27

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
BULLETIN 27

CONTRIBUTIONS TO THE ECONOMIC GEOLOGY OF WESTERN NEWFOUNDLAND

THE STRONTIUM DEPOSITS OF PORT AU PORT PENINSULA
By Helgi Johnson

THE MAGNETITE AND GYPSUM DEPOSITS OF THE SHEEP BROOK-LOOKOUT BROOK AREA
By David M. Baird

THE IRON DEPOSITS OF INDIAN HEAD AREA
By Allen V. Heyl and John J. Ronan

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
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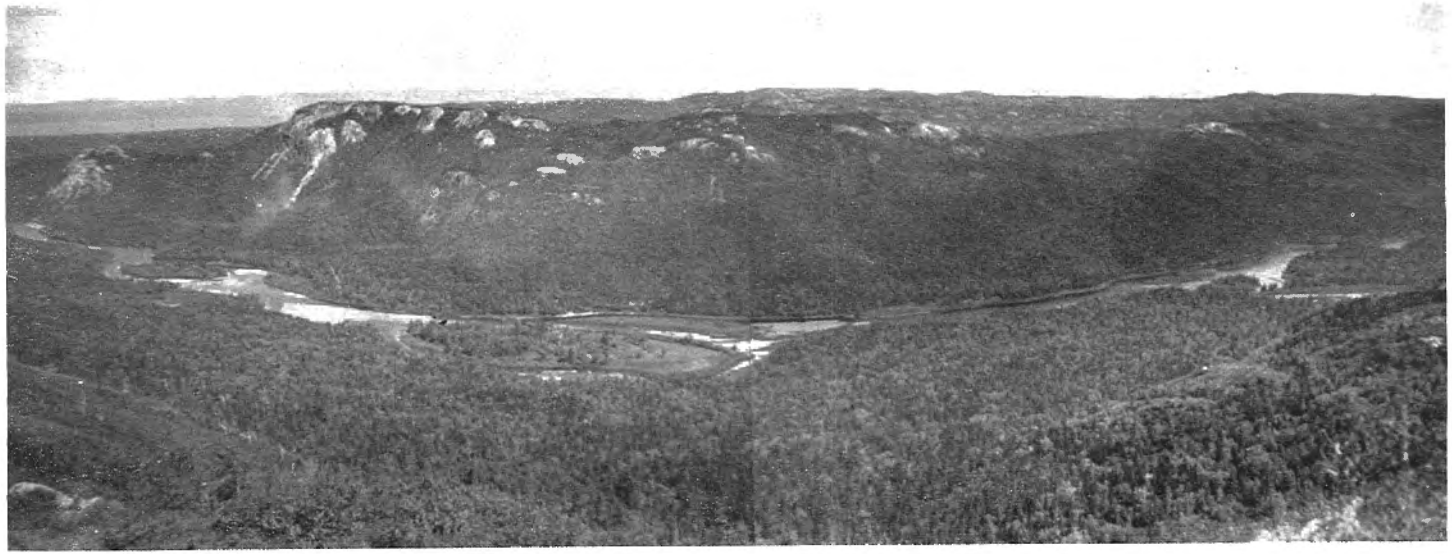
PLATE I



Panorama looking northward across the valley of Flat Bay Brook. Cairn Mountain at left is near the fault boundary between anorthosite highlands (right) and Carboniferous lowlands (far left). Distant water is St. Georges Bay. (Pages 6, 9.)

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PREFACE

The present report deals with three separated areas in western Newfoundland, centring about St. Georges Bay, in which a number of occurrences of metallic and industrial minerals had been reported.

Barite was known in Carboniferous rocks of the Port au Port Peninsula before the turn of the century, but not until 1937 were such deposits known to carry strontium-bearing minerals. Titaniferous magnetite was first discovered in pre-Carboniferous anorthosite of the Long Range in 1888. Gypsum beds have long been known to exist as members of the Mississippian formations flanking the Long Range on the west. Lenses of magnetite and hematite were noted early in the century as constituents of the intrusive gneisses of Indian Head.

During World War II the Geological Survey of Newfoundland investigated these deposits. The reports on these investigations, written by officers of that organization and unpublished at the time of Confederation between Canada and Newfoundland, were later acquired by the Geological Survey of Canada, which now takes pleasure in presenting the results to the public.

W. A. BELL,
Director, Geological Survey of Canada

OTTAWA, June 22, 1953

THE STRONTIUM DEPOSITS OF PORT AU PORT PENINSULA

By Helgi Johnson[1]

INTRODUCTION

GENERAL STATEMENT

Occurrences of strontium in western Newfoundland were studied by the writer during the latter part of the summer of 1943. Mr. John J. Ronan, a field officer of the Geological Survey of Newfoundland, had spent part of the previous season studying these same deposits. He had supervised the drilling of ten diamond drill-holes on the most promising showings near the village of Boswarlos, and had progressed far toward completing a geological study of the area at the time of his untimely death in October 1942. His field notes and all his detailed plans were lost with him when the *S.S. Caribou* was sunk by enemy action in the Gulf of St. Lawrence. He left only a short summary of his investigation, which has been used in the preparation of this report.

LOCATION AND ACCESSIBILITY

The known deposits of strontium minerals in western Newfoundland are in the eastern part of Port au Port Peninsula near the village of Aguathuna and the small settlement of Boswarlos (*See* Figures 1 and 2). The largest of these is approximately 3,000 feet southwest of the church at Boswarlos; a second is at Gillams Cove, about ¾ mile west of Aguathuna; a much smaller lens is exposed in a gully a few hundred yards west of Gillams Cove; and a slightly mineralized zone occurs in the sea cliff about 200 feet beyond the last mentioned. In addition to these occurrences, indications of strontium mineralization may be seen in three gullies in the limestone quarry at Aguathuna.

The mineral-bearing areas are located at or near tide-water on East Bay of Port au Port Bay. They are about 22 miles by road from Stephenville Crossing, the nearest point on the Canadian National Railways from which it may be reached by motor road. Shipment by sea from Boswarlos would necessitate the use of barges and trans-shipment to a vessel anchored in the roadstead, inasmuch as the sea is shallow close to shore.

Fresh water for processing, washing, and ore dressing may be obtained from small brooks adjacent to the properties. The construction of small dams would probably provide a constant water flow through a 4-inch pipeline with a head of 10 to 20 feet.

Electric power is generated at a hydro-electric plant on Flat Bay Brook, some 28 miles south of east from Boswarlos, and transmission lines at present extend to Aguathuna, 2½ miles from the larger strontium deposits.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the able field assistance of Arthur S. Hawley, who helped with the work during the initial stages of the study. Mr. J. Tuff and the government diamond drill operators co-operated in

[1]Professor of Geology and Director Bureau of Mineral Research, Rutgers University, New Brunswick, N.I.

making the drilling program successful. Mr. B. Robinson, a government prospector, was assigned to the task of traversing the small brooks, and through his conscientious work resulted the discovery of one small mineralized area that had not been previously known. The writer expresses his sincere thanks to Mr. Arthur House, manager of the Dominion Steel and Coal Corporation at Aguathuna, for the help and encouragement that he

