*, 608 pp. (1925).

⁷ Johnson, D. W.: "Shore Processes and Shoreline Development"; *J. Wiley and Sons, N.Y.*, 584 pp., pp. 173-186 (1919).

⁸ Johnson, D. W.: "Shore Processes and Shoreline Development"; *J. Wiley and Sons, N.Y.*, 1919, 584 pp., pp. 1-158.

waters which accompany them. This large amount of shoreline gives a greater opportunity for coastal erosion, but, on the other hand, the irregularities and islands break up and restrict the bodies of water, and it would be difficult for the wind to form waves and currents of sufficient intensity to erode and transport the material were it not in an unconsolidated condition.

The Carboniferous sediments outcrop at only six places along the lowland shore, and even there the rock exposed is in four cases gypsiferous. Wherever gypsiferous strata are exposed, cliffs are prominent, and it appears as if the erosion of the soft strata was too rapid to permit solution to soften the cliff-like form. From the tops of many of the gypsum cliffs the land slopes downward away from the shore. This feature is due to the sink-hole topography so characteristic of land underlain by gypsum.

The unconsolidated glacial deposits, mantling the Carboniferous strata, give a variety of shore forms, for they suffer rapidly from erosion, and the materials are apparently transported with ease by waves and currents. For the most part the deposits are of boulder clay, consisting of a mixture of rounded crystalline boulders, with flatter sedimentary boulders and pebbles, in a clayey matrix. Without doubt the post-Glacial shoreline was much more irregular than the shoreline of today. Not only were small bays and inlets more numerous, but there were many more islands.

The effect of the wave action has been to form cliffs in the more exposed glacial deposits, to transport the eroded material along the base of the cliffs, and to deposit it at the first opportunity. Where the glacial deposits are in the most exposed positions, as at Malagawatchkt point, Pellier point, and the islands of West bay, the erosion has been at a maximum. The drumlin forming Malagawatchkt point is transverse to waves from the centre of the lake, and the material has apparently been transported in two directions, depending upon the direction of wave attack. This drumlin is tied to Malagawatchkt peninsula by two tombolos, one of which forms a baymouth bar at the entrance to Gillis pond. The material for this bar has been derived from the small, nearly destroyed drumlin to the southwest, as well as from the Malagawatchkt drumlin. The second tombolo appears to be the result of wave attack from the north, and very little if any material has come from the south. The recurved spit, at the eastern end of the Malagawatchkt drumlin, is in the main the result of wave attack from the south and west, with perhaps some attack by waves from the southeast. The Malagawatchkt drumlin, at the present time, is about half eroded parallel to its length, and presents a high cliff of glacial material on the southeast side, whereas the northwest slope is wooded and gently convex upward.

Pellier peninsula is made up of three drumlins, with the largest to the east. The peninsula originally consisted of two islands separated by a narrow, shallow channel. Wave attack from the northeast has caused a fusion of the islands by means of a tombolo, which in reality, because of the narrow, shallow separating channel, has been built as a baymouth bar. Pellier peninsula is tied to Militia peninsula by a tombolo resulting from the growing together of two cusped bars. The lagoons enclosed by the original

bars may be seen at either end of the tombolo as marshy depressions. The material making up the recurved spit at the south end of Pellier peninsula has been derived from the largest drumlin by truncation at an angle to its main axis. This spit has apparently been built out into moderately deep water, as the writer was informed that schooners had been known to anchor within the hook. The effect of wave attack and transportation, even within the restricted Pellier harbour, is illustrated by the slight truncation at the south end of the two smaller drumlins, and the formation of a series of recurved spits at the western side of the harbour.

Where the glacial deposits were built on higher ground, and did not form islands, as at Militia peninsula and Malagawatchkt peninsula, the original shoreline was scalloped by many small bays. Wave attack on the headlands, and transportation along shore has now resulted in the formation of baymouth bars enclosing shallow, swampy lagoons, most of which have no connexion with the open water. Lagoons of this character may be seen on either side of Grammo point, and at several places on Militia peninsula. The transported material appears in every case to be derived from the immediately adjacent cliffs of glacial material, but characteristically it is made up of a relatively large proportion of sedimentary pebbles. It appears that the flat shape of these, in contrast with the more rounded pebbles of igneous origin, permits their being more easily transported.

The islands of West bay are exposed to waves from the east, southeast, south, and southwest, and show many examples of wave-built forms. The large, irregular peninsula, of which the point called George island is a part, is made up of at least seven drumlins, most of which were probably at one time islands. They are now connected by a series of pebbly tombolos, built of material eroded from the sides and ends. The innermost drumlins are exposed only to waves from the southwest and consequently are eroded to only a slight extent. Were the drumlins of Cameron island not so far removed from the George Island peninsula, these also might have been added to the assemblage. Tailor island and Crammond islands each consist of several drumlins. They differ from the other islands in that the low ground between the drumlins has not been submerged to any extent and consequently exhibits only baymouth bars built across the small scallops of the original shoreline. Two small, but perfect, recurved spits are developed at the south end of the channel between the Crammond islands. Each is built by the transverse erosion of a drumlin, and the direction of wave attack has apparently been from the southeast and southwest. Very good examples of double tombolos are to be seen at Clarke island, and the island to the southeast of Cow island. The latter two islands may eventually become joined through the growth of cusped spits from each.

It is to be expected that, as wave attack proceeds, it will eventually carry away and disperse all the glacial material; and that in time the islands will have become entirely eroded, provided that no resistant rocks occur as cores in the drumlins. Examples of this process are to be seen at Magnus island, east of the village of West Bay, and at Ronald island (spelt 'Ranald' on Admiralty chart), southeast of Tailor island. Both islands are now quite small, but show traces of their former extent

in the shoal water that surrounds them, and in the number and size of the boulders that fringe the shore. Magnus island has evidently been attacked by waves coming directly from the east. It shows a small cliff facing east, at the bottom of which are many large boulders. From the top, the cliff slopes gently westward to the water-level.

The lowland between Ross brook and the village of West Bay is of very irregular outline, and has many baymouth bars enclosing lagoons between deposits of glacial material. The deep bays in the vicinity of Ross brook are evidently too restricted to permit wave action of any consequence, but on the southeast shore the glacial headlands are being energetically cut back and the material carried to the heads of the bays. Two long, curved spits are built by the transverse truncation of two drumlins on either side of Head Bay cove and their development restricts the channel leading to the village of West Bay.

That part of the crystalline mass of North mountain exposed to the waters of West bay, presents an entirely different class of shoreline. On the lowland, the shoreline is of irregular pattern, and is chiefly built up on the glacial deposits, with few occurrences of the Carboniferous strata; whereas the upland shoreline is comparatively straight, has few sharp indentations, and at several points the crystalline rocks outcrop at the water's edge. Where the crystalline rocks are exposed at the shoreline, they have been cut into cliffs which generally do not exceed 10 to 12 feet in height, but which may reach heights of 60 feet. The cliffs are as a rule steep, but wave-cut notches are not prominent.

The beach of the upland shore is composed almost wholly of pebbles and boulders of crystalline rock, many no doubt of glacial origin, but some derived from the rocks in the immediate vicinity. The material is coarser than that found in the glacial deposits, and, on that account, transportation by shore currents and waves is not prominent. Where the streams from North mountain have brought down finer material, and have built alluvial cones and fans near the shore, transportation has taken place, and as a consequence the mouths of some of the larger streams show small, cusped bars enclosing marshy lagoons.

A certain amount of protection is given the south shore by the islands in West bay, and on that account erosion and transportation are perhaps not as great as they would normally be. An example of this is to be seen along the shore of Clarke cove, near Marble Mountain. This shore is well protected from the east and south, but is comparatively open to winds from the southwest. The quarrying operations at Marble Mountain have resulted in large dumps of broken rock that has reached the shore, and has been transported in an easterly direction as far as the hooked spit near the mouth of Mill brook. Because of the character of this material, a white, crystalline limestone, the amount of transportation may be clearly discerned. It was noted that none of the crushed rock had been transported to the west of the point where the rock dumps reach the shore. Farther to the west, in the vicinity of Lime Hill and towards Ross brook, transportation takes place in the opposition direction, namely, to the west.

The Carboniferous sediments at two points along the south shore are in contact with the crystalline rocks. At both places the dip is high, (about 70 degrees) and, therefore, is not an original structure. Faulting has undoubtedly taken place along the base of the mountain, but there is also evidence of a certain amount of upward drag of the early sedimentary beds during or after deposition.

The few outliers of Carboniferous sediment on the north slope of the mountain indicate that this slope is a resurrected and tilted surface of erosion; and it appears probable that the south slope is also, in part, of this character. In the absence of direct proof that the south scarp of North mountain is a fault-line scarp, it appears best to classify the south shore of the mountain as a resurrected peneplain shore-line, and since there are two erosion surfaces, one of which does not affect the form of the shore-line, it is of the morvan type.

MINERAL RESOURCES

The minerals of economic importance in North Mountain district are limestones and gypsum, but up to the present time only the limestone has been worked. This rock is part of the George River series, and has a widespread occurrence, but a great deal of it is not favourably located for easy transportation. The gypsum occurs with anhydrite in the Windsor formation flanking North mountain, and evidences of gypsiferous formations are to be found at many points on the lowlands. At Maple brook, a small stream flowing into Big brook from the northwest, exposures of coal have been known for several years. Traces of metallic minerals are to be found at several points on North mountain, and some little work has been done in connexion with these occurrences, but the results obtained appear to have discouraged any extensive exploration.

LIMESTONES

The limestones of the George River series, where developed in quantity and favourably situated, as at Marble Mountain, have been worked for lime, building stone, and metallurgical flux for about fifty years. The centre of the industry was on the shore of West bay, where close proximity to the water gave cheap and easy transportation. The value of the rock in this locality was first realized in 1861^{1, 2}, but although limestone was no doubt quarried for local use by the early settlers, it was not until 1873 that the rock was extracted on a commercial scale,³ when 8,000 barrels of quicklime were produced.

In 1888 the Bras d'Or Lime Company was incorporated to manufacture quicklime, and also to quarry marble for building purposes.⁴ This company continued in operation until about the year 1900. About 1899 the Dominion Iron and Steel Company acquired property at Marble Mountain,

¹ Honeyman, D.: "Record of Observations on Nova Scotian Geology Since 1855"; N.S. Inst. Nat. Sc., Pr. Tr., 3, pp. 6-18, 18-40, p. 10 (1871-74).

² Fletcher, H.: "Report of Explorations and Surveys in Cape Breton, Nova Scotia"; Geol. Surv., Canada, Rept. of Prog. 1877-78, pt. F, 32 pp.

³ Province of Nova Scotia, Rept. of Dept. of Mines, 1876, p. 69.

⁴ "Mining and Metallurgical Industries of Canada"; Mines Branch, Dept. of Mines, Canada, 2 vols., 972 pp., p. 918 (1907-08).

and shortly afterwards started shipping limestone to the iron furnaces at Sydney, distant about 60 miles by water. Operations were carried on by this company until the year 1922 when work was discontinued and the quarry abandoned. The quarry was worked by benching and the rock was broken by dynamite. The early drilling was done by hand, but later steam drills, and still later air drills were used. The broken rock was trammed from the face in horse-drawn cars, and after being crushed was screened through trommels. From an inspection of the screenings, all sizes passing through a 2-inch ring were rejected. The oversize was conveyed by gravity to bins near the shore, from whence it was loaded into steamers for conveyance to Sydney. During the war, from 600 to 700 men were employed at the quarry. When production was at a maximum, two 10-hour shifts were worked each day. The greatest production was in 1915 when 399,407 tons of crushed rock were shipped.¹

The quarry is situated on the southeast slope of North mountain, and above the village of Marble Mountain. It consists of two pits, one above the other. The limestones are in contact with the quartzites of the George River series exposed on the northwest side of the large pit and on the south side of the smaller pit. Lime silicates with quartz, olivine, serpentine, and specks of sulphides, occur on the northeast edge of the smaller pit, and apparently indicate that igneous rocks are close at hand.

Two varieties of limestone occur. The first, which is in greatest quantity, is a coarse white rock with no structures. The second, also coarse, is grey with distinct banding. Calcite veinlets and stringers are common in the grey variety. The relations between the two varieties are obscured by broken rock, faults, and folds, but it appears that they grade one into the other.

Analyses of the limestone are given below:

	(1)	(2)	(3)
SiO ₂	2.58	0.90	2.54
Iron oxide and Al ₂ O ₃			2.12
CaCO ₃	88.67	96.31 CaO	50.07
MgCO ₃	7.89	0.83 MgO	3.06
Sulphur.....	0.00	0.01	0.086

(1) Rept. of the Director, Geol. Surv., Canada, Ann. Rept., vol. VIII, 1895, pt. A, p. 110A (1897). Average of ten analyses.

(2) "Mining and Metallurgical Industries of Canada"; Mines Branch, Dept. of Mines, Canada, 2 vols., 972 pp., p. 918 (1907-08).

(3) Dominion Iron and Steel Company. Average analyses 1911-20.

¹ For these historical data the writer is indebted to the Dominion Iron and Steel Company, and to Mr. A. C. Campbell of Marble Mountain, who was an employee at the quarry for over twenty-five years.

Tests made on the stone with regard to its structural characteristics are as follows:

Specific gravity ¹	2.72
Weight per cubic foot.....	169.5 pounds
Pore space.....	0.087
Ratio of absorption.....	0.032
Coeff. of saturation, 1 hour.....	0.87
“ “ “ 2 “.....	1.00
Crushing strength.....	18,197 lbs. per sq. in.
“ “ “ dry after freezing.....	16,148 “

The limestone as exposed at the present time is not suitable for a structural stone, as it is badly shattered and broken. A very fissile structure is also present at some points, and several faults were noted on the quarry face. The explosives used when the quarry was worked for metallurgical flux were no doubt the cause of much of the fracturing.

Although apparently limited to the north, the rock in this vicinity is by no means exhausted, and further exposures of limestone occur to the south and west of the quarry. A diamond-drill core, stated to have come from a point 247 feet below the floor of the main pit, consists of a pure white crystalline rock apparently free from close fracturing.

At several other points on North mountain, limestone occurs in greater or less quantity. West of Little Harbour, the hillslope below the bare bluff known as “The Creigan,” has many outcrops of a contorted, blue-weathering limestone. A small quarry near the shore has been driven in a well-bedded limestone which is associated with graphitic shales.

The lakes at the head of Mill brook, east of Marble Mountain, are in an area of numerous limestone outcrops. The extent, however, is not believed to be great, as granite occurs nearby and apparently surrounds the individual outcrops. Relations similar to these are to be found in the area west of Sydenham brook, on the farm of Mr. Christopher McRae. Several pits opened in this rock show it to be coarsely crystalline, and white when freshly broken, but turning a bluish colour on weathering. Granite outcrops occur in the immediate vicinity, and in the gorge of Sydenham brook the granite extends nearly to the shore. Through the courtesy of Mr. George McKenzie, of Marble Mountain, the writer was permitted to examine a small map of this property that had been made for the Bras d'Or Lime Company about the year 1902. An analysis given on the map was as follows:

	Per cent
SiO ₂	0.66
Fe ₂ O ₃	0.74
Al ₂ O ₃	1.45
CaCO ₃	59.50
MgCO ₃	37.80
Sulphur.....	0.06

West of Marble Mountain, several small quarries have been opened close to the road, but in none of these does the extent of the limestone appear to be very great. North of Lime Hill, at McMillan's farm, blue-weathering limestones are well exposed. Further exposures are present on the ridge to the east of Campbell brook, and strike towards River

¹ Parks, W. A.: “Report on the Building and Ornamental Stones of Canada”; Mines Branch, Dept. of Mines, Canada, 2 vols., p. 178 (1914).