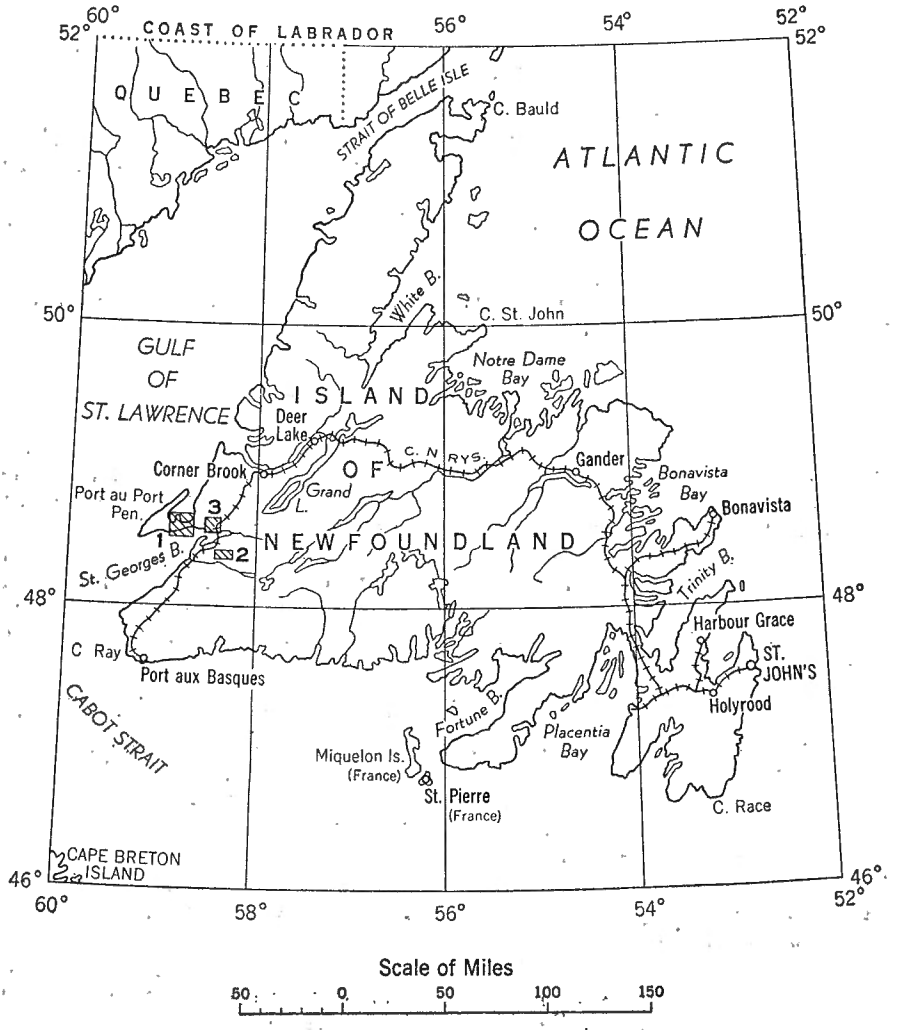

Figure 1. Outline map of Newfoundland showing localities referred to in this report: 1, area of strontium occurrences on Port au Port Peninsula; 2, Sheep Brook-Lookout area; 3, Indian Head area.

gave to the project, and for providing accommodation for the members of the field party in the company staff house for the greater part of the season. Finally, deep appreciation is expressed to the many residents of the Port au Port area who on all occasions were ready and willing to expedite the work.

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GENERAL NOTES ON STRONTIUM MINERALS

GENERAL OCCURRENCE

Minerals bearing strontium and barium are frequently found in close association with one another. The occurrence of strontium in western Newfoundland is no exception to this rule, because celestite (strontium sulphate) and barite (barium sulphate) are about equal in the three known lenticular orebodies.

Although strontium and barium minerals are widely distributed as minor constituents of rocks, deposits in which these two elements are sufficiently concentrated to be of economic interest are rare. This is particularly true of strontium, whose only economic minerals are celestite and strontianite. Hitherto most of the world's supply has been obtained from two districts of England. The English ore is a fairly high-grade celestite, averaging more than 90 per cent strontium sulphate, and occurs in lenticular to irregular massive orebodies that lie within the upper part of the Triassic marls of Gloucestershire and Somersetshire.

Germany is the second largest producer of strontium, but during recent years[1] production has declined steadily, from an output of several thousand tons prior to 1900 to an amount fluctuating from 73 tons in 1932 to 300 tons in 1938. The ore is strontianite, and is found as shallow vein-filling in the upper Cretaceous marls and limestones of Westphalia, Prussia.

[1]It should be noted that this report was written in 1943.—*Ed.*

In Sicily, small veins of very pure celestite have been worked sporadically, but output has depended on unusually high prices or actual shortage during time of war.

In 1943, Mexico became the chief source of strontium for the North American market, the source being small but evidently very high-grade deposits of celestite. No detailed information as to reserves is available at time of writing but it is understood that the mineral localities are fairly far removed from transportation and that probably the mines cannot be operated profitably in peace time. Minor deposits of strontium minerals are known in the United States of America, Canada, U.S.S.R., France, India, and Tunisia. Some of these are of considerable extent and some have produced limited quantities of ore. With the possible exception of deposits in the U.S.S.R., where information pertaining to mineral reserves is not made available, these occurrences are of such low grade, such small size, or are located so far from the chief markets, that economic recovery has not proved successful except in time of emergency.

WORLD PRODUCTION OF STRONTIUM MINERALS

Strontianite was first mined in Germany as early as 1840, but production was small until the discovery of the 'Strontia or Scheibler' process in desaccharization of beet sugar concentrates in 1870. The annual output then rose sharply until 1884, at which time English celestite came on the market. Because of lower mining costs the latter mineral soon displaced the German ore even on the German market, and there has been a steady decline in the production of German strontianite since that time. Up to the beginning of World War II, Germany had produced a total of about 85,000 metric tons of ore. England's production of celestite for about the same period exceeded 500,000 long tons. Other countries have produced only minor amounts of strontium minerals, and a conservative estimate of world production to 1943 is probably in the neighbourhood of 750,000 long tons.

PRICES OF STRONTIUM MINERALS

Finely powdered celestite containing 90 per cent strontium sulphate was quoted in 1940 in the United States of America at $37 a ton. In 1941, specifications were increased to 92 per cent strontium sulphate and prices advanced to $45 a ton laid down at Atlantic seaports. Powdered carbonate was quoted at $55 a ton in 1941. The average price of lump ore of English celestite f.o.b. Bristol docks was about $12 a ton, but by 1941 the price had advanced to $13 a short ton[1].

USES OF STRONTIUM

In this report it is neither possible nor desirable to discuss in detail the many uses for the element strontium in modern industry. To emphasize its relative importance, however, a short list of uses is included. Its compounds are employed in munitions for tracer bullets, tracer shells, signal flares, and star shells, as well as for pyrotechnic signals; for the 'Strontia or Scheibler' process in refining beet sugar; for fillers and brighteners in paints and lacquers, plastics, hard rubber, linoleum, and asphaltic compounds as well as for brighteners in phonograph records; as

[1]In 1952, prices for strontium sulphate were between $55 and $66 a ton, 90 per cent pure.—*Ed.*

cleansing and fluxing agents in steel melting where ore is high in sulphur and phosphorus; and in the chemical, pharmaceutical, and ceramic industries. Metallic strontium has recently found new application in certain alloying processes where it is combined with copper, tin, and lead to produce special purpose hard alloys of those metals. The crude ore has also been used as a substitute for barite in making lithopone and as a weighting agent in fluids for deep-well drilling.

GENERAL GEOLOGY

PREVIOUS WORK

Interest in the geology of Port au Port Peninsula began soon after the founding of the Geological Survey of Newfoundland. Early reports by Alexander Murray and James P. Howley (8)[1] describe some of the rock formations, the structure, and the occurrence of economic minerals. The Carboniferous sequences received particular attention because of their coal and gypsum beds. Howley (6) later noted the occurrence of barite but gave no description of the deposit. More recently, Professors Charles Schuchert and Carl O. Dunbar (10) studied the stratigraphy and palæontology of the peninsula. In 1937 Professor Albert O. Hayes and the writer (5) visited the localities where barium and strontium had been found; a short description of the mineral occurrences was published but the strontium mineral present in the deposits at Boswarlos was reported incorrectly as strontianite.

A geological study of the entire peninsula was commenced in 1937 by J. Wentworth Sullivan, for the Geological Survey of Newfoundland (14). The manuscript and maps were made available to the writer for the present investigation. Sullivan mentions barite as a mineral of economic interest, but makes no reference to strontium minerals. Mr. John J. Ronan (9) commenced a detailed examination of strontium occurrences in 1942, but it was terminated by his untimely death late in the same year.