Denys, where a considerable development is found on McLeod's farm. This rock is banded, of various colours, but is invariably coarse grained. It occurs in a belt about 1,000 feet wide, but is possibly interbedded with other members of the George River series. The limestone belt is bordered on the southwest by the volcanic series, and on the northeast by the quartzites. From appearances this is an extensive occurrence, but it has not the advantage of being close to the water, as have those on the south side of the mountain.

GYPSUM

Gypsum and anhydrite occur at many points within the area mapped, but are most abundant towards the eastern end of the mountain, and no outcrops of these minerals were noted southwest of River Denys on the northwest, and Crammond islands on the southeast. The exposures are not confined to the areas adjacent to the crystalline rocks where the Carboniferous strata are turned up against the former, but may be seen at other points on the lowland where the gypsiferous strata are brought to the surface by folds.

In the neighbourhood of River Denys there are several indications of gypsum, but the exposures are neither abundant nor large. Three small outcrops of a white, fine-grained, and finely laminated rock are to be seen in a railway cut about $\frac{1}{2}$ to $\frac{3}{4}$ of a mile east of the station. The rocks dip about 30 degrees northeast. Other indications were observed south of Denys river near Munroes Bridge where cliffs of gypsum skirt the river bank east of the bridge. This belt trends eastward across the small peninsula, and its extension is indicated by sink-holes on the farm of Mr. L. McLean near South Side Basin of River Denys. Other sink-holes occur in the lower part of the valley of McKenzie brook, and the small lakes at this place may be due to water-filled sink-holes. Plaster island, between South Side Basin of River Denys and Plaster cove, exhibits cliffs of gypsum and anhydrite.

The gypsum to the east of Munroes Bridge occurs on three farms, owned respectively by Messrs. Alan McLean, John McLean, and Malcolm McLean. The cliffs on the farm of the former show the greatest quantity observed in the vicinity. The exposures extend along the water's edge for over a quarter mile, and the cliffs rise in places to heights of 40 or 50 feet. The point of the peninsula is occupied by a sandy, oolitic dolomite, which from its position near the water's edge is believed to underlie the gypsum. Small layers of grey, fine-grained, unfossiliferous limestone, up to 6 inches in thickness, occur within the gypsum. Three such layers were noted on one face. Grey clayey material is also intercalated with the gypsum at some places, and appears to increase towards the top and bottom of the exposures. At some points, large, oval, or pillow-shaped masses of clay lie within the gypsum whose bedding planes curve around the oval masses. The ground at the top of the cliffs, as is common in such localities, is pitted with sink-holes and depressions. These extend across the peninsula to the farm of Malcolm McLean, where the gypsum is again exposed, and is underlain by a dark grey, fossiliferous limestone. No anhydrite was observed in any of these exposures, and the gypsum,

varying between compact and granular, is of fair quality. Due to the inactiveness of foreign material, which is not carried off when the gypsum dissolves, the exposed surfaces appear to carry more impurities than is actually the case. An analysis from the locality, given by Jennison,¹ is as follows:

	Per cent
Lime.....	33.17
Sulphuric anhydride.....	45.42
Water, loss on ignition.....	20.63
Insoluble mineral matter.....	0.93

Few exposures of gypsum are to be found along the belt of sink-holes that trends towards the valley of McKenzie brook, but a considerable area appears to be underlain by these rocks. Plaster island, the promontory east of South Side Basin of River Denys, is mainly composed of gypsiferous strata. The cliffs exhibit alternating bands of anhydrite and gypsum, in the proportion of about 3 to 2. Small veinlets of gypsum cut the anhydrite layers. From the top of the cliffs the strata dip rather steeply northward, and at the north side of the peninsula the proportion of gypsum increases over the anhydrite. The rock is grey-white and coarsely granular.

Boom island, the large island at the eastern end of Denys basin (See Fletcher's map), has several exposures of gypsum along its north shore. The cliffs in this case are not high, and many of the exposures are obscured by slumping. Although anhydrite was not noted, the gypsum varies considerably in quality, being in many cases mixed with nodules of limy clay. Some of the material is of alabaster quality, of medium grain with a slight tinge of pink. Grey-green rosettes of selenite are common in some of the gypsum layers. They grow in a matrix of white, fine-grained gypsum.

Two exposures of gypsum occur at Grammo point. The outcrop extends along the shore for about 600 feet and dips to the northeast beneath the water. The gypsum extends downward into a limy clay, and like that at Boom island is characterized by rosettes of selenite in a groundmass of white gypsum.

Near Big Harbour post office, gypsiferous strata occur in a belt running parallel to the road, and near the contact of the sediments on the crystalline rocks. The strata are exposed on the farms of Messrs. D. J. McKinnon, L. McKinnon, J. M. McKenzie, C. McLean, and Mrs. Donald McKinnon. The most southerly exposures, on the farm of D. J. McKinnon, show from 40 to 50 feet in section, but they may not be traced laterally for any distance. One section consists mainly of anhydrite, becoming gypsiferous towards the top, and showing the change to gypsum with the development of cracks. The second exposure shows a coarse grey gypsum, irregularly banded, and with only minor quantities of anhydrite. A little to the north, and directly behind Big Harbour post office, a rather extensive exposure of gypsiferous strata trends northeastward along the bank of a small stream. The strata form a small cuesta with the gentle slope to the northeast. The main mass of the exposure consists of anhydrite

¹ Jennison, W. F.: "Report on the Gypsum Deposits of the Maritime Provinces"; Mines Branch, Dept. of Mines, Canada, 171 pp., p. 50 (1911).

trending laterally up the face of the cuesta. Exposed sections show from 30 to 50 feet of anhydrite capped by varying thicknesses of banded gypsum. The gypsum in places grades into the anhydrite and in other places is sharply separated from it. The dip of these strata is to the northeast, and they may be an extension of the beds outcropping at Grammo point. In this particular area none of the associated rocks, either above or below the gypsum, were noted.

The embayment of the Carboniferous strata in the valley of the stream running into Little harbour also contains gypsiferous strata. The exposures in this locality, however, are small, and the rocks are masked by drift and stream wash.

OTHER MINERALS

The George River series, where it is closely associated with the intrusive igneous rocks, may carry various sulphides, and in some cases graphite. Although no large bodies of sulphide were noted, and none of the occurrences is believed to be of economic importance, their recognition is worthy of note. At a point on the road, immediately to the east of Mill brook, a slight, local deviation of the compass needle was very marked.

A small showing of pyrite and sphalerite occurs about half-way between Lime Hill and Ross brook, on the farm of Mr. D. Campbell. The sulphides, and the enclosing rock, apparently a metamorphosed limestone, are exposed in one small pit that was opened by Mr. Campbell several years ago.

The zone of mixed rocks between West Bay Road and Big Brook post office contains a few small areas of limestone associated with schists and igneous rocks. One of these areas, on an abandoned farm near the top of the mountain, shows graphite-bearing rock exposed in two pits, 10 feet deep and 475 feet apart. The pits are said to have been opened about twenty-five years ago. The graphitic rock is schistose, iron stained, and shows much crumpling. It is in close association with a limestone carrying garnets and serpentine.

The dark slates occurring at the fault zone west of Little harbour, in the upper part of Campbell brook, and again lower in the brook, contain small lenses and streaks of pyrite following the foliation of the slate. As a general rule the rocks are sheared along this zone, and have a brilliant lustre on the schistose surfaces. Gold is said to occur in this zone on the lower part of the brook, and some years ago a tunnel (now caved) was driven into the hillside. The rocks are cut by anastomosing and strike veinlets of carbonate.

Farther up Campbell brook the other members of the George River series carry pyrite, associated with quartz, in irregular streaks and bands. Carbonate veinlets also cut these rocks. Although pyrite was the only sulphide noted in this locality, pebbles in the stream bed, when wholly or in part composed of lime carbonate, were seen to have the latter crusted with a thin coating of green copper carbonate.

CUMBERLAND SOUND AREA, BAFFIN ISLAND

By L. J. Weeks

CONTENTS

	PAGE
Introduction.....	83
Physical features.....	88
Glaciation.....	90
Coastal fluctuations.....	90
General geology.....	92
Economic mineral deposits.....	93

Illustrations

Map 2170. 219 A. Head of Cumberland sound and route to Nettilling lake, Baffin island.....	In pocket
Plate I. A. Nettilling fiord, 5 miles east of first big tide rip, showing "boulder line" about 155 feet above high tide.....	119
B. Pangnirtung fiord, looking east from Aulatsivikjuak.....	119
II. A. Duval mountain, raised beaches in distance on right, winter quarters in foreground.....	120
B. Looking east from height of land between Nettilling lake and Nettilling fiord.....	120

INTRODUCTION

In recent years there has been an increased interest in those vast, virtually unknown regions known as the Canadian Arctic archipelago. Since 1922 it has been the custom of the Government to send north a ship each year and to maintain police posts in those out of the way places for the administration of justice and allied affairs among the natives. This yearly boat offers a means of access to the country and in July, 1926, the writer, with one assistant, M. H. Haycock, sailed from North Sydney, N.S. One year was spent in Cumberland Sound region, with winter quarters at Pangnirtung, the party returning to North Sydney in September, 1927.

The writer wishes to acknowledge with thanks the many courtesies extended by officials and staff of the Hudson's Bay Company, and by the officer in charge, N.C.O's and men of the Royal Canadian Mounted Police in the eastern Arctic. Dr. L. D. Livingstone, of the Department of Indian Affairs, wintered with the writer at Pangnirtung, the two parties occupying the same winter quarters, and the writer is grateful to him for many courtesies. Ugjuarlo, Naulalik, Ikkaling, and Joanasi, Eskimo of Cumberland sound, assisted very efficiently in the role of dog drivers, hunters, guides, and boatmen, and took a very intelligent interest in the progress of the work. To name all the natives of this region from whom kindnesses were received at one time or another would probably result in an enumeration of the entire population. In fact the success of any work in this country depends primarily upon the friendliness and hospitality extended by the Eskimo.

LOCATION AND PREVIOUS WORK

Baffin island is the largest island of the Canadian Arctic archipelago. Cumberland sound is an indentation about 140 miles long on the southeast side. The northeast corner of the sound is bounded by very high, snow-capped country known as the Penny highland.¹ The region in the vicinity of the sound has been the seat of much research, biological, geographical, and ethnological, a considerable amount having been done by European scientists. The first evidence of modern interest in this locality was the establishment in 1882 of the German polar station on Isorituk fiord. Dr. Franz Boas spent the winter of 1883-84 in Cumberland sound, his interests being chiefly ethnological, although he accomplished a great deal of geographical exploration. In 1909, Bernhard Hantsch entered the sound for a two-year period, his object being to make an ornithological collection, and to explore Foxe channel. He underwent many privations and these finally resulted in his death on Foxe channel in June, 1911. His records, however, were not lost to the world as they were brought back by his faithful Eskimo. In 1923-24, Major L. T. Burwash of the Department of the Interior wintered in Cumberland sound and in the spring made a trip overland to Hudson strait by way of Nettiiling and Amadjuak lakes. From 1924 to 1926, J. D. Soper of the National Museum of Canada made his headquarters at Pangnirtung and made natural history collections from that region and also from the interior and Hudson Strait regions. In 1925 the writer paid a short visit to Pangnirtung, it being part of the itinerary of the C.G.S. *Arctic*, on which he was a passenger. Dr. L. D. Livingstone, wintered at Pangnirtung in 1926-27, and in the spring of 1927 made extensive sled trips from Lake Harbour to Pond inlet, at the south and north extremes respectively of Baffin island. For a number of years a mission house has been in use at Blacklead island, and in 1927 a mission was erected at Pangnirtung.

SCOPE OF WORK

As the only previous geographical work in this region was that of Boas, published as a map on a scale of about $17\frac{1}{2}$ miles to 1 inch, it was planned that much of the writer's work should be mapping and should cover, both geologically and geographically, as much territory and in as great detail as possible. Living and travelling conditions, climate, movements of sea ice, game, etc., were to be noted for the benefit of later travellers. At the conclusion of the year's residence, sufficient data had been secured for the compilation of a map of the west end of Cumberland sound from Kekerten on the east to Nettiiling fiord on the west and of the country inland to and including part of Nettiiling lake.

ITINERARY

The government ship sailed from Pangnirtung on August 22, 1926, leaving supplies, instruments, and equipment for one year piled on the beach. The building of a substantial shack for winter quarters and the

¹ Name given by F. Boas: Baffin-Land, *Erganzungsheft* No. 80 zu "Petermanns mittheilungen", 1885.

construction of a deck on a 23-foot power boat, the *Zeolite*, consumed all the time until September 10. Between this date and November 1, several boat trips were made. These trips had as objectives, primarily, the securing of a supply of seal meat for dog food during the winter, and of deer-skins for winter clothing. During this time a plane-table and micrometer survey of Pangnirtung fiord was made. A cache of three barrels of gasoline, several cases of provisions, 400 pounds of biscuits, and the power boat was made on Nettilling fiord on the last boat trip of the season. Almost immediately after this trip ice began to form on the fiords and travelling was at a standstill until the sound became frozen over solidly in December. During December and January, the sun was too low and the days too short to permit surveying, but several trips were made to secure dog food. Early in February, with the sun setting between 3 and 4 p.m., geographical work was commenced. Between February 8 and May 11, a total mileage of 2,300 miles was covered by the two dog teams of the party. The writer and Haycock travelled separately, meeting at pre-arranged places for astronomical observations, and returning to Pangnirtung between laps to plot notes and replenish provisions.

On May 9, the party, accompanied by two Eskimo families, left Pangnirtung for the point on Nettilling fiord where the *Zeolite* had been left the previous autumn. This move was made because it was thought that navigation could be resumed on Nettilling fiord much earlier than on the sound proper. This was found to be true, although floe and floating ice prevented the launching of the *Zeolite* until July 9. Proceeding up the fiord, much pan ice was still found and did not disappear until July 16. On this date the party was within sight of what the natives call Sarbakjuarlo, or Big tide rip. This tide rip and another farther on were navigated with extreme caution, several days being consumed in the task. The chief danger was caused by the large amount of floating ice which rushed through these tide rips with considerable speed. The knowledge gained of these currents stood in good stead on the return trip in August, when very little time was wasted. The tide rips past, the power boat was finally beached at the head of Tassiuyak, and a portage made to Nettilling fiord beyond. This portage was made to avoid an 8-mile tide rip which it was thought would be too much for the *Zeolite*. From here to the head of Nettilling fiord and across the height of land to Nettilling lake, the journey was continued in two canoes, and a towed kayak. On August 17 the party while on Nettilling lake was recalled by radio, and the return journey commenced. Although bad weather was encountered, Pangnirtung was reached on August 21, the Government boat being already there.

CLIMATE, ICE, NAVIGATION, TRAVELLING, GAME, POPULATION

In Cumberland Sound region temperatures of -30° F. during the winter are common, the lowest recorded being -40° F. Very seldom during the winter and spring months up to April does the thermometer rise above zero, and if it does, the rise is usually accompanied by a snowstorm and blizzard. The proximity to open seawater (at Pangnirtung, not over 20 miles in the winter) may account for the comparatively high tempera-

tures during the winter months. In summer no temperature above 55° F. was recorded, although it may have occurred. The summer of 1927 has been generally regarded throughout the north as very unusual. Very few days of unobscured sunshine were experienced during the entire season.

Winds are unusually destructive in this region, and buildings must be especially constructed to resist them. The worst storms were experienced in October, although June was marked by one or two very bad gales. During the winter, storms are more infrequent, but occasion greater hardship on account of the lower temperature.

Ice begins to form at night in small bays as early as the last of September. This ice is seldom a serious inconvenience until the last of October, when it may prove quite an impediment to small boat navigation. Power boats were used on Pangnirtung fiord as late as November 11, 1926, but a great deal of ice was floating around. By the last of November dog teams may travel out of Pangnirtung into adjacent bays, but the sound is still uncertain. The first natives to travel from Black-lead island, crossing Nettilling fiord, arrived on December 18. From this date until the last of April, travelling is generally good all over the north end of the sound.

Owing to the high tides in Cumberland sound (25 to 35 feet), and the narrow sounds joining large bodies of water, tide rips are numerous. In summer these are a source of peril to the small boat navigator, but in winter they are doubly so to the dog driver, as these places seldom, if ever, freeze. The amount of open water varies as the tide is spring or neap. As the water is usually open from shore to shore, to pass one of these tide rips usually necessitates a land crossing, which is both difficult and arduous. However, the tide rips are not entirely without utility, as they are one of the chief sources of seal during the winter. The other chief source is the flow-edge or edge of the open sea, which is usually situated just south of Kekerten.

In travelling during the winter, the one big problem is that of dog food. Very seldom can a sufficient supply of seal meat be laid in during the autumn. However, an attempt to do so should certainly be made. Among the sea mammals found in Cumberland sound are the common hair seal, the harp seal, the square flipper seal, and the white whale. Walrus and polar bear are not found at the head of the sound, but are fairly plentiful near cape Mercy and Bear sound at the eastern and western sides, respectively, of the mouth of the sound. Caribou are quite plentiful around Nettilling lake and at one time were very plentiful during the winter around the sound. The advent of the rifle among the natives has, however, done much to decrease their numbers. Rabbit, white and blue fox, and ptarmigan are quite generally plentiful, and tracks of the wolf are commonly seen.

The native population of Cumberland sound is three hundred and fifty persons. This includes the inhabitants of two camps on the east coast near cape Mercy, and, therefore, not in the sound proper. In the area mapped were nine native villages, each usually composed of two or three families. The principal native industries are trapping, sealing, and whaling. The products are bartered for the necessities of life.

METHOD OF GEOGRAPHIC WORK

In traversing Cumberland Sound area, three methods of determining distance were used. During the winter, a sled meter was almost exclusively used. On the summer trip into Nettilling lake, both a rochon micrometer and boat log were used. A sled meter consists of a wheel fastened behind a dog sled and equipped with some means of counting the number of revolutions. Bearings were taken with a prismatic compass and tripod, the latter being used, not only for greater stability, but also that in winter the bare hand need not touch the metal compass more often than necessary.

In the traverse to Nettilling lake, one main traverse was run with a rochon micrometer, and detail, more especially deep bays, was mapped with a canoe and outboard motor, using a boat log. The log was several times calibrated over a measured distance. The correction was found to vary somewhat at varying speeds.

Latitude was determined by simple observation. For longitude observations Greenwich mean time was determined by means of a small, portable, long-wave receiving set. There being no timber in the country, two 20-foot masts that collapsed to 10 feet were carried. Two chronometers, a Nardin and a Dent, were employed. During the summer, when the radio receiving set was carried in the canoes, usually not more than a few hours elapsed between the time of an observation and the checking of the chronometers by radio. During the winter the intervening period was often long, as the radio set could not be carried during cold weather. In the winter the Nardin half-chronometer watch was carried in a small sealskin bag hung to the neck of the observer in order to maintain as constant temperature and position as was possible. Four stations were located during the winter traversing, and three during the summer. Those located during the summer should possess a higher degree of accuracy for two reasons. First, a shorter time elapsed between the time of checking the watches by radio, and the time of observation; and second, there was no limit to the number of observations which could be made at a station, whereas in winter the number was limited by the ability of the observer to resist freezing of the hands. Twenty-four hours were spent at a station for observation. At the spring camp on Nettilling fiord, however, observations for latitude and longitude were made on thirteen occasions. For all computations that involved the determination of altitude of a celestial body, a Heath sextant was employed. A 6-inch Berger transit was used to determine magnetic declination and longitude by meridian transit.

Summer work in arctic and sub-arctic regions does not vary essentially from summer work farther south. Winter work, however, involves a change of technique which is rather important. This change is necessitated by the effect of cold on instruments, and on the person. Messrs. Chipman and Cox¹ have given a quite extensive account of the technique of observing at low temperatures. These notes were found to be very valuable.

¹ Report of the Can. Arctic Expedition, 1913-18, vol. XI, pt. B, pp. 9 and 10.

Before using an instrument during the winter months it should be especially prepared. All lubricating oil should be removed, and if lubrication is absolutely necessary, bearings should be moistened with kerosene. All parts of the instrument that are commonly touched by the hand should be covered with adhesive tape. Once the instrument is taken outdoors during the winter, it should not be brought indoors again until warmer weather. These points apply to transits, compasses, sextants, cameras, rifles, and micrometers.

For travelling and outdoor work in winter, the native garb is the most satisfactory. This is of deerskin, and a traveller entering a country for the winter where deer are scarce will do well to take some deerskins with him. A very important item is socks, made of soft deerskin, and of which at least two pairs should be taken on a trip.

Geographical Positions

Stations occupied in winter	Latitude north	Longitude west
	° ' "	° ' "
Duval's house at Usualung.....	66 15 43	66 32 14
Kanainak's camp at Nunatak.....	66 28 20	67 03 57
Angmaling's camp at Iglungayung.....	66 17 04	67 08 44
Pangnirtung fiord, small point $\frac{1}{2}$ mile southwest of Police post ..	66 07 43	
Stations occupied in summer		
Spring camp, on mainland west of Ikkarluli island, Nettilling fiord.....	65 55 02	67 20 34
Nettilling lake, at outlet of the lake system on route from Nettilling fiord.....	66 22 09	69 19 14
Nettilling lake, last camp on summer traverse.....	66 13 35	

MAGNETIC DECLINATIONS

The magnetic declination was determined at the places listed below; the declination varied considerably within short distances, owing, probably, to the presence of considerable magnetite in the gneisses of the region.

	Magnetic declination
Pangnirtung winter quarters.....	57 $\frac{1}{2}$ ° W.
Spring camp, Nettilling fiord.....	59° W.
Height of land, southwest of Amittok lake.....	59 $\frac{1}{2}$ ° W.
Nettilling lake, end of portage to.....	57 $\frac{1}{2}$ ° W.
Iglungayung.....	55 $\frac{1}{2}$ ° W.

PHYSICAL FEATURES

Southern Baffin island may be divided into two physiographic provinces, the uplands of Precambrian rocks and the lowlands underlain in their western extension by Palæozoic strata. The uplands occupy by far the greater area, the lowlands being confined to the vicinity of Nettilling lake and west to Foxe channel.

The country due north of the head of Cumberland sound and a prolongation of it southeast into the peninsula between the sound and Davis strait, is probably the highest part of Baffin island and is known as the Penny highland. The elevation of the highest part of this highland has not been determined, as it lies inland from Home bay, one of the least explored parts of Baffin island. Estimates place the elevations of the higher peaks in excess of 10,000 feet. The highest elevations about the head of Cumberland sound are between Pangnirtung and Kingnait¹ fiords. Again actual measurements of heights are lacking, but 5,000 feet is a fair estimate for the extreme peaks. Elevations of 3,000 feet were determined in many places by rough triangulation while mapping Pangnirtung fiord.

The eastern side of Cumberland sound is much more rugged than the western; the country rises steeply from the sea, and islands are not plentiful as on the opposite side of the sound. As one travels westward across Cumberland sound a very marked change is apparent in the character of the country: the mountains markedly decrease in height; steep, rugged cliffs are not so numerous; and islands increase in numbers until the mouths of the westerly extending fiords are blocked with almost countless small and large islands. So numerous are the islands and so irregular are the shorelines that whether any specified stretch of shore belongs to the mainland or to an island or islands, can rarely be determined except by investigating an extended area. While sailing about half a mile off shore, an apparently straight shoreline may present itself, but if this same area is examined from the top of one of the higher hills, countless bays and inlets hitherto unseen are visible. The illusion that the shoreline is comparatively straight and simple is due, in part, to the difficulty of estimating distance in the barren lands.

The gradual decline in the general elevation of the land along a westerly direction continues as Nettilling fiord is followed to its head. Near the big tide rips the valleys in the bordering country for several miles inland nowhere rise more than 100 or 200 feet and lakes are numerous, whereas very few occur on the eastern side of the sound. At the head of Nettilling fiord many hills rise to 600 and 700 feet, but the country is so dissected that it may easily be traversed without crossing any elevation of more than 200 or 300 feet. The route from near the head of Nettilling fiord west to Nettilling lake is a canoe route 20 miles long and crosses the Baffin Island divide. The highest point along the route is 133 feet above high tide.² The elevation of Nettilling lake referred to the same datum is 103 feet. Lakes are numerous. Along the 20 odd miles of canoe route to Nettilling lake, about 1½ miles are divided among seven portages.

The country bordering the east side of Nettilling lake is low and rolling, elevations of as much as 200 and 300 feet above the lake being rather exceptional. Lakes and ponds are very numerous. The shore is indented by many winding inlets, and is fringed with many islands.

¹ The name Kingnait is from an Eskimo word descriptive of mountainous country.

² Elevations along the canoe route were determined by measuring distances with a Rochon micrometer and vertical angles with a transit.

Along the southern shore the general elevation decreases westward until the country becomes flat and featureless, rising only a few feet above the lake surface, and bedrock is nowhere visible. Farther west outcrops of Palæozoic rocks have been found.

GLACIATION

The peninsula between Frobisher bay and Hudson straight is occupied by the Grinnell glacier. The Penny highland is covered by an ice cap. Other ice-covered areas occur to the north. Many, small, isolated areas are covered with ice throughout the year and many of such are visible to the north from Cumberland sound.

The country has been intensely glaciated. The movements of the ice in the deeper valleys were controlled by the topography and, in general, as in Pangnirtung, Kingnait, Nettilling, and Kaggilartung fiords, was along the valleys and towards Cumberland sound. Striæ are not plentiful, but deep furrows, roches moutonnées, etc., are very marked. On Pangnirtung fiord five peninsulas, Nasauya, Aulatsivik, Kungkuk, Aulatsivikjuak, and one unnamed, are due to glacial action. Each consists of a rock knob joined on the north or northeast side to the mainland by a narrow, low isthmus, in most, if not all, cases, composed of drift. The glaciated rock knob of each peninsula has a low slope on the north or northeast side, but terminates in an abrupt cliff or has a much steeper slope on the opposite side facing the mouth of the fiord. Similar features are quite common over the whole Cumberland Sound region, but in few other cases are they so regularly developed as regards orientation and shape, because, perhaps, few other fiords are so nearly straight and have such steep, high walls as Pangnirtung. A slight depression of the region would make islands of these features in Pangnirtung fiord and it may be that many islands on the west side of Cumberland sound would present similar characteristics if elevated somewhat.

COASTAL FLUCTUATIONS

Evidence that the sea at one time stood much higher, relative to the land, is visible at many places. The highest observed beaches are on the east side of the sound and are much higher than any seen along the west side. Beaches were seen at an elevation above 600 feet on Pangnirtung fiord. Between Nasauya and Augpalugtung raised beaches were noted at an elevation of 150 feet. In the vicinity of Usualung many raised beaches were seen in the small bays and the home and trading post of Mr. W. Duval is built upon a raised beach, less than 100 feet in elevation.

Along Nettilling fiord, as already mentioned, the country for some miles inland is rolling, and the hills are only a few hundred feet high. Some of the slopes are steep, others are very gentle. Nowhere were boulders found resting in precarious positions on these slopes below an elevation of 155 feet above high tide. (This elevation was measured at the mouth of a deep, long bay on Nettilling fiord some 20 miles from Imigen and again about 12 miles northwest at Tassivyak bay.) Above

this elevation, not only are boulders much more numerous, but many of them lie in very precarious positions on the polished, rocky slopes. Some of them on being rocked, rolled, of their own accord, some hundreds of yards. The general condition is illustrated by Plate I A, a view taken on Nettilling fiord about 5 miles east of the first big tide rip. The foreground, at an elevation of about 120 feet, is of bare, glaciated granite. The skyline, about one-half mile away and at an elevation of about 200 feet, is literally covered with boulders and a sharp line divides the boulder covered, and the boulder free, terrain. Apparently after the retreat of the ice the sea-level relative to the land was 155 feet higher than now. The ice had left boulders both above and below the then water-level. During the succeeding relative uplift of the land of 155 feet, all points between the present and former shorelines must have been at one time or another at sea-level. Thus all the boulders that originally lay between the two shorelines would for long or short periods be subjected to the action of floating ice and during the winter of shore ice, also, which at the present time is sufficiently powerful to move large masses of rocks. As a result the polished rock slopes would be denuded of their boulders which would collect in crevasses and valleys or be concentrated just below the present sea-level in what are known as tide reefs.

The evidence presented by the boulders is more conclusive than that given by raised beaches, because, if the offered explanation is correct, the line dividing the boulder-strewn terrain from the boulder-free terrain marks the maximum amount of relative uplift, whereas a raised beach is only evidence that the shoreline was at one time at the same level, but not that it may or may not have been at a still higher level.

The evidence thus tends to show that there has been a differential uplift between the east and west sides of Cumberland sound. The topographic forms also suggest that uplift may have been higher on the east than the west, but before drawing broad conclusions data should be obtained from farther afield.

Terraces were observed at Nettilling lake as high as 22 feet above lake-level, or 135 feet above high tide. These terraces and the evidence of the boulder line on Nettilling fiord, putting the old shoreline there at 155 feet above high tide, would both indicate that the site of Nettilling lake was at one time part of a strait of the sea dividing Baffin island into two parts, for, as already mentioned, the highest point on the canoe route across the divide between the lake and Nettilling fiord, was found to be 133 feet.

The evidence seems to indicate that the highest of the ancient shorelines along the lower part of Nettilling fiord lies at an elevation of 155 feet and now is approximately horizontal for 12 miles along a course bearing about northwest. On Pangnirtung fiord, some 80 miles north 80 degrees east, beaches were observed as high as 600 feet above high tide. The elevations in Pangnirtung fiord, however, were determined by aneroid in winter, when for some undeterminate reason the instrument could not be relied upon. However, there can be no doubt that the highest observed beaches on Pangnirtung fiord are between 450 and 750 feet above high tide level. At the east end of Nettilling lake, about 60 miles

a little north of west from the place where the observations were made in Nettilling fiord, an ancient shoreline lies at 135 feet above high tide. Thus, the available information indicates a tilting in an east-west direction and at a rate increasing eastward.

GENERAL GEOLOGY

The rocks of Cumberland Sound region are all acid intrusives. Variations in texture and composition occur and in one or two places relationships were found which show that in part, at least, these variations are due to the presence of intrusives probably closely related to, or of slightly different, ages.

The rocks along Pangnirtung fiord and Cumberland Sound shore to Usualung, exhibit no great variation. The rock is a greyish granite, in many places weathered to a dull red. As a rule the granite is coarse grained, the texture varying somewhat from place to place. On Pangnirtung fiord small pegmatite dykes are very numerous. Examination of a thin section of a rock from Usualung showed it to be composed of quartz, microperthite, magnetite, and a little orthoclase and plagioclase. The predominant mineral was the microperthitic intergrowth of orthoclase and plagioclase.

On Koiyannak island just across from the village on Nunatak island, is a very fine-grained quartz-hypersthene diorite composed of quartz, andesine, hypersthene, and a little orthoclase and magnetite. This rock appears to be widely distributed in the locality. Eskimo brought a specimen of coarse-grained pyroxenite which they declared occurred in places on Koiyannak island. A thin section shows the rock to be almost wholly augite.