PHYSIOGRAPHY

Port au Port Peninsula is an eroded highland remnant of monoclinally folded and faulted Palæozoic strata (Figure 2). These now form a prominent cuestiform ridge that has been modified by erosion along the lines of faulting and by glacial scour. The range of hills, over 25 miles in length, trends in an east-west direction, is high along its southern margin, and slopes rather gently to the northern shore of the peninsula. White Hills, in the south-central part of the peninsula, rise 900 to 1,100 feet above sea-level, and a prominent hill named Round Head, at the western end of the cuestiform ridge on the northwest side of the peninsula, rises abruptly to an elevation of more than 800 feet. Gently sloping and rolling lowlands are developed on the more easily eroded sandstones and shales of the northern side of the peninsula. The lowlands are in part covered by glacial moraine and in general are heavily wooded or swampy.

Long Point, extending from Round Head in a northeasterly direction for approximately 18 miles, forms a narrow finger-like projection of land bounding Port au Port Bay on the west. It also is a cuesta, and is underlain by steeply dipping limestones and sandstones that rise to an elevation

[1]Numbers in parentheses refer to Bibliography, page 3.

of almost 400 feet at its southwestern end. Shoal Point, extending north from the peninsula for a distance of 8 miles, divides Port au Port Bay almost equally into two embayments, called respectively East Bay and West Bay. It is thickly covered with peat and clay, and underlain by steeply dipping sandstones and shales of Palæozoic age.

The shores on the south and west coasts, as well as those along the east coast of Long Point, are bold and bounded by cliffs. In contrast, except for a few small truncated headlands, the shores of Port au Port Bay are low and shelving. Wave erosion has truncated the northwardly dipping Ordovician limestones exposed along the shore of East Bay between Port au Port and Boswarlos, and pronounced coves have been developed where softer Carboniferous shales and limestones occupy depressions in the Ordovician limestones. Earlier workers have described theses coves, and have attributed their formation to faulting of a graben type. A close examination of the coves and the stream valleys extending inland from them failed to reveal evidence of such faulting. A more likely explanation of their origin is that Carboniferous sediments were deposited in karst or solution valleys of an old erosion surface (*See* Plates I and II).

Drainage. Streams are numerous, but are small. Those that drain down the dip-slope to the north are the larger, and two of these carry sufficient water to float pulpwood and timber during the spring thaws. Those that flow southward are smaller, generally shorter, and intermittent, having cut rather deep gulches into the cuesta face. The valleys reflect the underlying rock structure and are in most cases developed along lines of faults or minor dislocations or along zones of weakness. An exception to this appears where fairly large valleys carrying small misfit streams occupy either the partly or completely exhumed solution valleys already mentioned.

STRATIGRAPHY

Sedimentary rocks ranging in age from Middle Cambrian to Mississippian underlie Port au Port Peninsula. A complete sequence is not exposed because of stratigraphic hiatuses and loss of strata due to faulting. Silurian rocks are lacking, as elsewhere on the west coast, and parts only of the Cambrian, Ordovician, Devonian, and Carboniferous systems are preserved. Three of these rock groups are represented in the mineralized area under discussion, viz., the Lower Ordovician Table Head group; the Middle or Upper Ordovician Humber Arm group; and the Mississippian Codroy group. A brief description of the lithology of each of the groups follows.

Table Head Group. The Table Head group on Port au Port Peninsula may be divided into two parts, a lower, predominantly limestone member, and an upper, predominantly shale member. The lower member, which is about 800 feet thick, comprises thick-bedded, grey to buff limestones, in part replaced by dolomite, and is generally very fossiliferous. The most characteristic fossils in these beds are large cephalopods and gastropods, although other types are to be found. The thick-bedded limestones grade upward into more thinly bedded grey and black limestones with frequent black shale partings, and higher into black and greyish green shales with intercalated beds of green glauconitic sandstone.

The thinly bedded limestones contain a rich trilobite fauna, whereas graptolites, although less common, may frequently be found in the shale, and sometimes even in the sandstone. The grey and black limestones and the shales above constitute the upper member, which is 550 to 600 feet thick. The beds are mainly or wholly Middle Ordovician, but the lower member may include Lower Ordovician strata.

In the area under discussion the Table Head group is represented only by the lowermost 250 feet of the lower thick-bedded limestone member, which crops out along the shore from Belmans Cove west of the village of Port au Port, westward to a small cove, a little over a mile west of Aguathuna. Excellent exposures of these beds may be seen in the quarry of Aguathuna, and fairly complete sections may be measured in the valleys extending inland from the shore. At Belmans Cove the resistant layers of this limestone strike southwestward and westward and form a denuded and conspicuous ridge that extends to south of Piccadilly Bay where the strike changes abruptly. The upper part of the group, though intersected by drilling, is nowhere exposed in this district and is covered by an overlap of the younger Codroy sediments.

The dips of the beds are about 20 degrees to the north, but undulations cause local variations in both the dip and strike. Faults may be present within the mineralized district, although none was observed by the writer; if so, they are covered by glacial drift, or by undisturbed Codroy beds.

Humber Arm Group. The Humber Arm group is exposed along both shores of Shoal Point and, like the Table Head beds exposed farther to the south, forms the basement upon which Codroy beds were deposited.

The rocks of the group comprise a thick clastic series of conglomera tes sandstones, and shales with intercalated beds of argillaceous and siliceous limestone, commonly broken and brecciated. Sullivan (14) measured 1,850 feet of strata in continuous section on the west shore of Shoal Point, but found neither the upper nor lower limit of the group. This section may not represent more than half of the total thickness of the group, for in the type locality in the Bay of Islands region Schuchert and Dunbar (10) reported a thickness of well over 5,000 feet.

The beds exposed on Shoal Point form one limb of an anticline whose apex is exposed near the northern tip of the point. The strata on the point apparently lack fossils, and, consequently, cannot be accurately placed within the group as a whole. It is probable that they comprise a sequence near the bottom of the group, inasmuch as Table Head strata exposed south of the interval of Carboniferous beds appear to lie conformably below them. Fossils collected from similar strata exposed on Victors Brook on the west side of West Bay have been determined as *Glossograptus ciliatus* Emmons and *Emmelezoe* sp., and their presence indicates a middle Ordovician (Normanskill) age for the lower part of the group.

Codroy Group[1]. The Codroy group is best exposed in the Carboniferous basin, which borders Bay St. George to the south of Port au Port Peninsula, where it comprises a thick series of shales, sandstones, limestones, and evaporites. Similar beds are found in scattered localities on both sides of Port au Port Peninsula, but are much thinner inasmuch as the lower members are absent and erosion has removed much of the upper beds.

[1]Several factors favour the use of the term Windsor for this group. The author's designation is here used, but without prejudice, should the Geological Survey of Canada later decide, on the basis of work inaugurated by it, to apply the name Windsor to these rocks.—*Ed.*

They rest uncomformably on the bevelled edges of the older Ordovician rocks. The largest area of Codroy beds is in a drift-covered lowland extending west from Boswarlos to Piccadilly Bay. Small isolated patches of these rocks also occur in the valleys of streams flowing northerly from the Ordovician highlands. The thickness of the beds cannot exceed 150 feet and in most places is much less.

The lithology varies considerably, but in general the oldest beds are of a basal limestone conglomerate or a sandstone. The conglomerate comprises pebbles, cobbles, and boulders of the underlying Table Head or St. George limestone in a matrix of greenish sand. Thinly bedded limestone and calcareous shale overlie the conglomerate, and these in turn grade upward into sandy shale and sandstone. In many places these shales are gypsiferous and carry such secondary minerals as pyrite and galena as well as barite and celestite, which replace parts of the calcareous members.