At Iglungayung, some 20 miles west of Usualung, is a coarse granite very similar to that occurring at Usualung and eastward. It, however, differs in that a thin section shows many myrmekitic intergrowths. The quartz shows a wavy extinction and a slightly developed mortar structure. The minerals present are quartz, orthoclase and a little plagioclase, microperthite, and magnetite.

A very coarse-grained granite from Kangertlukjuak fiord was examined in thin section. This specimen comes from midway between Iglungayung and Koiyannak island. It is very similar both in hand specimen and thin section to the granite at Iglungayung, but does not contain any myrmekite or microperthite. The minerals present are quartz, orthoclase, and a little plagioclase.

A hypersthene granite occupies large areas among the many islands in Kaggilartung fiord. This rock exhibits more deformation than those at Iglungayung and Kangertlukjuak, a pronounced crystalloblastic texture being observed accompanied by optical deformation of the quartz. The minerals present are quartz, orthoclase, hypersthene, and a little sodic plagioclase.

On a small neck of land separating the heads of Kaggilartung and Isorituk fiords was found a fine-grained aplite. The relations of this aplite to the coarse granites was unobserved, but may be assumed to be similar

to those of the aplites on Nettilling fiord to be described later. Quartz, orthoclase, and myrmekitic intergrowths of quartz and plagioclase compose the rock.

At Saunirtungukjuin island, near Imigen island, the rock is quite coarse and similar in hand specimen to the granites of Iglungayung and Usualung. Much microperthite is present and some coarse graphic intergrowths of quartz and orthoclase were observed.

On the north side of Nettilling fiord, on a large island between Kekertarlung island and the mainland, is exposed an aplite very similar to the one seen on the head of Kaggilartung fiord. This rock outcrops on the south tip of the island and extends northward about $\frac{1}{4}$ mile. It is later than the usual coarse granite with which it is in contact on the north. Microperthite and myrmekite are both present. Quartz, orthoclase, and small amounts of garnet compose the rock. A slight porphyritic texture is observable in thin section, but not in hand specimen.

At Zeolite camp, west of Ikkarluli island, lenticular masses of quartz monzonite are enclosed by granite porphyry. The quartz monzonite exhibits a slight banding striking north and south. The minerals present are: oligoclase, andesine (ab_{29}), orthoclase, quartz, chlorite, and magnetite. The rock was seen only in large and small lenses completely surrounded by the later granite porphyry. The longest axis of the lenses is parallel the strike of the banding. The granite porphyry shows no evidence of banding. It is composed almost wholly, both phenocrysts and groundmass, of quartz and orthoclase. Small amounts of plagioclase occur in the groundmass.

On Nettilling fiord, about 10 miles east of the first big tide rip, a micrographic hypersthene granite was observed. The rock contains many inclusions of coarser granitic rock and has undergone considerable deformation, resulting in a pronounced mortar structure. The minerals present are quartz, orthoclase, hypersthene, and very little plagioclase. Micrographic intergrowths of quartz and orthoclase are visible. On the last lake on the route to Nettilling lake a very fine-grained granite or aplite is exposed, very much cut by stringers and dykes of pegmatite. No ferromagnesian minerals are present, the only dark mineral being magnetite. Quartz and orthoclase occur in a very fine-grained admixture.

On Nettilling lake, about 1 mile south of the end of the portage route to Cumberland sound, a deformed granite now resembling a granite porphyry was found. The large crystals of the original rock, that remain, are broken and sheared, and very irregular in shape. Quartz and orthoclase are the predominant minerals. About 10 miles south is an outcrop of essentially similar rock.

ECONOMIC MINERAL DEPOSITS

No occurrences of economic minerals are reported from the area mapped. Magnetic sands are found on Pangnirtung and Kingnait fiords, but do not appear to be extensive. Graphite has long been known to occur on Blacklead island about 90 miles south of Pangnirtung. An attempt was made by the Hudson's Bay Company to mine this material in 1926, but operations were discontinued the same year. Mica in fairly large

sheets occurs here and there throughout the region, and is often brought in by natives, who, however, can give little information as to its extent. The geological conditions in general are not favourable for the formation of metallic mineral deposits.

OTHER LOCALITIES IN THE EASTERN ARCTIC

While a passenger on the S.S. *Beothic* a number of calls were made at points among the eastern Arctic islands. Some of these, viz., Rice strait, Craig harbour, Dundas harbour, and Pond inlet were described in 1925,¹ and will not be further mentioned here. During 1927 stops of sufficient length to permit a hurried reconnaissance were made at Arctic bay and Lake harbour.

ARCTIC BAY

Arctic bay, at which three hours were spent, is a small indentation on the north shore of Adams sound, a long fiord on the west side of Admiralty inlet, North Baffin island. The topography is rugged, the land rising abruptly from the sea to elevations of 800 or 1,000 feet. A small Eskimo village is located on Arctic bay.

The west point of Arctic bay is underlain by diorite or gabbro which extends west $\frac{1}{2}$ mile or so to a contact with black slates and shales. The contact extends upwards along a gully in a cliff and is either an intrusive contact or a fault, presumably the former. A white, bitter salt, apparently soluble in sea water, leached from these slates and shales.

At the next point westward, diorite occurs and cuts interbedded massive limestone and sandstone with a vertical contact. Adjacent to the contact the limestone is heavily mineralized and much altered. The predominant mineral is pyrite with some copper sulphides. At the contact black shales and slates underlie the sandstone-limestone group with unknown relations.

On the east point of Arctic bay, the basic intrusive forms the point. A massive, hard quartzite was found on the northeast side of the bay. The relations of this quartzite to the other rocks was not ascertained.

Practically all reports of mineral discoveries in the eastern Arctic come from Admiralty Inlet region, Baffin island. Geological conditions there are much more favourable for the formation of commercial ore-bodies than in most of the remaining territory.

LAKE HARBOUR

Lake Harbour was one of the first establishments of the Hudson's Bay Company beyond the mainland of Canada. The post is situated at the head of a long, winding inlet behind Big island on Hudson strait. During the latter part of the nineteenth century mica was mined and shipped from a point about 12 miles from the post. In 1916 the Hudson's Bay Company commenced the development of a graphite deposit near here and in 1917 and 1918 shipped a small tonnage. Neither the mica nor the graphite deposits could be visited by the writer in the short time

¹ Weeks, L. J.: Geol. Surv., Canada, Sum. Rept. 1925, pt. C, pp. 136-141.

at his disposal. The graphite is of the crystalline or vein variety, the veins occurring in crystalline limestone at its contact with intrusive quartz dykes.¹

At the post two rock groups are exposed. The older, a white, coarsely crystalline limestone outcrops in bands 200 or 300 feet thick, dipping 78 degrees northwest. Several of these bands are exposed in the neighbourhood of the post and are separated by bands of acid intrusive of about the same width. Under the microscope this intrusive proves to be a very fine-grained quartz monzonite. The limestone is composed nearly wholly of calcite crystals from a fraction of an inch up to 2 or 2½ inches long.

¹ Spence, H. S.: "Graphite"; Mines Branch, Dept. of Mines, Canada, 1920, p. 61.
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SOME PROBLEMS OF PEAT BOG INVESTIGATION IN CANADA¹

By Väinö Auer

GENERAL POINTS OF VIEW

Canadian peat bogs have not yet been given enough scientific or practical study to afford much knowledge of their main characteristics or economic possibilities. It is true that a number of valuable investigations have been carried out, first and foremost among which are those of Ganong and Nichols, but these have not exclusively dealt with peat bogs and their characteristics. Mention should also be made of the short but lucid reports on the muskeg formations in Alberta, recently published by Lewis and Dowding, and the fuel-peat investigations by Anrep. From these and my own investigations, carried out in 1926, only the broader aspects of the distribution of peat bogs in Canada appear. In the eastern part of Canada, where the climate is maritime in character, peat bogs are very abundant. So are they in the northern part of central Canada where the muskeg formations gradually change northward into tundras. There are, also, west of the Rocky mountains, plenty of peat bogs that resemble the sloping peat bogs of Europe.

As Canadian peat bogs occupy many thousand square miles, their enormous importance is readily appreciated. In attempting to outline the underlying principles that should govern their investigation the writer is under the limitation of having personal acquaintance only with such peat bogs in eastern Ontario, southern Quebec, and the Maritime Provinces as he could visit during about three months in the summer of 1926. The opinions advanced here are, therefore, only the first tentative conceptions of one observer. On the other hand, considerable similarity exists between Canadian conditions and those in northern Europe, with which the writer has greater familiarity. It is taken for granted these investigations should serve practical needs and, therefore, at the outset it should be emphasized that for purposes of intelligent utilization a good understanding of the nature of peat deposits is more important than is generally recognized.

The investigation and classification of peat deposits may be made in different ways depending upon different points of view. Peat bogs in a biological sense are peat-forming plant associations, and, in a geological sense, natural peat deposits. But as the surface vegetation of peat bogs depends on the subjacent peat for its growth, there is a casual connexion

¹ The author of this article has specialized in the study of peat deposits in his own country, Finland, and elsewhere in northern Europe. In 1926 he was granted a fellowship by the International Education Board, New York, founded by John D. Rockefeller, jun., to assist him in comparing peat deposits and peat-forming conditions in North America with those in Europe. As peat deposits are much more numerous and widespread in Canada than in United States and are of greater practical concern an arrangement was made among Dr. Auer, the International Education Board, and the Geological Survey, Canada, whereby some additional assistance was given Dr. Auer by the Survey for his work in Canada and the International Education Board agreed that the results of the investigation should be offered to the Survey for publication.

The present article is a preliminary statement intended to draw attention to some of the problems presented by our peat bogs and some of the principles underlying the solution of these problems. *Director.*

between the two. Particularly is it difficult to interpret the relations of plants to topography unless one knows exactly the earlier history of the peat bog, just as it is impossible to understand the stratigraphy of peat bogs unless the changes that take place on their surface are well understood. Moreover, the scientific-practical classification of peat bogs depends on the purpose for which peat bogs are used. As is well known, peat bogs are used for fuel and litter, but they are perhaps still more used for agricultural purposes. In North Europe, particularly in Finland and Sweden, very productive forest lands have been gained by the draining of peat bogs. Agriculture and industry are exploiting the peat of the peat bogs, and, with these usages in mind, the classification of peat bogs must be based on peat-geological studies. On the other hand, the forestial classification is based primarily upon the surface vegetation, as the forest belongs to the vegetation and is subjected to the laws that govern the plant life. The forestial usage, therefore, demands that the classification should be based on plant-topographic studies, especially as—with the exception of drainage by means of ditches—the forestial economy does not imply any great improvement of the subjacent soil; but the habitats must be taken mainly as they are in nature, characterized by their vegetation.

DISTRIBUTION OF PEAT BOGS

As is well known, the distribution of peat bogs is influenced by climatic and topographic conditions, by the character of the soil, and by the geologic nature and age of the subjacent deposits. As the formation of peat depends upon the degree of oxidation of plant remains by the oxygen of the air, the determining factor in the formation of peat is water which is the general preserving agent. Either rain-water or water in the ground may come into question. The former causes a regional and the latter a local paludification (conversion of dry lands or water-covered areas into swamp). Climatic conditions, thus, primarily determine the distribution of peat bogs. Where the amount of rain is great in comparison with evaporation, there peat bogs are likely to be widespread. The damp oceanic climate is the cause of intense peat formation in the Maritime Provinces of Canada. It is not yet in all details clear in what degree climatic factors in other parts of Canada have influenced distribution, mode of formation, and character of peat bogs. In southeastern Canada many regular characters in the plant-topography, as well as the geology of the peat bogs, may be traced back to climatic causes. In what degree among the climatic factors, temperature directly influences the appearance of peat bogs remains an open question.¹ The general topography has a great influence, particularly upon the size of peat bogs. For example, narrow valleys are less favourable for the accumulation of peat than are wide, flat valley bottoms. The physical and chemical characters of the soils each in their own way influence the appearance, origin, and development of peat bogs. Soils, for example clay and glacial drift, that are nearly impervious to water, are favourable to the formation of peat

¹ Indirectly temperature acts by increasing or diminishing evaporation.

bogs; sterile lands are more likely to become peat bogs than are fertile regions. A careful and detailed study of the soil factors would be welcome to complete our knowledge of the use of peat bogs, especially for agricultural purposes.

The glaciated parts of eastern Canada are closely comparable with the glaciated areas of northern Europe. Investigations in Finland have shown that the appearance of peat bogs is greatly influenced by warpings of the land crust and, in general, by changes in the boundaries between land and water. Peat formations have thus come earlier into existence on geologically older lands, i.e., on those areas that were first freed from the water cover, than on geologically younger lands. Hence it follows that the thickest peat deposits are found on geologically old areas, though, of course, thin, young peat deposits may be found at any place where conditions are, or have been, favourable for their formation. As shown by the investigations of geologists in Canada, changes in land and water areas have taken place, owing to the warping of the land, and at the same time as the water-lines have altered in the lakes, the river beds have also changed. Moreover, many peat bogs have originated by following the coast-line of the receding sea, and others have formed in the valleys when the river or lake water had disappeared.

PLANT-TOPOGRAPHICAL INVESTIGATIONS

The plant-topography of peat bogs is concerned with the "living" part of peat bogs. Consequently, it deals with the general principles of plant-topography and plant-sociology. Comprehensive investigations along these lines have been carried out, especially during the last few years, on a large scale, in several European countries. Only a few important points in connexion with the classification and use of peat bogs are here dealt with.

As is generally known, the plant cover shows more or less distinct regularities, caused by all the factors influencing each habitat, and revealing themselves as a result of the struggle for existence among the plants. As the plant cover is chiefly dependent upon the habitat factors, its character in very many cases indicates the biological value of the habitat. The vegetation may thus also indicate the value for agricultural or other purposes of a certain land area. Indeed, it is common knowledge that richer plant associations with more pretentious species are more often found in fertile regions than in infertile areas.

Extensive investigations have been carried out in Finland during the past few years, dealing with the classification of forests, and the whole forestial activity, scientific as well as practical, is based upon these investigations. In accordance with the principles outlined above, A. K. Cajander¹ prepared his theory about forest types, an English summary of which has recently been published. He divides the Finnish forests into types, the characters of which he defines in the following way:

"Consequently, all those stands are referred to the same forest type, the vegetation of which at or near the time of maturity of the stands, and provided the stands

¹ Cajander, A. K.: "The Theory of Forest Types"; Acta Forestalia Fennica 31 Helsinki 1926.

are normally stocked, is characterized by a more or less identical floristic composition and by an identical ecologico-biological nature, as well as all those stands the vegetation of which differs from that defined above only in those respects which—being expressions of differences due to age, fellings, etc.—have to be regarded as merely accidental and ephemeral or at any rate as only temporary. Permanent differences call forth a new forest type in cases where they are sufficiently well-marked, or a sub-type in cases where they are less essential, but, nevertheless, noticeable. In a forest type, therefore, as a rule, only those primary—climatic and edaphic—factors of the locality are reflected, which factors may be assumed to remain active, even when the locality is laid bare of all plants."

Forest types are thus distinguished on the basis of the vegetation. This has been done chiefly from the surface vegetation, due to the fact that it, even in cultivated forests, reaches at least a comparatively stationary condition, quicker than the tree vegetation, as it is composed of short-lived individuals and, consequently, is usually allowed to develop more naturally than the trees. The composition of the tree flora, however, is not without importance, as, for example in Finland, among barren forest types, only the pine forest thrives, among medium types all the common tree species, and among the best types are found the hardwood. The floristic composition, even of stands that have been cultivated, characterizes the type in a high degree. But still more are the "ecological-biological" characters of the trees, as of any other plants, and particularly their growth relations and the development of stands very characteristic of each forest type. The natural forest types, therefore, are the most suitable basis for a comparison of the productivity of forests, both with regard to forestial investigations and forest economy.

From the same points of view Cajander has divided the Finnish peat bogs into types and these types are used to some extent as a basis for forestial peat bog investigations in Finland. It has been proved that a peat bog type, as a result of ditching, turns into a definite forest type whose value may, under the most favourable conditions, equal that of the best forest types. It has also been proved that as a rule better peat bog types are found in fertile areas than in barren regions. In their relationship to one another the Finnish peat bog types appear as definite groups or complex types. The results of investigations by the writer strongly support the type theory and show that in areas of definite plant-topographic complex types, the boundaries of which are regionally very regular, there are peat-geological types that are characteristic for each area. The plant-topographic regional classification, according to these principles, may thus indicate the occurrence of different kinds of peat turf strata. Therefore, nowadays in Finland, during the orientating investigation work, in the search for regional regularities, bog types are used also in peat-geological studies.

The fact that more pretentious peat bog plant-associations appear on better land, and as a rule form better peat than do less pretentious ones shows that the quality of the ground-soil influences even the later development of the peat bog, as Cajander has observed. Good and fertile peat bogs are formed in places where there is an abundant and flourishing water-vegetation, as rush and horsetail vegetation and huge sedge stands. A large part of Canada's peat bogs have, however, formed on dry land, and the first peat-forming vegetation obtained all its mineral nourishment

from the mineral soil. The more abundant the nourishment the larger are the quantities of nutritive substances in the roots and stalks of the plants. As the peat strata grow thicker, the uppermost layer receives its mineral nourishment from the subjacent layer, and the more nourishment the latter contains, the more does the former receive. As the uppermost layer is never able wholly to exhaust the lower layers, the peat layers, unless they can receive nourishment from outside sources, must become poorer the higher the peat bog grows. Even in fertile regions the surface peat in thick parts of the bogs may thus be very poor, but it is evident that the same degree of poorness is attained much earlier in places where the ground-soil is meagre than where it is fertile; the bogs in areas where the soil is poor are likely to contain poor peat.

It is clear from the above-named facts that investigation of the surface vegetation alone is not sufficient for the study of peat bogs. The peat layers become more meagre from the bottom upwards, even during an undisturbed development of the peat bogs, and waters flowing from surrounding lands cause considerable alterations and changes in character of the peat. Still more so do the climatic changes during geological periods. Peat bogs of similar type may have represented very different types at different stages of development. In forestry, when no improvements of the land other than ditching are undertaken, a study of the present peat bog type in many cases suffices to give an idea as to the afforestation possibilities. In agriculture, on the other hand, the question of tillage of the soil and, perhaps, the removal of the surface peat, have to be considered and, therefore, more attention must be paid to the character of the deeper peat layers. By means of manuring and fertilizers, etc., a poorer peat may be rendered more productive, but even in this case the peat bog type may not be without importance in giving indications as to the value of the bog. Finally, when there is a question of using peat for fuel litter, etc., all the peat strata must be studied.

As to the applicability of the type principle, Cajander says the following concerning the forest types:

"Within the range of similar climate types characterized by various forest types and within the range of the same degree of quality of locality, as indicated by the forest types, it, therefore, appears to be possible to place forestry everywhere on a common foundation and to treat it from an international point of view. On such a basis it further seems to be possible to generalize as common international methods of procedure, all those sylvicultural methods that have been developed or are being developed in the various local districts, and that have led or are leading to satisfactory results. At the same time it should, however, be noted that the market conditions of the different regions will always furnish forestry with local features, since these conditions are vitally important in deciding which of the methods of treatment possible from the biological point of view are economically advantageous, and how near it is possible to approach to the sylviculturally and biologically most productive method of treatment after first taking the economic point of view into account.

The above statements hold good not only in forestry, but clearly also in plant cultivation in general, as well as, more or less indirectly, in those industries which are founded on plant cultivation or depend upon it. While agriculture in the southern half of Finland—to give one example—consists mainly in growing crops, in North Finland, where the areas under the plough are relatively small, as well as in corresponding districts elsewhere, for instance at corresponding altitudes in the Central European mountains, agriculture consists for the most part in the cultivation of meadows. In the Central European hardwood forest regions, where the proportion of land suitable for cultivation is incomparably greater than in the southern half of Finland, wheat growing takes precedence over the growing of the other crops."

The question arises where it is possible to make a similar plant-topographic classification of Canadian peat bogs. In southeastern Canada there are extensive, open *Sphagnum* bogs covered or partly covered with shrubs (*Kalmia*, *Cassandra*, *Empetrum*, etc.). In many places there are other moss species, of the *Amblystegium* group. Especially on the peat bogs of the river valley flats these form a continuous moss-cover, growing a very rich sedge and grass vegetation. A similar floristic composition is found in the bogs formed on lake shores by filling up of part of the lakes with peat. Quite common also are the tree-growing bogs: *Picea mariana* and *Larix Americana* in places form even very extensive forests on the bogs. The marginal parts of bogs and bogs in small depressions in places grow maple as well as spruce. All of these kinds of plant associations are widespread, and as each of them is the result of the development of the surface vegetation of a definite kind of bog, they may be regarded as the Canadian peat bog types. From a plant-topographical point of view the following type-groups, therefore, may be distinguished.

(1) *White moors*, or open bogs, whose moss-vegetation principally consists of *Sphagnum*. The brushwood as a rule is sparse. Tufts are absent or are low.

(2) *Brown moors*, mostly wet bogs without any tufts, the moss-vegetation principally consisting of so-called brown-moss (*Amblystegium*, *Paludella*, *Meesea*, etc.). There may be some *Sphagnum*, and in that case usually of more pretentious kinds. The grasses are richer than on the white moors.

(3) *Dwarf-shrub moors*, generally dry bogs with plenty of brushwood, with or without hummocks and the moss vegetation principally consisting of *Sphagnum*. They almost always grow forest, the commonest trees being *Picea mariana* and *Larix*.

(4) *Marshes*, forest-growing bogs whose tree vegetation consists of spruce, pine, and hardwood, particularly maple. The moss vegetation usually consists of more or less pretentious *Sphagnums*, but occasionally other kinds of moss, as *Polytrichum* and other leaf moss species.

The investigations by the writer were restricted chiefly to the structure of the bogs, all the more detailed botanical classifications were left to other investigators. Some of the most characteristic types are dealt with in a more comprehensive report to be submitted to the Geological Survey, Canada. It may be stated that a plant-topographical classification of the peat bogs in Canada will show the same regularities as in Finland and that the character and development of the plant associations of the bogs also change according to regular laws. The brown-moors have been changed by drainage into excellent forest lands resembling grass-herb forests, whereas relatively poor white-moor types have been changed by drainage only into poor *Larix-Picea* forests. As soon as the forest types in Canada are definitely fixed and their yielding capacity accurately determined by forestial investigations, the forest value of a bog can be estimated, if its type and development are known.

From the point of view of forestry it is also necessary to study the characteristics of bogs with regard to drainage, as to the direction, depth, and frequency of the ditches that are required as well as the changes in the peat resulting from ditching, the durability of the ditches under different conditions, etc. Important results may be arrived at by experiments and by a comparative study of earlier ditchings.

A classification based on the plant cover is not sufficient, however, even for forest valuation; the character of the peat also must be taken into consideration. For example the big Alfred peat bog in Ontario, near Ottawa, is in a very good forest-growing condition, which shows that its eastern and southeastern parts are of a better type than that suggested by the unbroken *Sphagnum*-cover. The investigations carried out on this peat bog show, however, that there is a good *Amblystegium*-*Carex* peat under the thin *Sphagnum* surface layer.

The bog types of Finland are definite combinations, or complex types. Analogous regional complex types also exist in Canada, and a study of them is of importance because each complex type has its peculiar mode of origin and development, as well as other characters of its own. Different complex types may be distinguished at least in the following areas: in Nova Scotia where the northern and southern parts also differ in some respects from one another. In the St. Lawrence lowland there is a different complex which may be called a continental form, and between the two above-mentioned areas there is a complex apparently intermediate between the oceanic and continental forms. Special continental groups probably exist in the Interior Plains region, and in northern Quebec, not to speak of the wide areas of northern Canada in general, as well as of eastern Canada, where numerous and regular areas of complex types no doubt may be found. It would be interesting to investigate in what degree these regular variations coincide with the floristic areas set up by Macoun and Malte¹.

The regional boundaries of the vegetation types in many cases are not very definite, nor are they very regular. The geological development of Canada, especially during post-Glacial time, has greatly affected the distribution of plants. Northern forms may be found in isolated spots within the areas of the southern type regions, and southern forms in more northern areas than those of their regular distribution. The vegetation after the ice age, spread from south to north, but climatic variations in post-Glacial time have caused migrations of plants in a north-south direction as well as in an east-west direction, particularly near the boundaries between the oceanic and continental climatic zones. For example, in southern Quebec and New Brunswick, there are distinctly northern plants, and in Nova Scotia, among others, purely southern forms.² A closer investigation of the relict occurrence of whole types, as well as of individual floristic elements, probably would give interesting scientific results, and would show the character of the changes in the vegetation and possibly in the type regions.

¹ "The Flora of Canada"; Geol. Surv., Canada, Mus. Bull. No. 26 (1917).

² Among the latter, an oozy *typha* swamp form deserves particularly to be mentioned. This is a term for a combination of the growth-place and the plant-cover, and, consequently, must not offhand be compared with the above plant-topographic forms.

The principle of classification by means of types, with very few exceptions, has been recognized and accepted all over the world. The fact that the whole forest economy of Finland as well as the very comprehensive investigations in botany and forestry, are based on the type system, gives at least some kind of guarantee for its value as a scientific-practical method. It would be desirable, however, to try other investigational methods in Canada, for in such an extensive country other methods and classification principles may be necessary, but it is certain that the type principle, correctly applied, will lead to positive results.

FORMATION AND DEVELOPMENT OF PEAT BOGS

Plant-topographic investigations should include a study of the mode of formation and development of the peat bogs, as well as a study of the types, according to the principles outlined above. Peat bogs are formed in many different ways; by the filling up of water areas, by the changing of dry lands, or flooded lands, and seashores into marshes, and in other ways. They are being formed by the filling up of small lakes and ponds by vegetation. This action depends upon the kind of lake as well as upon the kind of vegetation. The character of the vegetation and the way in which filling takes place in fertile areas are quite different from that found in barren regions. The question is very complicated, for many different physical conditions exist in different parts of an extensive country. Modern methods for the study of sediments of lakes are well illustrated by the results of work published by the International Limnological Society. Examination of the sediment types of the lakes of Canada that have been, or are being, filled up should show many important scientific and practical results. By applying the classifications used in limnology, for example, the distinction between fertile and barren lands would appear. An investigation of this kind should be of value also for the study of fish culture and, indirectly, should have a bearing on the question of the utilization of land for colonization purposes.

The paludification of forest land, or dry land in general is, however, the principal method of formation of peat bogs, as is shown by the investigations in northern Europe. This appears to be the case also in Canada. Many places which within the memory of man had consisted of dry lands have turned into extensive peat bogs. Dry land turns into peat bogs chiefly in areas having an oceanic climate, as in Nova Scotia. This action is much less pronounced inland, and, as alleged by Lewis and Dowding, the interior parts of Canada are drying up. The intensity of paludification is evidently variable in different parts of Canada, being greatest along the coasts where peat may be found directly stratified on convex rock surfaces. Whether the growth and extension of peat bogs in the interior parts of Canada have entirely ceased, remains to be established. It is probable that forest lands in the northern parts of interior Canada still continue to turn into peat bogs on a considerable scale, though perhaps not as much as during the early parts of post-Glacial time.

A study of the degree of intensity by which dry land or forest land turns into peat bog in different parts of Canada would be of considerable

economic importance. For the investigations, especially in Nova Scotia, have proved that forest fires have great influence on the formation and spreading of peat bogs. Within a few decades peat bogs have spread rapidly over wide areas that have been burnt over. This is due chiefly to the fact that, after the forest has been destroyed, the surface of the groundwater rises. In places also the burned-over area becomes water-soaked and this causes spreading of *Sphagnum*. As great attention is being paid in Canada to the effects of forest fires, as well as to measures for their prevention, attention will, sooner or later, be paid to the importance of peat bog formation due to forest fires. In Europe, these effects cannot be proved so clearly as in Canada where the importance of forest fires is much greater than could be imagined by a stranger.

Paludification of dry land takes place mainly in the following ways: (1) A peat bog spreads to neighbouring heath; (2) water from the higher situated peat bogs flows onto lower areas which, as a result, are turned into peat bogs; (3) primary peat bogs are formed in depressions by the stagnation of the surface water on soils that are poorly penetrated by water, and extend until they join one other and form more extensive bogs; (4) the raising of the surface of groundwater, for some reason or other, causes the appearance of new peat bogs in the depressions. A closer exposition of these different forms of paludification, using the plant-topographic methods, would lead in Canada to far-reaching and economically important results, and, in connexion with these investigations, other regional factors, such as soil and climate, influencing the distribution of peat bogs, should also be taken into consideration.

An investigation of the way in which paludification affects Canada's numerous tree species would be of great importance to forestry and would suggest methods of protecting the forest from paludification. The draining experiments, ditching, etc., together with calculations concerning the profitableness of the same, would complete the studies suggested in connexion with the afforestation of peat bogs.

As already mentioned, investigations in southeastern Canada have shown that the intensity of paludification probably has changed during the epochs of the post-Glacial period. An investigation of the intensity and forms of paludification in different parts of Canada at the present time, as well as at different stages of the post-Glacial period, would lead to many important scientific results, and would serve as a basis for the regional investigation of Canada's peat bogs.

Flooded lands along rivers and seashores in places turn into peat bogs, a matter that has received little attention from a scientific point of view. The paludification of the flood-plains of rivers is, of course, of great practical importance, considering that the rivers in wide areas of Canada still continue to serve as transport ways and as channels for the spreading of settlement.

Peat bogs may develop progressively or regressively. The latter means that the surface of a peat bog is, in one way or other, drying up, the former that it is becoming wet. Each peat bog type has its own characteristic forms of development, and may show successive changes

from a more damp to a more dry condition, or vice versa. As the *Amblystegium* and *Sphagnum* bogs develop in different ways, and as each locality has its special features, the different habits and regional distribution of these bogs in Canada can be studied with the aid of botanical methods. The changes in humidity are shown by the stratigraphic structure. Thus, thin stripes in the *Sphagnum* surface layer indicate a struggle between the more damp and the more dry moss species; the product thus formed is called regeneration peat. Regeneration means a development from a more dry to a more damp condition. The regressive peat bog forms in Europe become more general towards the north; a somewhat similar rule also should apply to Canada. Regressive and regeneration forms are also found on southern peat bogs, especially on big *Sphagnum* bogs. In the investigation of these questions the methods used by Osvald in Sweden are of value. Southern peat bogs may show signs of development characteristic of northern peat bogs, and northern ones may indicate a southern influence, i.e., forms mainly showing a progressive development. Consequently, it is to be expected that both forms may appear together in the boundary areas of the regional zones.

When, as a direct result of drought, the *Sphagnum* cover of peat bogs starts to disappear, there is retrogressive development. According to the investigations of Lewis and Dowding this would be quite a usual feature, at least with regard to the peat bogs in some parts of Alberta. Judging by their published reports and illustrations, the question should remain to some extent open, because it seems that there is a question of the parallel appearance of a progressive and regressive development together with the influence of forest fires, each being very strongly represented.