The following sections, which were examined in detail, are assumed to be fairly representative for the entire region, though all of the known exposures were not studied:

	Feet	Inches
Shore at Boswarlos, west of the Church		
Glacial drift	2	6
Thinly bedded, fissile, grey to greenish shales and sandy shale	10	
Arenaceous and shaly limestone	2	
Thinly bedded, platy and knobby (concretionary) limestones	4	6
Green, fissile shale		6-8
Limestone conglomerate; boulders of the Table Head limestone up to 3 feet in diameter lie in a matrix of green shale and sand. The basal conglomerate is exposed at lowest tide level	4	
Total	23+	
Diamond drill-hole No. 12, 3,000 feet southwest of Boswarlos		
Glacial drift	8	
Crystalline sulphate ore, made up mostly of celestite, but with irregular lenses of barite, and some sandy layers	29	
Limestone with celestite	1	
Celestite ore	2	6
Shale parting		2
Celestite-barite ore	6	
Thinly bedded, nodular limestone	3	
Brecciated, thinly bedded limestone	1	
Calcareous sandstone		6
Massive limestone conglomerate. Drilling stopped at this horizon	1	
Total	52	2
Gillams Cove		
Irregularly bedded, crumpled and fractured siltstone and sandy shale	29	
Celestite-barite ore (predominantly celestite) in irregular lumpy masses. To sea-level	10	
Total	39	
Cove in Aguathuna West Quarry		
Buff to cream-coloured limestone (weathering almost white); highly fossiliferous, fractured, containing barite, celestite, calcite, and sulphides	20-25	
Barite, slightly reddish to pink; in matrix of sandy shale	12-15	
Buff to dove-coloured, massive limestone (Table Head) in bottom of cove	2	
Total	34-42	

By comparing the measured sections of Port au Port Peninsula with those of the Bay St. George area (5), it is evident that sedimentation began here later than to the south as thick shale and evaporite successions beneath the limestones in the section at Codroy are almost lacking at Port au Port. Subsequent erosion has also removed much of the upper beds, leaving what are essentially only remnants in pre-Codroy topographic depressions.

Fossils are plentiful in the limestone and many species are identical with those found in the limestones of the Windsor group in Nova Scotia. An upper Mississippian age is, therefore, considered to be established.

Structurally the beds are relatively undisturbed, and this is particularly true in the basin extending westward from Boswarlos to Piccadilly Bay. Slight crenulations were noted with axes normal to the general trend of the basin. An unusual structural feature may, however, be seen in the section west of Boswarlos where fissile shales lying between competent beds of sandstone are corrugated or accordion pleated, without any visible disturbance of the sandstone beds. Deformation of a similar type has been observed in shale layers lying between limestones in the Ordovician Green Point series at Green Point, and in silty beds lying between limestones in the Mississippian of the northeast coast of Newfoundland near Conche.

The Carboniferous basin extending from Aguathuna to Piccadilly Bay has been previously described as a downfaulted block. This interpretation is based mainly on the presence of a high straight scarp of Ordovician beds to the immediate south of the lower, Carboniferous strata of the basin and on the presence of secondary minerals such as galena and pyrite, calcite, and the sulphate minerals, barite, and celestite near the supposed fault. A careful examination of Carboniferous exposures on the north side of the peninsula failed to show any proof of downfaulting of the younger beds. Instead, wherever the contact between the Carboniferous and Ordovician was observed the former was clearly depositional against steep valley walls developed on an irregular Ordovician erosion surface. This relationship may be seen in the largest valley cutting the limestone quarry at Aguathuna. Here a veneer of Codroy limestone still remains in place and clearly overlaps the irregular wall of St. George dolomite. The Codroy is almost horizontal, fills crevices and extends without folding or squeezing under overhanging shelves in the older strata. It shows no signs of having been dropped into its present position. Even more striking examples of depositional valley fill may be seen in Gillams and Belmans Coves, where miniature lateral valleys and small underground caverns are filled with horizontal limestone conglomerate, limestone, and sandy shales of Carboniferous age. In addition, a fine example of a pre-Carboniferous sea cave filled with Codroy sediment is exposed between the East and West quarries at Aguathuna (*See* Plates I and II). Here, to be sure, the younger beds are arched, broken, and highly mineralized, but they rest between unbroken parts of the roof and floor and butt against the older rock of the cavern; here also, parts of the roof have collapsed and are incorporated into the younger sediment (Plate II). Presuming that celestite has replaced calcareous beds lying in depressions on a pre-Carboniferous basement, it is important to know whether the depressions are caused by downfaulting of the later rocks, or whether they existed on the pre-Carboniferous land surface prior to deposition of the Codroy. The writer has found no evidence to support the first conclusion, and much to support the latter.

ECONOMIC GEOLOGY

GENERAL STATEMENT

Many minerals of potential economic value have been reported from the Port au Port area. With the exception of limestone, which is quarried extensively at Aguathuna, and small amounts of chromite from Bluff Head, northeast of the peninsula, none has been produced on a commercial scale. Attention was directed during the war to occurrences of celestite and barite, and these minerals are now known to be present in sufficient quantities to be of economic interest. As these two minerals occur together, the recovery of both might be feasible.

Celestite ($SrSO_4$) is commonly a light blue to white mineral, transparent in thin section but translucent when massive, having a hardness of 3 to 3·5 and specific gravity of 3·95 to 3·97. It crystallizes in the orthorhombic system in tabular to fibrous masses, frequently resembling barite with which it is associated. It contains 56·4 per cent strontium oxide when pure.

Barite ($BaSO_4$) sometimes called "heavy spar" is a heavy, white, pink, bluish, or brown, opaque or translucent mineral, having a hardness of 2·5 to 3·5 and specific gravity of 4·3 to 4·6. Its orthorhombic crystals are similar to those of celestite but are frequently united by their broader sides in crested groups and in curved or straight lamellar masses. When pure, barite contains 65·7 per cent barium oxide.

Mineralization. Irregular tabular to wedge-shaped masses of ore containing celestite, barite, aragonite, and calcite, with minor amounts of sulphides of lead and iron, are found in four or more localities within the area studied. Here the strontium and barium minerals are considered to be replacements of the calcareous and arenaceous beds of the Upper Mississippian Codroy group. Meteoric water percolating through underground channels in the relatively porous, fossiliferous, and sandy limestones carried mineralizing solutions that replaced the lime with celestite, barite, calcite, and aragonite—probably in that order. Marcasite, pyrite, and galena appear to have been introduced later under conditions that favoured replacement of the shattered limestones, for their greatest concentration is found where the beds are most disturbed. Minute veinlets of celestite and narrow gash veins filled with sulphides occasionally appear in the older Ordovician strata, but these veins are so small and their occurrence so infrequent that they may be disregarded as possible sources of ore.

DESCRIPTION OF DEPOSITS

Gillams Cove. Gillams Cove lies about ½ mile west of Aguathuna, in the northern end of a small brook valley. On the east wall of this valley a bench of horizontal Codroy strata is bounded on the west by the brook and on the east by a wall of Table Head limestone. The bench is approximately 40 feet high, 150 feet wide, and extends southward from the cove for a distance that may be as much as 2,000 feet (Figure 3).

The Codroy beds are buff to brown, sandy to shaly limestones that enclose irregular masses of sulphate minerals at the base of the cliff. The visible mineralized zone is approximately 10 feet thick and may extend below sea-level. It is exposed for a short distance inland along the side of

the valley, but trenching through the down-washed and slumped overburden has revealed the presence of ore for a further distance of 250 to 300 feet, and boulders of bluish celestite were found as float as much as 600 feet from the brook mouth.