Reforestation of peat bogs is possible at a certain stage of their development, irrespective of climatic factors. This is shown by the fact that in many peat bogs on seashores, woody peat and *Sphagnum* peat form upon a thin *Carex* peat layer at the same time. The same phenomenon is also shown by structure of peat bogs that regularly consist of *Carex* peat at the bottom, overlain by a *Sphagnum* layer starting with a stump-layer, a remnant of an ancient forest. On the surface of the peat bogs one often comes across local development of forest, a detailed explanation of which must be left to future investigations.

It is, on the other hand, just as important to explain the causes of the occurrence of dead pine forests, in many cases very extensive, whose white, dead trees leave a peculiar seal on some peat bog landscapes. It is important to determine in what way the lateral growth of peat bogs, freezing phenomena, insect damages, and other factors, cause the wholesale dying out of trees on peat bogs or on their edges. The dying of trees on heath lands in many cases is caused by the general rise of the water surface owing to the upward growth of an adjacent peat bog. Just as the forest revives on the surface of peat bogs from which the water flows down to lower lands, so the more lowly situated peat bogs become moist, and the forest that may grow there, eventually dies out. By stem analyses of the trees and by careful floristic investigations of the humidity changes of different plant associations it is possible to explain this question and in general to elucidate the problem of paludification of forests. Investiga-

tions in Finland have proved that progressive development, due to the drainage of peat bogs, proceeds as a rule gradually into a definite forest type, and that, when a drained peat bog becomes wet again development can proceed in an opposite direction, in a definite succession of types. Consequently, the question of progressive and regressive development of peat bogs in Canada is important, especially as similar peat bog types reach different final stages depending upon the mode of development. For example, the final stage of a wet peat bog which has become dry is not always a forest-growing type, it may be a mossless type, growing a lichen-covered, low twig vegetation.

PEAT-GEOLOGICAL INVESTIGATION

Changes, in the living parts of peat bogs, give rise to the formation and distribution of different peat soils. A peat-geological investigation, therefore, should be as comprehensive as is possible and should include a study of the whole peat bog. The chief methods to be followed are: (1) The peat soils are defined on the basis of their physical characteristics; or (2) they are classified according to a system, based on the original biological type of each kind of peat. If these methods prove unsatisfactory a combination of the two may be used. As no systematic classification of peat deposits in Canada has been made, it is proposed by the writer that the genetic system, generally used in Europe, should be adopted. According to this system, the peats are divided into four groups.

(1) The limnic (lake) group comprises all material deposited under water. It includes different kinds of ooze, mud, detritus, shore and inundation peat, *Equisetum*, *Scirpus*, and similar peats stratified under water.

(2) The telmatic (marsh) group comprises the *Carex* peats and those belonging to the *Amblystegium* and *Sphagnum cuspidatum* groups.

(3) The semiterrestrial group comprises *Eriophorum*, *Sphagnum*, and some broad leaftree forest peats, formed near the water surface and in most conditions, such as *Alnus* peat whose equivalent in Canada has not yet been found with certainty, but which seems to be a grass-herb forest peat.

(4) The terrestrial group comprises peats of various forest peat bog types, the essential parts of which consist of remains of trees.

The investigation work, of course, must be founded on a regional basis, particularly in view of the fact that the application of peat bogs to agriculture and industry depends upon the character of the peat. Such an investigation will give an idea of the possible uses of different peats in Canada. For defining the actual value of the peats, physical and chemical investigation should be made and should be as comprehensive as possible. The geology of the surrounding lands also must be taken into consideration, especially in connexion with the application of peat to agriculture.

STRATIGRAPHY OF PEAT BOGS

Peat bogs as a rule consist of layers of different kinds of peat. It is evident, therefore, that the sequence and reciprocal relations of the different peat layers, i.e., the stratigraphy of the peat bogs, should be investigated. The investigation should aim at the establishment of definite stratigraphic types and especially should determine the regional distribution of these types. Investigations by the writer in southeastern Canada, showed that at least a few stratigraphic types may be distinguished such as those in which *Sphagnum* peat and those in which *Carex* peat forms the thickest layers, the former representing the oceanic area and the latter the more continental area. There is a transition type between the two areas. Grass-herb forest peat bogs are also found in the area of the continental type. The *Carex* peat bog of southern and southeastern Canada should, however, be distinguished from the *Carex* peat bog of northern Canada. It is probable that *Amblystegium* peat bogs occur in western Canada and, locally, at places where the rock substratum contains limestone.

Along with the more or less practical investigations attention should be paid to many scientific problems. The most important are those that deal with the origin and development of the peat bogs in the light of the stratigraphy. The peat-geologic investigations should show the relation one to another of the different modes of formation of peat bogs. The structure of the layers that lie under the peat is of prime importance in determining whether the peat bogs formed in ancient lakes or on dry land. Investigations in southeastern Canada have proved that the filling up of water bodies has been of much greater importance in the area of the continental type than in the maritime area where the paludification of forest lands has been the prevailing feature. Comparative investigations such as these naturally lead to research upon the nature of paludification as shown by the different sediments and vegetable filling of the ancient lakes, as well as by the general structure of the bottom layers of the peat bogs. The results of work by the writer prove, for example, distinct differences in the mode of formation of peat bogs in early post-Glacial time and at present, and that the greater part of the peat bogs investigated in Finland have been formed close to the shoreline of the receding sea. This fact is of special importance to investigations concerning the elevation of land and the chronology of the post-Glacial period.

FORM OF PEAT BOGS

Peat bogs have definite forms due to the stratigraphic development of the bogs and a study of the forms in connexion with that of humidity changes on the surface of bogs is of practical value. Some main forms, particularly those of the *Sphagnum* peat bogs in the area of the oceanic type, may be mentioned. The surfaces as a rule are convex, but there are large variations due to the manner of growth as well as to other factors that influence the surface form of the bog. The convexity of the surfaces increases during the development of the bogs. This causes various changes in inclination of the surfaces and these changes, together with the growth

of moss, cause a variety of forms that are in many cases difficult to explain. In this connexion the profiles to be published in the report by the writer may be consulted. The many-sidedness and importance of the question will be apparent from these.

THE RECORD OF THE PEAT BOGS

The investigations in southeastern Canada prove that the regional regularity for the most part is due to climatic causes. It is reasonable to suppose, therefore, that climatic changes during the post-Glacial period will be indicated by the structure of the peat bogs and by the occurrence of certain types outside their regional areas. The peat bogs record the development of the vegetation during the course of thousands of years, and, therefore, are important for the study of climatic and other changes in post-Glacial time.

The investigations in Canada show that there are distinct regularities in the stratigraphic development of the peat bogs throughout the whole area investigated, that the regularities can be correlated from place to place, and that the changes of climate in Canada are comparable with those in Europe. Consequently, it is possible to apply to Canada the whole comprehensive investigation method used in Europe, altered, of course, in accordance with Canadian conditions. This result is of importance also as it gives a chronologic basis for the investigations concerning the geographical history of the post-Glacial period. The peat-geological method of investigation, therefore, appears to be more important in a chronologic respect than the method of investigation based upon a study of the ancient shorelines, which studies have led to a variety of conclusions. Moreover, archæologic investigation in Canada cannot offer such a good chronological foundation as does European archæological chronology. It should be possible, however, to combine the geochronological investigation based upon various kinds of sediments, as warve clays, moraines, etc., and the peat-geological investigations, so as to arrive at a definite continuous chronologic series, and thus establish a consistent basis for all future investigations concerning the history of the Quaternary period.

Before dealing with further investigations concerning the various phases of the post-Glacial period, it is necessary to explain briefly the method by which the chronologic development of peat bogs is determined. This method has been used by the writer in connexion with the investigations in Canada. The buried pollen particles of the plant species in the different layers of the bogs can be determined microscopically. The examination of the occurrence of pollen is made quantitatively, i.e. all the determinable pollen particles in thin sections of a definite size are counted, and the results are shown by diagrams in which the different depths in a section through a peat bog are plotted on the ordinates, and the relative number of pollen of each species, expressed in percentages of the total number of pollen particles counted, on the abscissæ. The points for each tree species are joined by lines, which form curves representing the variation of the relative amount of pollen of each tree species in different layers of the peat bog. These curves show practically the same regularities in different sections of a peat bog and also in peat bogs

far away from one other. The curves thus enable the investigator to connect synchronous layers in different peat bogs. If the pollen of a certain tree species is not found below a certain point in the peat layers, then this limit indicates a time when the said tree migrated to the area. The peat bog investigations in southeastern Canada have proved that the regular variations in the development of the peat bogs, according to this method of determination, are of the same age. If, as seems probable, the same climatic changes have taken place in Canada as in Europe, where these changes have already been fixed in a complete chronological system, it is possible to establish an absolute time scale for the different epochs of the post-Glacial period in Canada. In areas where there is no evidence of climatic changes, it is possible by the application of this method at least to determine the synchronous horizons for different peat bogs. By correlation of the curves it may be possible also to extend the chronology all over the country. In connexion with future peat-geological investigations of this character in Canada it is necessary first of all to eliminate all possible sources of error in the application of the method in each area. To this end it is necessary among other things to examine the surface of the peat bogs, to find out in what way the present composition of the tree flora is indicated by the pollen percentages in the layer that is being formed. The method is important both for the study of the chronology of post-Glacial time, and for the history of the vegetation during the same period. The pollen limits indicate the times when the different tree species have arrived at certain localities. To determine this question in Canada investigations should be carried out in straight lines from south to north, and from east to west. The changes in the boundaries and zones characterized by different trees during post-Glacial time also would be shown in this way. The investigations so far made show that at least in a north-south direction there have been movements in close connexion with climatic factors other than the ordinary migration of the vegetation. For example, in the bottom layer of the peat bogs of southeastern Canada, *Picea* and *Abies* pollen appear in abundance, but their curve, a little higher up, rapidly drops to a minimum, when the pollen amounts of the hardwood reach their highest value. In the surface parts the pollen amount of spruce trees again increases, whereas that of hardwood is decreasing. Particularly noticeable is the absence of *Tsuga* in the oldest bottom layers.

The method is applicable also to a study of the flora of the interglacial periods, and is proved by investigations of the interglacial peat in Moose River basin in northern Ontario. It may be used to compare the relative ages of different parts of a peat bog, and thus to show the nature and intensity of the different kinds of paludification. Besides, the method may be used in many cases to indicate critical peat varieties and the rates of accumulation of the peat.

As proved by geological investigations in Canada, the unequal upheaval of land in many areas has caused the shorelines of the lakes to move, either upward or downward, depending on the position of the outflow of the water with regard to the centre of upheaval. Peat-geological investigation methods according to the genetic system set forth

above, therefore, may be applied to peat bogs on lake shores where changes of the water-level are shown by the characters of the peat. By this method the rates of retreat of the ice-sheet and upheaval of the land may be established on a chronological basis, as the investigations in Finland and Scandinavia have demonstrated in such a beautiful way.

Megascopic plant-palæontological investigations should also be made for determination of fossil plants and animals, especially in the sediments of ancient lakes. The megascopic investigations in southeastern Canada have given good results and should be extended to the whole of Canada, as they would complete the microscopic method, and in some respects are more reliable.

PRACTICAL PEAT BOG INVESTIGATIONS

In the preceding pages attention is drawn to features of peat deposits, an understanding of which is indispensable for the intelligent utilization of these deposits. Some consideration will now be given, shortly, to purely practical questions in connexion with the peat bogs of Canada. The present writer's conclusions regarding peat bogs in southeastern Canada differ, somewhat, from a practical point of view, from the results of investigations that the Geological Survey has carried out in recent years with the use of peat for fuel in mind.

Many of the peat bogs that the writer investigated had already been explored by Mr. Aleph Anrep, so the writer had a fairly large amount of information at his disposal, which facilitated his own observations and afforded him knowledge of the methods that had been used in making these earlier surveys. A creditable amount of labour and time have been devoted to these investigations. There appears, however, to be room for the application of some further methods of study to complete these earlier investigations and to bring them into accordance with current needs and with the best methods employed in other countries.

First of all, investigation of the peat bogs should be as many-sided as possible. Even the European peat bog specialists have to deal also with numerous branches of practical activity, as well as with theoretical questions, and they have to apply industrially their theoretical conclusions. Such an extensive and complexly developing country as Canada has especial investigational work of this comprehensive nature. Canadian peat bog investigations should deal with the use of peat bogs, on a scientific basis, with an eye to all the different possibilities of practical application. Investigation of this kind is, of course, not fully practicable until the various practical uses in Canada have been discovered, but an exact analysis can be made of the structure of the peat bogs, the ways of paludification, as well as of their development. More specific methods for utilizing the various kinds of peat deposits can only be chosen on the basis of the first general scientific results.

The investigations so far carried out have dealt only with the use of peat bogs for fuel and litter and they have been carried on chiefly in eastern Canada. The present writer believes that out of some thirty cases which he checked very few could be profitably used for making fuel, and

even in these cases the greatest caution should be observed in selecting a suitable method. Among peat bogs thus usable are the Large Tea Field, Alfred, Newington, and Perth bogs. Considering that some enterprises even on these peat bogs have failed, it is doubtful in what degree other bogs less suitable can be used. It appears from profiles made by the writer that Sphagnum peat, which forms the predominating layer in most of these thirty peat bogs, is so raw that it is more or less unsuitable for use in the fuel-peat industry. And even in the few instances in which the degree of mouldering or humification of the peat would somewhat correspond to the requirements for fuel-peat, its mechanical removal from the bog presents many difficulties on account of the presence of numerous stumps and other obstacles. A distinction must be made between the suitability of the material for a given purpose and the profitability of that use. In the possibly profitable cases mentioned above, this estimation refers mainly to *Carex* peat.

Not in a single case has the writer been able to find any type that corresponds to the European hochmoor which, under the raw Sphagnum layer, contains an older, highly mouldered Sphagnum layer, and, underneath this, a forest peat layer usually containing plenty of *Alnus*. The fuel-peat value of these mouldered layers is in Europe high. Neither with regard to their physical nor chemical qualities do the mouldered Sphagnum layers of eastern Canada in a single case stand comparison with the European ones. It may be added that the comparatively rare forest peat in Canada is of a different nature from the corresponding variety in Europe. From the investigations carried out in Canada one is not, however, in a position to judge the value of this Canadian forest peat, because in these investigations the different peat varieties have not been studied separately and systematically. Analyses should invariably be made on definite varieties of peat whose distribution has been ascertained beforehand.

The principal uses to which the peat bogs of eastern Canada can be put are the moss litter industry and afforestation. Many chances are offered to agriculture, at least on the borders of peat bogs, and the peat material derived from the peat bogs may, particularly on clay soil, yield good results. The substantial report of the Canadian Peat Committee, published last year, deserves special attention also in so far as attention is drawn to other than the fuel-peat uses. Of course, as long as an abundance of fertile arable land remains the use of peat bogs for agriculture will be deferred; but even so the classification and valuation of the peat bogs, as well as a valuation of their future possibilities, is desirable. Some of these bogs have peculiarly high agricultural values for the raising of special crops like onions, celery, and cranberries.

DEEP BORINGS IN ONTARIO AND MARITIME PROVINCES¹

By E. D. Ingall

The Borings Division of the Geological Survey exists for the purpose of securing, when possible, records of borings made in Canada, whether in search for water, petroleum, or natural gas, etc. It is now universally recognized that the collection of reliable data illustrative of the nature and structure of the strata passed through in boring is of the utmost importance for the intelligent direction of efforts to locate gas, oil, water, etc.

This work is carried on directly in co-operation with operators in some provinces, and in others with the assistance of provincial and federal government organizations, and results in the building up of extensive reference files of well records obtained from drillers, geologists, and others. In order to study the characteristics of the strata penetrated by boring operations, samples, in the form of pulverized rock or cuttings of the material produced during the process by the ordinarily used percussion tools, are taken by the driller at about 10-foot intervals and sent to the Borings Division. They are there submitted to intensive study by chemical, mechanical, and microscopic methods, and the succession and characters of the strata established and utilized for the guidance of further drilling operations.

The policy of acquiring and filing sets of samples in an orderly way has justified itself on many occasions. In many cases where districts have been abandoned for years a renewal of boring operations has led to a demand for the logs of old wells and to need for further examination of the samples. With the advance of geological science, new methods of study of the material are developed, and new data are sought in the laboratory examination of the well cuttings, which were necessarily not foreseen in the past.

Apart from the efforts made to collect samples and all available data relating to deep borings for gas and oil, efforts are made to get in touch with drillers who are engaged in the business of boring for water supplies. Considerable difficulty has always been encountered in this line of investigation as most of such borings are made by drillers operating locally, with whom it is difficult to get in touch and to maintain relationship. The solution of this problem might be arrived at by inaugurating in Canada a movement recently introduced in some of the states of the United States of America in which drillers' associations have been formed. Annual conventions are held at which problems of interest to drillers are discussed and where the members of the association can become familiar with drilling machinery exhibited by the manufacturers. Through the discussions the practical experiences of the members are rendered available to all.

The Borings Division of the Geological Survey could then perform more effectually its function of providing a central "clearing house" for well

¹ Information regarding boring records for the Prairie Provinces will be found in part B of Summary Report, 1927.

records and for their correlation and interpretation and the utilization of the aggregate results for the guidance of future operations.

The question of water supplies is a most difficult and important one and becomes more so as the country becomes more closely settled. The water required must, of course, be pure enough for domestic use and free from any large percentage of dissolved mineral salts. The water encountered in deep borings into the underlying rock formations is so frequently highly mineralized that the accumulations of rain water in the porous portions (gravels and sands) of the surface deposits has to be depended on in many districts. These, being in their nature very irregular in their distribution, the problem becomes one of making intensive local studies. The data it has been so far found possible for the Division to acquire by correspondence are too scattered to give anything but general conclusions.

But few records of deep borings have been received by the Borings Division from the Eastern Provinces.

The near exhaustion of the pools of natural gas and petroleum of Ontario has led to an inevitable limitation of deep boring activities. The particulars regarding whatever deep wells were put down in this province will appear in a forthcoming report of the Ontario Bureau of Mines, by Col. R. B. Harkness. Thanks to Col. Harkness' co-operation the samples collected by him are eventually received by the Borings Division, together with copies of logs.

As stated in the accompanying laboratory report, examinations were made of samples from a well near Inglewood in Peel county, Ontario, in connexion with the search for helium-bearing gas, prosecuted under the auspices of the University of Toronto.

In the province of Quebec no deep borings for gas or oil have been prosecuted since the campaign carried on near St. Hyacinthe in the years 1914 to 1916.

Judging, however, from inquiries received during the year, fresh interest is being taken in the possibilities of the district and in consequence the 1,473 samples from these wells which had formerly only received a preliminary examination, were submitted to more intensive research, as stated in the laboratory report appended. The views expressed in former reports of the Borings Division were confirmed and no definite change of formation was recognizable in any of the sets of borings samples from the eight wells studied, the deepest of which attained the depth of 3,455 feet.

While for reasons stated above, the collection of fresh data regarding borings has been less than formerly, the Division has performed its other function in meeting the needs of numerous inquirers regarding the geological conditions to be encountered at various places in connexion with proposed boring operations in search of gas, oil, or water-supplies.

In the Maritime Provinces the only deep boring from which samples were received was that put down by the Henry L. Doherty Company of New York on Governor island near Charlottetown, Prince Edward Island. Samples were received last year from this company's No. 2 well to a depth of 4,127 feet, at which depth boring was suspended for the winter. On resumption of work in the spring of 1927 the well was continued to a

depth of 5,965 feet, when operations were finished without encountering any definite change of formation. Samples to a depth of 5,870 feet were received and examined in the laboratory.

The laboratory report, herewith appended, gives particulars of the examinations made on samples from the Gautreau well in Moncton district, N.B. As a very large amount of well cuttings from the numerous borings of the New Brunswick Gas and Oil Company had already been accumulated, it was agreed with the company's officials that further sets of samples should only be sent from new borings at outlying points in the district and where they would not be a mere duplication of wells already bored at nearby points. No samples were, therefore, received during 1927. Thanks are due to Dr. Henderson who during the whole period he has been in charge of the operations of the company has accorded to the Borings Division the most friendly assistance.

In Nova Scotia no particular deep boring operations were reported.

The International Petroleum Company and the Eastern Gulf Company put down a number of shallow holes to demonstrate structure at a number of points. Nothing conclusive was reported, however.

The following report by Mr. D. C. Maddox gives the results of the laboratory examinations of borings materials made under his supervision.

REPORT ON LABORATORY WORK

The only work done on Ontario samples was in connexion with the well drilled in lot 4, con. I, Caledon tp., by the University of Toronto, for the purpose of obtaining a supply of helium gas. One hundred and one samples from this well were washed and examined and the residue insoluble in hydrochloric acid was determined in the cases of ninety-two of these samples.

A series of samples obtained some time back from wells drilled in the area north of the town of St. Hyacinthe, Quebec, were washed and examined. One thousand four hundred and seventy-three samples from the following eight wells were so treated.

	Depths	Number of samples
	Feet	
Canadian Natural Gas Co. No. 1.....	350—1,880	12
“ “ “ 2.....	98—2,907	258
“ “ “ 3.....	75—3,455	339
“ “ “ 4.....	120—2,380	226
“ “ “ 5.....	110—2,430	241
National Gas Co. No. 1.....	110—2,050	194
“ “ “ 2.....	120—1,826	169
Ste. Madeleine.....	185— 525	34

In addition to the routine examination involving the use of the binocular microscope and cold dilute acid, the residue insoluble in acid was determined for seventy-two samples. Distillation tests were made with samples from Canadian Natural Gas Company's No. 3 well, the samples

chosen being from depths of 75 to 2,000 feet and from 3,215 to 3,415 feet. It was considered that these tests would help to indicate whether the Utica shale was reached in this well.

Three hundred and sixty samples were examined from the Gautreau No. 2 well of the D'Arcy Exploration Company. These covered depths of 20 to 1,806 feet. All the samples from shale horizons in this well were subjected to distillation tests. Tests for the amount of material soluble in water were made on twenty-three samples.

One hundred and eighty-nine samples were examined from "P.E.I. No. 2" well the second of the two wells drilled by the Doherty interests on Governor island in the harbour of Charlottetown, P.E.I. These samples covered depths of 4,100 to 5,870 feet. A number of distillation tests were run on these samples, with negative results as far as oil and gas are concerned.

OTHER FIELD WORK

Geological

H. M. BANNERMAN. Mr. Bannerman completed the detailed examination of pyrite- and iron-bearing formations in the vicinity of Nickel and Pipestone lakes, Rainy River district, and Staunton on the Canadian National railway, Thunder Bay district, and commenced a detailed study of the Timagami iron range, Nipissing district, Ontario.

T. L. TANTON. Mr. Tanton investigated many of the mineral deposits in the Port Arthur silver-bearing area from Nipigon southwest to Arrow lake, Ontario. The results of this work will be incorporated in a memoir now being prepared.

R. C. EMMONS. Mr. Emmons concluded the geological survey of the Woman River and Ridout areas, Ontario. The two maps and accompanying memoir are being prepared for publication.

T. T. QUIRKE. Mr. Quirke completed a geological survey of the Key Harbour area which borders the northeast corner of Georgian bay, Ontario. A geological map and report are being prepared.

W. H. COLLINS. Mr. Collins assisted by R. Thompson completed the geographical and geological mapping of Espanola area, immediately west of Sudbury nickel basin, Ontario. The geological map of the area is being prepared for publication. Field work was extended to the adjoining map-area to the east. Mr. Thompson began a special study of the nickel-bearing intrusive and various associated formations.

C. TOLMAN. Mr. Tolman continued the mapping and studying of the Birch Lake granite body that extends northward from Espanola area, Ontario.

G. M. BROWNELL. Mr. Brownell geologically mapped the district in Leeds county, Ontario, represented by the southwest part of the Westport sheet of the Department of National Defence.

A. E. WILSON. Miss Wilson continued the geological mapping of the Cornwall map-area, Ontario.

H. C. COOKE. Mr. Cooke made detailed geological examinations of various mineral deposits in Rouyn district, western Quebec. The results obtained will be incorporated in a memoir on the geology and mineral deposits of Rouyn district.

W. F. JAMES. Mr. James reinvestigated the geology and examined the principal mineral discoveries within Duparquet map-area, Rouyn district, Quebec. A revised edition of the geological map is being prepared. An account of the mineral occurrences will be included in the above-mentioned memoir on Rouyn district.

T. H. CLARK. Mr. Clark commenced the geological study and mapping of the area in southeast Quebec represented by the Sutton sheet, Department of National Defence.

W. V. SMITHERINGALE. Mr. Smitheringale examined various manganese occurrences in New Brunswick and Nova Scotia and visited Michipicoten district, Ontario, for the purpose of investigating the manganese-bearing iron formations. The information relating to manganese is to be incorporated in a proposed report on the manganese deposits of Canada. Several lead-zinc occurrences in Ontario were also examined by Mr. Smitheringale.

F. J. ALCOCK. Mr. Alcock, in addition to work in Gaspé reported upon in a preceding section of this volume, examined a number of mineral deposits in New Brunswick and Nova Scotia. The information obtained in the case of various lead-zinc deposits will appear in a proposed report on the lead-zinc deposits of Canada.

E. R. FARIBAULT. Mr. Faribault completed the geological survey of the Digby map-area, Nova Scotia.

W. A. BELL. Mr. Bell made a geological reconnaissance of the area including Port Hood, Mabou, and Inverness coal districts, Nova Scotia.

G. W. H. NORMAN. Mr. Norman commenced the geological study and mapping of Ainslie map-area, Cape Breton, Nova Scotia.

Topographical

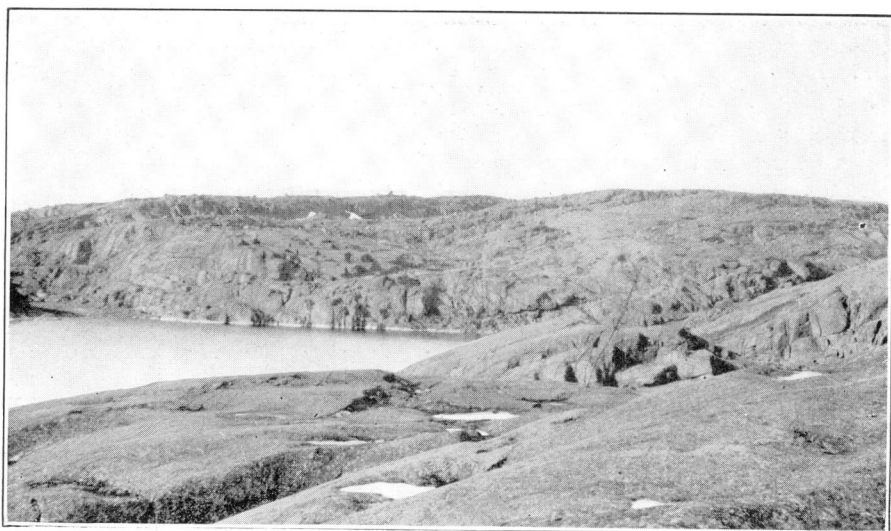
A. G. HAULTAIN. Mr. Haultain carried out surveys in Rutter and Key Harbour map-areas, bordering Georgian bay, Ontario.

H. N. SPENCE. Mr. Spence completed the survey of Carleton map-area, bordering Chaleur bay, Quebec, and New Brunswick.

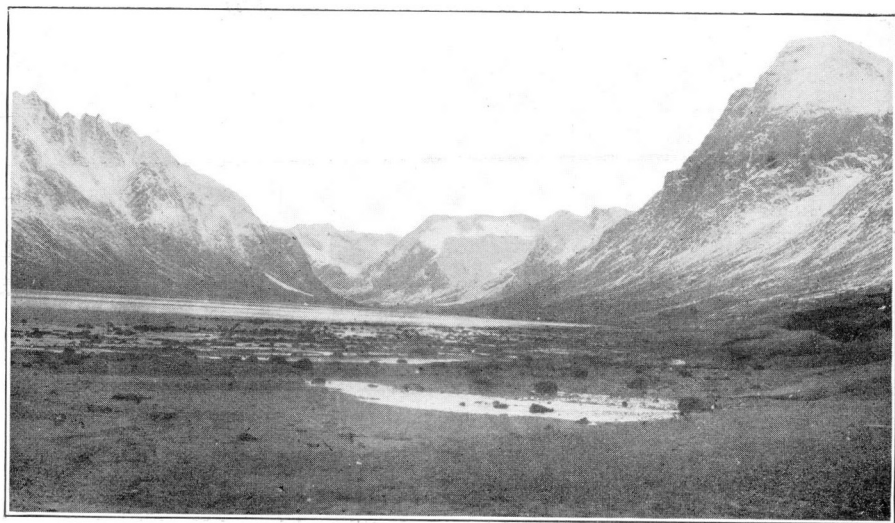
R. BARTLETT. Mr. Bartlett completed the survey of the west half of Loch Lomond map-area, and the whole of Cape Spencer map-area, east of St. John, New Brunswick.

K. G. CHIPMAN. Mr. Chipman topographically mapped the drainage basin of Chamcook lakes, near St. Andrews, New Brunswick.

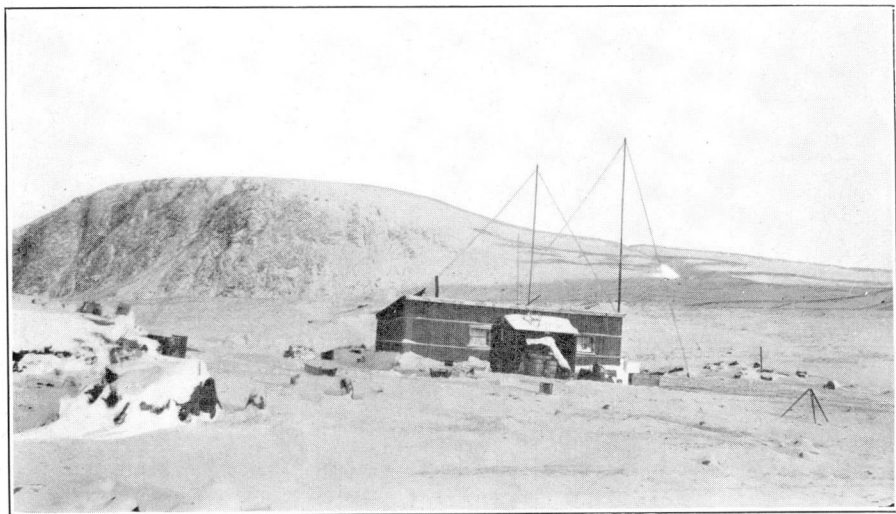
J. V. BUTTERWORTH. Mr. Butterworth commenced surveying the Ainslie map-area, Cape Breton, Nova Scotia.



A. Nettilling fiord, 5 miles east of first big tide rip, showing "boulder line" at about 155 feet above high tide. (Page 91.)