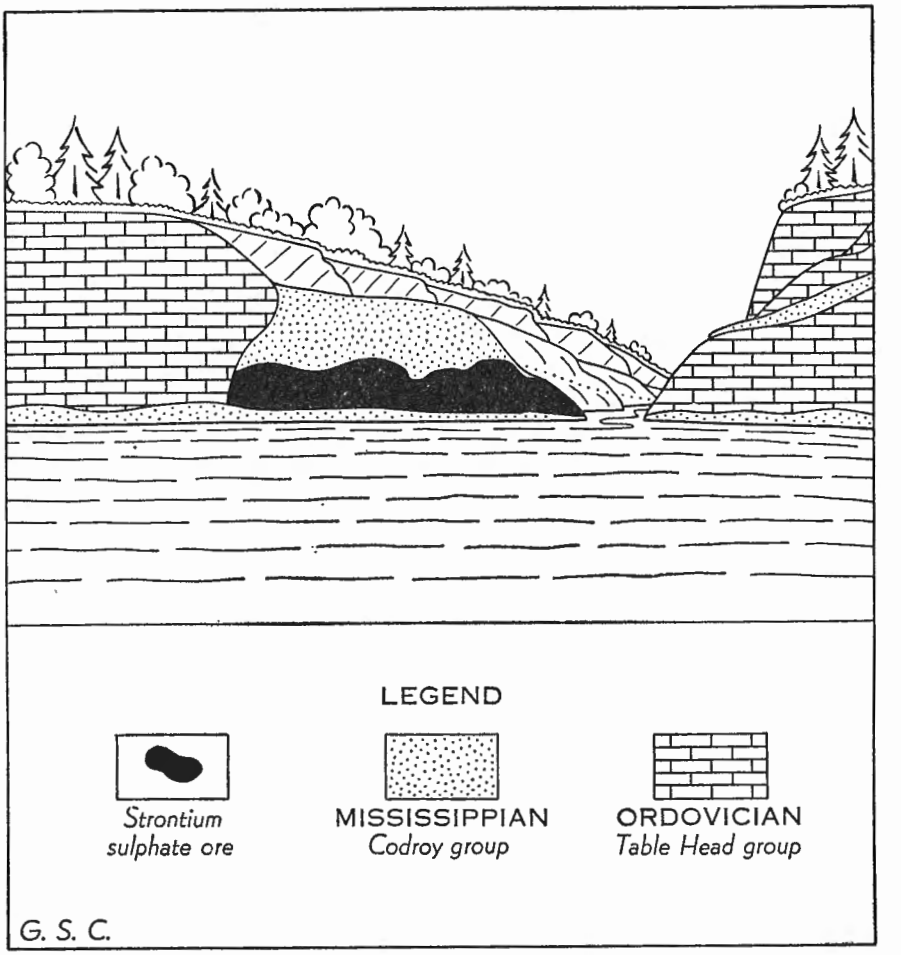

Figure 3. Sectional diagram of Gillams Cove strontium deposit.

The ore-bearing zone is a mixture of crushed and shattered sandy limestone in irregular bouldery masses together with crystalline aggregates of celestite that enclose smaller amounts of barite, calcite, and aragonite. It is estimated that 35 to 40 per cent (by volume) of the ore zone is a mixture of these minerals and that 60 to 65 per cent of the mixture is celestite. If the mineralized area continues beneath the overburden to the limit of the pre-Carboniferous valley, the minimum size of the orebody is estimated to be 150 by 250 by 5 feet; in that case it would contain at least 17,400 tons of mixed strontium and barium ore.

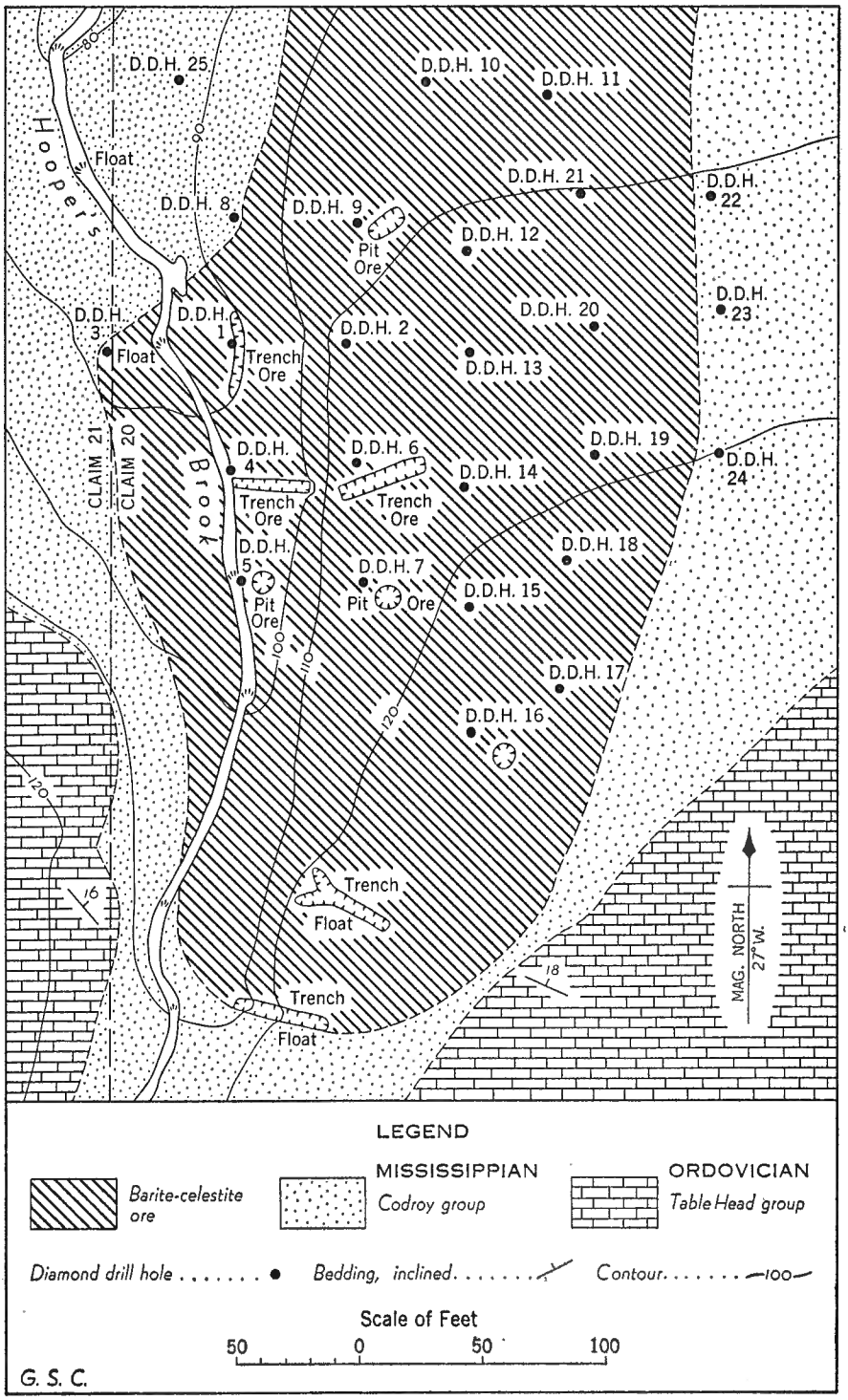

Figure 4. Plan of Ronan strontium deposit.

As yet no development work has been done at this locality. To prove the inland extension of the ore it would be necessary to trench at 20- to 30-foot intervals down the side of the bench. As the east wall of Table Head strata is well defined and the ore is not visible beyond the contact in the face of the cliff, it is deemed unnecessary to drill as trenching and stripping would prove the horizontal extent of the ore.

Ronan Deposit. The discovery of strontium minerals on Port au Port Peninsula was made on Hoopers Brook in the settlement of Boswarlos ½ mile southwest of the brook mouth. Originally referred to as the Boswarlos deposit, this name was later officially changed to Ronan deposit, in honour of the late Mr. John J. Ronan, who first examined the occurrence. The details of the occurrence, together with the locations of diamond drill-holes, are shown on Figure 4, and a diagrammatical structural view is shown on Figure 5.

Limestones of the Table Head group form a low escarpment to the south of the deposit, and their strata dip 16 to 18 degrees northward. A marshy, rolling, drift-covered lowland slopes from this limestone hill to the shore and is underlain by more than 50 feet of gently warped basal conglomerates, grey to brown, sandy and shaly limestones, and gypsum-bearing shales of Codroy age. These beds rest unconformably on the Table Head and fill irregularities and depressions in the pre-Carboniferous land surface.

The orebody, as proved by drilling, appears to be wedge-shaped; it is parallel with the bedding of the Codroy strata and is confined to a pre-Carboniferous depression that may be a buried valley. The thin edge of the wedge is almost exposed in the notch cut by Hoopers Brook through the scarp and it thickens northward to the limit of drilling. It is bounded by the partly exhumed west wall of the subterranean valley and interfingers with the unaltered Codroy beds at the limit of drilling to the east (Figure 5).

A study of the drill cores and of hand specimens taken from trenched surface exposures indicates considerable variation in the occurrences of the ore minerals. Those most commonly noted are as follows: (1) intergrowths of blue granular and radiating white platy crystals of celestite in a groundmass of aragonite and of finely intergrown celestite and aragonite; (2) large lenticles of friable, coarsely crystalline, blue celestite in a buff to brown, shattered, muddy limestone; (3) large, rounded, crystal masses of celestite, commonly in sharply defined contact with sugary, white or slightly pink, massive barite; (4) an intergrowth of finely crystallized celestite and barite; (5) celestite filling vugs and cavities in limestone; (6) veins and veinlets of celestite in thinly bedded limestone.