B. Pangnirtung fiord, looking east from Aulatsivikjuak. (Page 90.)



A. Duval mountain, raised beaches in distance on right, winter quarters in foreground.
(Page 90.)



B. Looking east from height of land between Nettilling lake and Nettilling fiord.
(Page 91.)

INDEX

	PAGE		PAGE
Abitibi territory. <i>See</i> Eagle River area		Brandy Brook camp	41
Albert mt.	29, 31	Bras d'Or lake, C.B.	49, 73
Alcock, F. J.	117	Bras d'Or Lime Company	77, 79
Rept. by, on zinc-lead field of central Gaspé, Quebec	27-46	Brownell, G.M.	116
Alfred peat bog	102	Buckell l.	8, 10
Altitudes		Building stone. <i>See</i> George River series	
Cumberland Sound area, Baffin island	89	Burwash, L. T.	84
David Lake area, Quebec	3	Butterworth, J. V.	117
Shickshock mt., Quebec	29	Caché l.	7
Andesite	7	Cajander, A. K.	98, 100
Anhydrite	77, 80, 81	Caledon tp.	114
Anorthosite	8	Cameron bk., C.B.	66
Anrep, Aleph	110	Cameron is., C.B.	75
Arctic archipelago. <i>See</i> Cumberland sound		Campbell, D.	82
Arctic bay	94	Campbell bk., C.B.	53, 55, 58, 65, 68, 70, 82
Arctic seas, navigation	85	Canadian Natural Gas Company	114
Asbestos	14	Cape Breton co. <i>See</i> North mt.	
Asbestos is.	14	Carboniferous	50, 64
Asinitchibastat l.	9, 20	Caribou	86
Altitude	3	Cascapedia Mines	29
Rocks	4, 5	Cedar bay	8, 13, 15, 17
Atlantic upland	70, 71	Chalcopyrite	
Auer, Väinö		David Lake area, in auriferous deposits	15-20
Rept. by on Some Peat Investigations in Canada	96-111	Gaspé pen	36, 42-44
Aulatsivik pen.	90	Chibougamau dist., Que. <i>See</i> David Lake area	
Aulatsivikjuak pen.	90	Chibougamau l.	2, 3, 11
Baffin is. <i>See</i> Cumberland sound		<i>See also</i> Asbestos is.	
Bannerman, H.M.	116	McKenzie bay	
Barite	40	Altitude; area	3
Barlow, A. E.	2	Chibougamau McKenzie Mining Corporation	15
Bartlett, R.	117	Chipman, K.G.	117
Beaches	90, 91	Claim Q 1393	14
Beidelman, J.	28	Clark, T. H.	117
Beidelman property	27, 39, 46	Clarke cove, C.B.	76
Bell, J. MacIntosh	28	Clarke is.	75
Bell, W. A.	47, 66, 70, 117	Climate	
Berkey, C. P.	47	Cumberland Sound reg.	85
Berry Mountain bk.	28, 30, 34, 42	Coal	77
Berthe bay	8	Coastal fluctuations	90
Big bk., C.B.	49, 68, 73	Cobalt bloom	
Big vein	40, 43	David Lake area, in auriferous deposits	16
Big Brook, C.B.	61, 66	Collins, W. H.	116
Big Harbour, C.B.	65, 71, 81	Colony, R. J.	47
Blacklead is.	84, 93	Conglomerate	65
Blake cl.	13, 21	David Lake area, Que.	4, 11
Blake Development Co., Ltd.	14, 18, 19	Conglomerate pt.	12
Boas, F.	84	Consolidated Mining and Smelting Company of Canada, Ltd.	18
Boisdale hills, C.B.	51	Contact bay	11
Bon Ami limestone	33	Cooke, H. C.	23, 116
Boom is.	81	Copper. <i>See</i> Chalcopyrite	
Boulder clay	68, 74	Craignish hills, C.B.	52, 66, 70, 71
Boulders in		Crammond is., C.B.	75
Cumberland Sound reg.	91	Craunaena	66
Lemieux tp.	31	Creelman, E. F.	27
Bourdeau l.	30, 40, 43	Cretaceous peneplain	71
Brandy bk.	30, 40, 43		

	PAGE		PAGE
Crooked vein	45	George Island pen., C.B.	75
Cumberland sound, Baffin is.		George River series	48, 51, 53, 55, 77
Rept. on area by L. J. Weeks		Gillanders, E. B.	27
(with map)	83-95	Gillis pond	74
Dallas bk., C.B.	55	Gilman, R. T.	19
D'Arcy Exploration Company	115	Gilpin, E.	52
David Lake, Que., rept. on area ...	1-22	Glaciation	
Dawson, Sir William	47	Cumberland Sound reg.	90
Declinations, magnetic	88	David Lake area, Que.	14
Denys basin, C.B.	49, 65, 66, 72, 73	Eagle Lake area, Que.	25
Denys river, C.B.	49	Gaspé co., Que., and Newfoundland	31, 32
Devonian	32, 34	North Mountain area, C.B. ...	50, 51, 72-74
<i>Dielasma davidsoni</i>	66	Gladstone l.	10
Djingheuzian, L.G.	28	Gold	82
Doherty, Henry L. Company	113	David Lake area	4-20
Dominion Iron and Steel Company..	50, 77	Goldthwait, J. W.	48
Donald, J. T., and Company	36	Governor is.	113
Doré l.	7, 8, 14, 19	Grammo pt.	75, 81
<i>See also</i> Cedar bay		Grand Greve limestone	33
Altitude; area	3	Granite	
Rocks on and near	4, 6	Cumberland Sound reg.	92
Drumlins	69, 74-76	David Lake area, Que.	4, 7, 9
Dulieux, E.	2	Eagle River area, Que.	25
Dumonde, Austin	17	North mt., C.B.	56
Duval, W.	90	Shickshock mt., Que.	29
Duval mt., photo	120	Granite porphyry	93
Eagle River area, Que., rept. by		Graphite	82, 94
Mawdsley, J. B.	23-26	Gravel for ballast	
Eastern Gulf Company	114	North mt., C.B.	68
Eden siding, C.B.	72	Great Bras d'Or channel	73
Ells, R. W.	34	Greywackes	56
Emmons, R. C.	116	Grinnell glacier	90
Erythrite. <i>See</i> Cobalt bloom		Guernsey, T.D., rept. by, on geology	
Faribault, E. R.	2, 117	of North mt., C.B.	47-82
Farming		Gwillim, J. C.	3
North Mountain area, C.B.	50	Gwillim l.	12
Federal mine	27, 33, 36, 38, 42	Gypsum	77, 80, 81
Federal Zinc and Lead Company ..	27,	Hantsch, Bernhard	84
28, 35, 37, 44		Harkness, Col. R. B.	113
Felsites	52	Harvie Mines, Ltd.	29, 45
Fetterly, O. I.	27	Haultain, A. G.	117
Field work	116	Haycock, M. H.	83, 85
Finland	102	Head Bay cove	76
Fishing industry		Helium gas	114
North Mountain area, C.B.	50	Hogsback mt.	35
Fletcher, Hugh	48	Home bay	89
Forest fires, influence on peat bogs..	104	Honeyman, Rev. David	47, 51
Formation. <i>See</i> Tables of Forma-		Horton series	70, 71
tions		Hudson's Bay Company	83, 93, 94
Fortune, T.	14	Huronian belt	42
Fossils		Ice	
Gaspé co., central	34	<i>See also</i> Glaciation	
North mt., C.B.	66	Cumberland Sound reg.	86
Fox	86	Iglungayung, Baffin is.	88, 92
Foxe channel	88	Indian reserve on Malagawatchkt	
Fruit farming		pen., C.B.	50
North Mountain area, C.B.	50	Ingall, E. D., rept. by, on Deep	
Gabbro		Borings in Ontario and Maritime	
David Lake area, Que.	4, 10	Provinces	112-115
Eagle River area, Que.	24	Inhabitants r., C.B.	49, 65
North mt., C.B.	59	International Petroleum Company ..	114
Galena	36-38, 40, 41, 43, 45	James, W. F.	116
Gaspé co., Que.		Jennison, W. F.	81
Lead-zinc deposits, rept. by Alcock.	27-46	Johnson, D. W.	47, 73
Gaspé mine	46	Kaggilartung fiord	90, 92
Gaspé Limestone series	33, 34	Kangertlukjuak fiord	92
Gaspé Mines, Ltd.	27, 28, 45	Kapotina l.	25
Gaspé Sandstone series	34	Kelly, Hon. John H.	45
George is., C.B.	75	Kemp, J. F.	47

	PAGE		PAGE
Kingnait fiord	89, 90, 93	Merrill is.	13, 19
Knoll is.	19, 21	Mica	93
Koiyannak is.	92	Militia pen.	69, 73-75
Kungkuk pen.	90	Mill bk., C.B.	53, 54, 56, 58, 79, 82
Lac du Bras Coupé	25	Minerals Exploration Company	29, 45
Lake harbour	94	Mining Corporation of Canada	29, 45
<i>Larix Americana</i>	101	Moore, J. G. W.	27
Lead, Gaspe co., rept. by Alcock	27-46	Munroes Bridge, C.B.	80
<i>Leia</i> sp.	66	Nasanya pen.	90
Lemieux tp., Que.		National Smelting Company of London	27, 28
Zinc-lead deposits. <i>See</i> Gaspe co.		Natural Gas Company	114
Boulders	31	Navigation, Arctic sea	85
Lemoine, C. E.	2	Nemenjish series	24
Lepage, C. S.	2	Nettilling fiord	88-91, 93
<i>Leptodesma borealis</i>	66	Boulder line, photo	119
Lime Hill, C.B.	53, 58, 60, 67, 76	Nettilling l.	86, 88, 89, 91, 93
Limestone quarry	50, 54, 55, 77, 78	Map showing route to, from coast	
Little harbour, C.B.	66, 71, 82	In pocket	
Little Harbour, C.B.	53, 55, 65-67, 69	Newfoundland	32
Little Lake r.	33	New Richmond Mining Company	42
Livingstone, Dr. L. D.	83, 84	New Richmond Prospecting and Mining Company	28
Logan, Sir William	34	Norman, G. W. H.	117
Logan mt.	31	North mountain, Cape Breton	
Low, A. P.	2, 12	Rept. on geology, by Guernsey	47-82
Lyall, Mr.	28	North American properties	46
Lyall mt.	30, 31	North American Mining Company	28, 30, 44
Lyall property	27, 39, 46	North Brandy bk.	43
Mabou highland, C.B.	71	Nova Scotia. <i>See</i> North mt.	
McCuish bk.	59, 60, 61	Nunatak, Baffin is.	88
McKenzie, George	79	Obalski, J.	2
McKenzie, J. M.	81	O'Brien, M. J., Ltd.	29, 45
McKenzie, Peter	2	Oskelaneo river	1, 24
McKenzie bay	11	O'Sullivan, Henry	2, 23
<i>See also</i> Asbestos is.		Pangnirtung fiord	86, 88-93
McKenzie bk.	65, 67, 81	Photo	119
McKenzie cl.	15, 21	Peat	
McKinley, James	28	Canada, rept. on some problems	96-111
McKinley vein	38	Pellier harbour, C.B.	75
McKinnon, D. J.	81	Pellier pt., C.B.	74
McKinnon, L.	81	Pennsylvanian (?)	51
McKinnon, Mrs. Donald	81	Penny highland	90
McLean, Alan	80	Phelps-Dodge Company	29, 45
McLean, C.	81	<i>Picca mariana</i>	101
McLean, John	80	Pioneer cl.	42, 46
McLean, Malcolm	80	Pioneer Mining Corporation of Canada	27, 28, 42
McLeod bk., C.B.	57, 66-68	Plaster is.	81
McLeod farm	80	Pleistocene and Recent	
McMillan, Neil	58	<i>See also</i> Glaciation	
McMillan's farm	67, 68, 79	David Lake area, Que.	4, 14
McRae, Christopher	79	North mt., C.B.	67-69
Madame is., C.B.	48, 70, 71	Population of	
Maddox, D.C.	114	Cumberland sd.	86
Magnus is., C.B.	69, 75	North Mountain area, C.B.	50
Malachite	43	Porphyry	35
Malagawatchkt pen., C.B.	50, 69, 73-75	Precambrian	51, 88
Maple bk., C.B.	77	David Lake area	4
Maps		Eagle River area	24
Cumberland Sound area	In pocket	Prince Edward Island	113
David Lake area	In pocket	Prospectors, hints to	
North mt., C.B.	In pocket	David Lake area	21-22
Marble	77	Eagle River area	26
Marble Mountain, C.B.	50, 53, 54, 58, 67, 77	Lemieux tp.	31
Maritime Provinces, rept. on deep borings in	112-115	<i>Prototaxites</i>	34
Marshes, C.B.	66	Proulx bay	14
Matthew, G. F.	51	<i>Psilophyton</i>	34
Mawdsley, J. B., rept by, on		Ptarmigan	86
David Lake area	1-22		
Eagle River area	23-26		

	PAGE		PAGE
<i>Pteronites gayensis</i>	66	Surveys, electrical	22
Pulpwood	23	Sydenham bk.	54, 58, 79
Pyrite	82	Syenite	35, 44, 51, 52
Pyrrhotite		Table of formations	4, 32, 51
David Lake area, in auriferous		Tabletop mt.	29, 31, 35
deposits	13, 15, 18, 19	Tanton, T. L.	116
Q 581	15	Terraces	91
Quartz monzonite	93	The Creigan, C.B.	53, 79
Quartzites	54	Tides	86
Quebec province		Tolman, C.	116
Reports on		Tomboles	74, 75
David Lake area	1-22	Trees, North Mountain area, C.B....	50
Eagle River area	23-26	Usualung, Baffin is.	88, 92
Gaspé zinc field	27-46	Vegetables, North Mountain area,	
Quirke, T. T.	116	C.B.	50
Rabbit	86	Volcanic flows	
Recent formation, David Lake area,		David Lake area, Que.	4, 5
Que.	4, 14	Eagle Lake area, Que.	25
Retty, J. A.	1, 23	North mt., C.B.	51
Richardson, James	2	Wakonichi l.	11
River Denys, C.B.	53, 54, 65, 68, 73, 79, 80	Area	4
Robb, Charles	48, 52	Wave action	
Ronald is.	75	Brad d'Or lakes, effect of	73, 76
Ross, J. G.	19	Weeks, L. J., rept. by, on	
Ross bk., C.B.	59, 76	Cumberland Sound area	83-95
Royal Canadian Mounted Police	83	West bay, C.B.	49, 68, 72-77
Rush l., Que., area	4	West Bay, C.B.	66, 69, 75
St. Hyacinthe, Que.	113, 114	West Bay Road, C.B.	61, 66-68
Ste. Madeleine gas well	114	Whycocomagh, C.B.	70
Sands, magnetic	93	Williams, R. M.	1, 23, 47
Sandstone. <i>See</i> Gaspé Sandstone series		Wilson, Miss A. E.	116
Selenite	81	Wilson, M. E.	47
Shickshock mts	29, 31	Windsor series	51, 64-66, 71, 77
Shorelines	73	Windy l.	25
Simon l.	7-9, 20	Wolf	86
Smitheringale, W. V.	117	Xenoliths	62
Soper, J. D.	84	Young, G. A.	48
Spence, H. N.	117	Zeolite camp	93
Sphalerite. <i>See</i> Zinc		Zinc	36-38, 82
Sporting mt., C.B.	67, 71	David Lake area, in auriferous	
Steele, T. A.	14	deposits	15, 20
Surveying methods, Cumberland		Gaspé co., Que., Rept. by Alcock ..	27-46
Sound area	87, 88		