It is difficult to distinguish between the celestite and barite without the aid of chemical or microscopical tests, and, consequently, great care should be exercised if hand picking of the ore is to be attempted. In the limited number of samples examined microscopically, the celestite varied from blue granular masses to white platy crystals, whereas much of the barite proved to be a finely crystalline, sugary, massive to open textured, white, brown, or slightly pinkish mineral. Much of the white platy mineral that had been identified as barite in the field proved to be a variety of celestite. The gangue is composed of a mixture of the two calcic carbonates, aragonite and calcite, but the latter is uncommon. Gypsum was tentatively identified in some of the cores, and quartz and kaolin were frequently found as residues among the crystal masses.

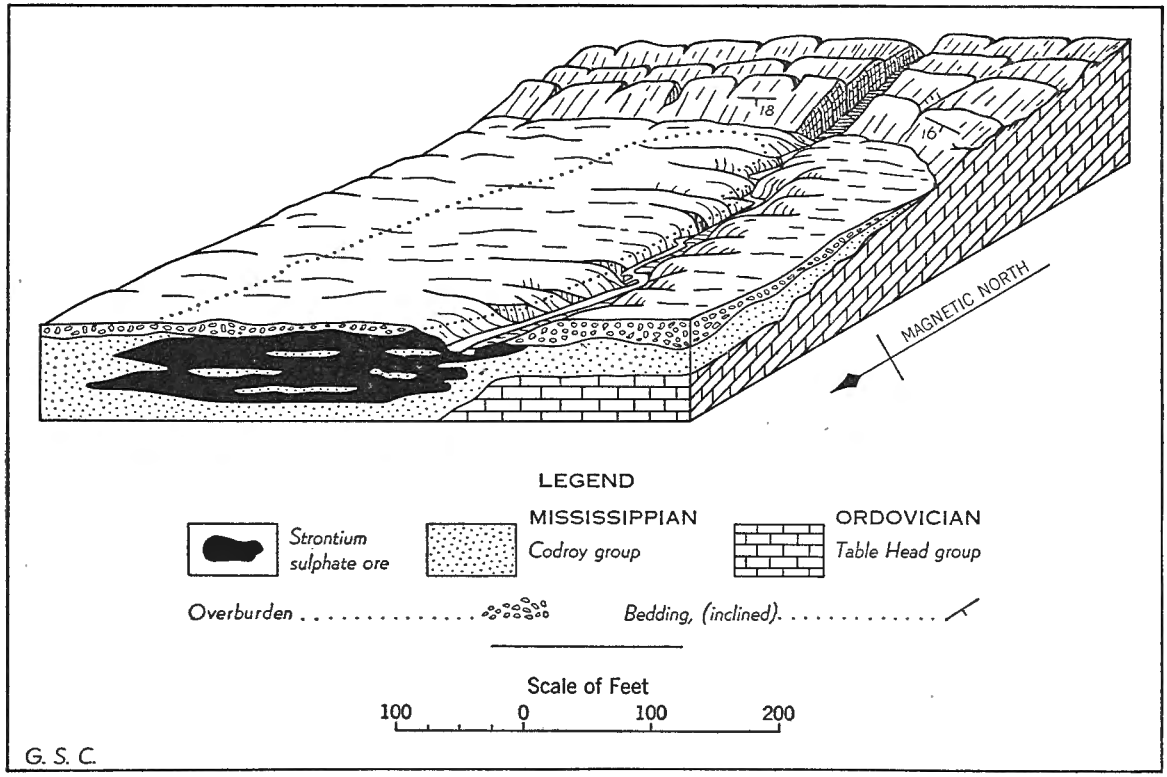

Figure 5. Block diagram of Ronan strontium deposit.

There is strong evidence that the sulphate minerals have replaced the calcareous part of the sandy limestones and that they have been deposited from ground-water solutions. There is also some evidence that indicates that two generations of such mineralization are present, inasmuch as cavity- and vug-fillings and small veinlets of celestite in cracks and joints are believed to be later than the replacements.

Some of the more obvious features that favour replacement are as follows: (1) the orebody, though irregular in shape, is roughly parallel with the sedimentary strata that enclose it; (2) in general, the orebody has boundaries that interfinger with these sediments; (3) lens-shaped masses of unreplaced limestone have been encountered at varying levels in the orebody by diamond drilling; (4) mud and sand residues having much the same composition as the impurities of the surrounding limestones are found intimately mixed with the crystalline masses.

Surface trenching and diamond drilling have proved that an area 250 by 350 feet contains ore. Of the twenty-five holes that have been drilled, ten were completed in 1942 and fifteen in 1943. They were drilled on a north-south and east-west (magnetic) co-ordinate system at approximately 50-foot centres and extended downward to the surface of the underlying, supposedly barren, Table Head limestones. The holes were not cased; standpipe was driven through the unconsolidated overburden to bedrock. Although many drilling difficulties were encountered, an adequate concept of subsurface conditions was gained (*See* Figures 4, 5, 6).

Trenches located at the southern margin of the outcrop and bore-holes Nos. 3, 8, and 25 establish the south and west boundaries of the ore. Borings Nos. 22, 23, and 24 presumably indicate the eastern limit. The north boundary of the orebody had not been reached when drilling ceased, as bore-holes Nos. 10 and 11 both yielded cores and sludges containing ore.

The mineralized zone varies in thickness from less than 1 foot in the trench at the southern boundary to more than 40 feet at the northern limit of drilling. It is known from the intervening drill-holes that the northward thickening of the ore is far from uniform; nevertheless, it is safe to assume that the average thickness of ore in the mineralized area is not less than 15 feet. As the limits of the orebody have not been reached in holes Nos. 10 and 11, it is only fair to assume that it continues in a northeasterly direction for some distance beyond the drilling.

Based on the dimensions already established by diamond drilling, this deposit should contain a minimum of 150,000 tons of mixed sulphate ores.

The sludge and cores obtained from the borings completed in 1942 have been analysed at the Newfoundland Government Laboratory, and the results of the analyses are presented in Tables I and II.

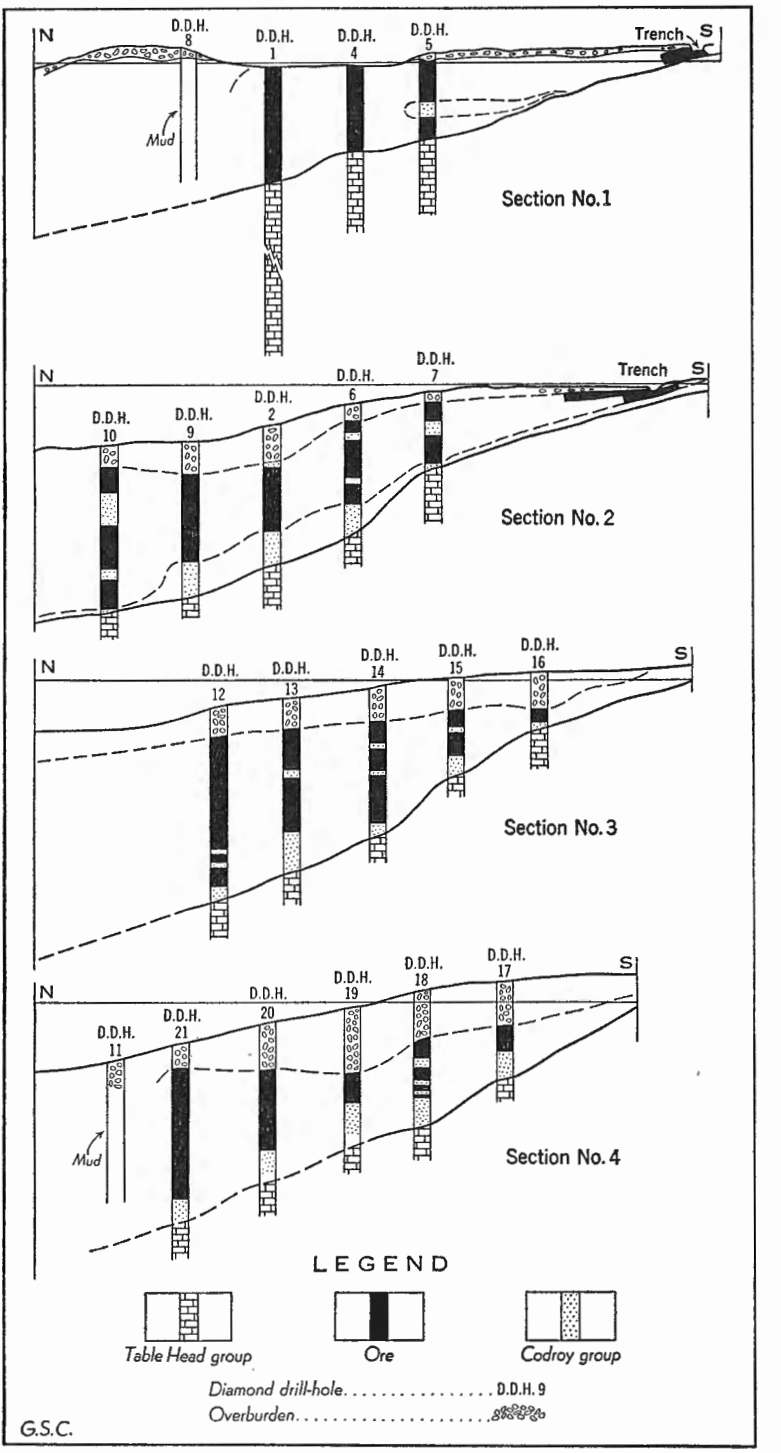

Figure 6. Longitudinal sections through Ronan deposit, showing extent of strontium ore.

Table I

Analyses of Sludges

(By the Newfoundland Government Laboratory)

Hole No.	Footage	$CaCO_3$	$SrSO_4$	$BaSO_4$
		Per cent	Per cent	Per cent
1	0–5	0·71	78·88	4·01
	5–10	1·28	74·31	3·77
	10–15	12·10	36·41	3·31
	15–20	29·26	10·52	44·38
2	10–15	29·51	1·27	39·14
	15–20	9·70	0·39	77·40
	20–25	8·67	1·20	78·17
	25–30	28·59	0·88	36·10
	30–35	2·47	1·73	40·94
	35–40	68·03	0·99	13·42
	40–45	75·92	1·63	3·18
	45–50	81·41	1·66	3·04
	50–55	47·90	1·59	6·33
	55–60	73·88	2·55	3·43
	60–65	68·60	1·59	7·00
	65–70	26·48	9·94	25·78
3	20–25	43·01	1·73	14·99
	25–30	39·47	0·19	16·19
4	0–5	28·80	0·23	59·02
	5–10	19·70	0·37	63·22
	10–15	14·11	0·19	69·42
	15–17	8·99	10·14	35·92
5	5–10	12·77	8·70	58·93
	10–15	11·13	1·02	45·69
6	5–10	10·06	13·56	8·90
	10–15	8·20	72·68	7·69
	15–20	6·60	73·49	6·52
	20–25	7·78	71·34	11·96
7	5–10	32·91	40·45	2·64
	10–15	17·77	56·84	4·62
	15–20	32·19	15·89	7·43
9	7–11	0·71	0·14	81·08
	11–16	0·21	0·17	88·24
	16–21	0·53	17·79	75·15
	21–26	16·65	0·42	69·16
10	6–11	18·63	17·05	45·66
	11–16	36·19	0·53	11·84
	16–21	21·81	0·42	7·21
	21–26	12·67	0·31	49·92
	26–31	9·06	0·42	58·27
	31–36	8·87	0·42	41·64
	36–41	18·52	0·21	45·11
	41–46	15·34	0·28	38·93

TABLE II

Analyses of Core

(By the Newfoundland Government Laboratory)

Hole No.	Footage	$CaCO_3$	$SrSO_4$	$BaSO_4$
		Per cent	Per cent	Per cent
1	13–17	10·92	33·20	2·04
	17–22	21·50	2·15	29·74
	22–27	13·10	1·70	71·89
	27–30	19·66	0·14	64·41
2	9–14	34·37	1·59	43·80
	14–19	27·41	0·21	56·71
	19–24	8·60	0·31	83·84
4	4–9	10·17	0·75	81·00
	9–14	16·04	6·97	43·85
	14–19	22·66	21·75	35·79
	19–23	15·10	2·41	73·64
5	7–12	14·81	1·27	56·61
	12–17	14·00	0·70	48·39
	17–22	14·21	0·24	68·86
6	7–12	12·54	60·33	6·94
	12–17	11·10	67·48	7·57
	17–20	14·17	54·11	6·11
	20–23	6·35	61·06	9·31
7	11–15	25·74	55·81	2·77
	15–20	14·81	43·61	7·82
9	20–25	10·38	61·59	4·41
	25–30	39·55	30·51	21·11
10	7–12	45·12	4·34	48·43
	12–17	51·90	2·55	30·87
	17–22	38·37	2·93	35·74
	22–27	14·45	2·05	87·66
	27–32	16·52	1·59	71·08
	32–37	15·56	0·21	68·21
	37–42	13·42	0·28	77·44

It is apparent from the analyses that barite is more abundant than celestite in this orebody; despite this fact there is a sufficient quantity of celestite indicated by diamond drill-holes Nos. 1, 4, 5, 6, 7, 9, and 10 to warrant development. Although analyses for the 1943 operations had not been received at time of writing a field examination of cores and sludges at the time of drilling revealed the presence of strontium in diamond drill-holes Nos. 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21. Diamond drill-holes Nos. 22, 23, and 24 did not produce cores, and little if any ore was present in the sludges that were recovered. Diamond drill-hole No. 25, drilled 100 feet west of Hoopers Brook, penetrated 19 feet of drift before striking the barren Table Head strata; it is, therefore, beyond the western margin of the orebody.

The diamond drilling has not necessarily proved the tenor of the ore adequately, because sludges were frequently lost through underground drainage and cores could not be obtained from the crystalline ore horizons because of their friable nature. This in part explains the seeming discrepancy between core and sludge analyses shown in Tables I and II.

SUMMARY AND CONCLUSIONS

Celestite and barite of potentially commercial grade occur as replacement deposits in Codroy (Upper Mississippian) calcareous beds.

The mineralized zones are associated with pre-Carboniferous topographic depressions that are thought to be solution or karst valleys; at least two such deposits, those at Gillams Cove and at Boswarlos, appear to be commercially attractive.

Mineralized zones found in the Aguathuna quarry and in the nearby coves are small, or represent only a remnant of larger deposits, not considered to be of economic value.

Other deposits may exist beneath the cover of glacial drift in the basin-shaped area between Boswarlos and Piccadilly Bay. Prospecting in this area because of this cover would of necessity be restricted to geophysical and to drilling methods. The problem presents interesting possibilities for the application of gravity and seismic geophysical techniques.

Selective marketing of the Boswarlos ore may be possible if great care is exercised in hand separation of the celestite and barite. As much of the ore is an intimate mixture of these two minerals, mechanical concentration and separation would yield a much higher percentage of marketable celestite and barite could possibly be recovered as a by-product.

THE MAGNETITE AND GYPSUM DEPOSITS OF THE SHEEP BROOK-LOOKOUT BROOK AREA

By David M. Baird

INTRODUCTION

General Statement

The magnetite deposits long known to exist east of St. Georges had never been thoroughly investigated, as earlier analyses had shown a discouragingly high content of titanium. A detailed investigation of these occurrences was undertaken by the Geological Survey of Newfoundland in 1942. The investigation had a twofold purpose; first, to obtain detailed information on the known deposits of magnetite; and second, to prospect the surrounding area for possible additional bodies of magnetite in the hope of finding ore with less titanium. Gypsum beds that occur in the western part of the investigated area were also examined.

Field work was carried out during the summer of 1942. Reconnaissance and prospecting were done by cross-country traverses during June and provided most of the general information of the region. The rest of the field season was spent on the detailed mapping of the known deposits of magnetite.

The area described in this report is mostly within the dissected plateau of the Long Range, but includes as well a narrow strip of the lowlands to the west. It lies between latitudes 48°19′ and 48°25′, and between longitudes 58°15′ and 58°27′. The area of investigation is about 42 square miles, and is shown on Figures 1 and 7.

Accessibility

The village of St. Georges, about 3 miles northwest of the area, is on the main line of the Newfoundland District of the Canadian National Railways. A road leads southeasterly from St. Georges into the map-area and follows the north side of Flat Bay Brook to the power station at the mouth of Lookout Brook. This road may generally be used by trucks and provides access to most of the area. The only permanent habitations in the area are at the power station near the mouth of Lookout Brook where maintenance workers reside with their families.

Previous Work

As early as 1873, Murray (26)[1] suggested that magnetite deposits would be found in the district. He based his prediction on the common occurrence of magnetite boulders in the rivers that flow westward from the highlands into Bay St. George. Trappers and prospectors eventually discovered several bodies of titaniferous magnetite, the two largest of which were discovered and staked by C. R. Bishop in 1888. They are both included in what is called, throughout this report, the "Bishop claim".

[1]Numbers in parentheses refer to Bibliography, page 21.

Smaller deposits were found on what are now known as the "Hayes Prospect" and the "Hudson Prospect". No detailed geological work had been done, although several geologists had visited the anorthosite and magnetite areas on short reconnaissance trips. Brunton (11) made a reconnaissance survey of the west coast of Newfoundland and his report included a brief mention of the magnetite and anorthosite.

Acknowledgments

Kind co-operation was extended the writer during the stay in St. Georges and vicinity by many in the community. Magistrate Dawson generously supplied information on local problems. Dr. A. K. Snelgrove, Newfoundland Government Geologist, offered many suggestions and supervised the work in general. Thanks are extended to Dr. H. L. Alling, of the University of Rochester, for many helpful discussions and aid in photo micrography.

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GENERAL CHARACTER OF THE REGION

Topography

The country underlain by sedimentary rocks in the western part of the area is low and gently rolling with a relief of about 200 feet. The scarp that separates the lowland from the high plateau on the east is marked by a line of cliffs and steep slopes that trends about north 20 degrees east.

On the plateau the skyline appears flat and regular from the highest points even though the elevation is about 1,000 feet. This suggests that the summit levels are part of an old peneplain, perhaps the Lawrence peneplain of Twenhofel and MacClintock (32, p. 1667).

The highest points in the area are along the eastern side, where elevations are over 1,300 feet. Cairn Mountain, 1,000 feet high, is a conspicuous landmark on the north side of the valley of Flat Bay Brook as it emerges from the plateau.

Flat Bay Brook occupies a steep-sided, east-west valley that is about ½ mile wide and from 600 to 1,000 feet below the plateau level. The river and its tributaries follow modified preglacial courses, as is indicated by the striæ and scour forms in all the valleys and the large amount of drift in the main valley. The steep-sided, U-shape of the main valley and the numerous hanging tributaries with waterfalls demonstrate that glacial deepening has been considerable.

The distribution of vegetation is typical of the southwestern part of Newfoundland, in so far as highlands are barren and valleys wooded. The valley of Flat Bay Brook is heavily grown with fir, spruce, pine, and birch. In the higher regions a growth of black spruce occurs in hollows and sheltered spots and indicates that the distribution of vegetation is dependent on shelter and foothold.

Rock exposures abound except in the areas of Carboniferous rocks and in the valley of Flat Bay Brook where glacial debris and forest litter obscure the bedrock.

Glaciation

Rounded hills, *roches moutonnées*, erratics on hilltops, U-shaped valleys with hanging tributaries, and the diversity of boulders found in the stream bottoms show that the region has been heavily glaciated. The multitude of lakes on the plateau region is characteristic of glaciated country. Some forty lakes and ponds can be seen from one prominence just north of the northern Bishop prospect. Glacial boulders as much as 15 feet in diameter occur in the beds of the streams. They vary in composition from dark green pyroxenite to granite-gneisses. Of particular interest among them are magnetite boulders as much as a foot in diameter and fragments of a bright red volcanic breccia.

In most places weathering since glacial times has removed enough of the rock surface to obliterate striæ. In a few places, however, large scratches are visible under special conditions of lighting. An example of such occurs just south of the southern Bishop prospect where the striæ are only visible in the late afternoon when the sun is low. At this locality the average direction is north 48 degrees west. Striæ, land forms, and distribution of drift all show that the last ice movement was northwestward off the plateau toward Bay St. George. Apparently, the preglacial physiography was modified rather than drastically changed by glaciation.

GENERAL GEOLOGY

General Statement

A complex of crystalline gneisses and intrusive rocks with numerous partly digested inclusions forms an elevated, partly dissected plateau that slopes gently eastward. This complex is abruptly terminated on the west by a great fault system that extends for at least 90 miles northeastwards from the southwest corner of Newfoundland and possibly extends across the island. In the map-area the rocks of the complex are anorthosite and gabbroic anorthosite with small masses of earlier gneisses and schists in the form of inclusions, together with a few small dykes and irregular masses of intrusive rocks that are younger than the anorthosite. Several dyke-like masses and irregular blobs of pegmatitic material, including some of massive pyroxene, massive feldspars, and massive magnetite occur within the anorthosite. The latter are of possible economic importance.

Rocks of Lower Carboniferous age are in fault contact with the crystalline rocks on the west. They include conglomerates of the Anguille group, succeeded by shale, siltstone, limestone, and gypsum of the Codroy[1] group.

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[1]Several factors favour the use of the term Windsor for this group. The designation of the Geological Survey of Newfoundland is here used, but without prejudice, should the Geological Survey of Canada later decide, on the basis of work inaugurated by it, to apply the name Windsor to these rocks.—*Ed.*

The accompanying table of formations shows the rock succession in the map-area, and the areal distribution of the rock types is shown on Figure 7.

TABLE OF FORMATIONS

Cenozoic	Quaternary	Recent	Stream deposits
		Pleistocene	Glacial drift
Palæozoic	Mississippian	Codroy group	Limestone, sandstone, shale, siltstone, gypsum
		Anguille group	Conglomerate
	Unconformity		
Palæozoic or earlier	Pre-Carboniferous	Intrusive rocks	Diabase
			Bostonite, rhyolite
			Pegmatite
			Anorthosite
		Intrusive contact	
		Volcanic and sedimentary rocks	Quartzite, gneiss; basic lavas or intrusions

PRE-CARBONIFEROUS SEDIMENTARY ROCKS

Quartz-mica-anorthosite hybrid rocks, quartzite, and amphibolite occurring as large inclusions in the anorthosite were interpreted by the writer as representing partly digested remnants of sedimentary rocks of pre-anorthosite age. Such rocks are uncommon north of Flat Bay Brook, but are frequently encountered south of that stream. A mass of quartzitic rock about 50 feet long outcrops on the western bank of Three Brooks about 200 feet above the lower falls. These rocks are gradational from almost pure quartzite with streaks and patches of dark minerals to a quartz-rich anorthosite. The grains of quartz, though recrystallized, are consistently small, about 2 mm. in diameter. Mica in tiny flakes, and also in books up to about 4 mm. in diameter, chlorite, and hornblende comprise the dark minerals.

Small outcrops of similar rocks occur farther up Three Brooks in a large zone at and above the upper falls. The falls apparently are in a fault plane that separates anorthosite, on the eastern side, from a quartzite-anorthosite hybrid rock that forms a prominent cliff on the western side.

North of Flat Bay Brook the largest exposure of such rocks occurs on a knoll, on the east side of Surveyor Brook, about ⅓ mile above its mouth. In general this rock is much the same as that described on Three Brooks, and is metamorphosed to rock with varying proportions of quartz and feldspar and narrow dark bands of chlorite, mica, and hornblende. Tiny folds, less than a foot from crest to crest, are visible in several places.

Anorthosite

An elliptical body of anorthosite lies east of the head of Bay St. George with its western border from 3 to 14 miles inland. It extends about 20 miles in greatest dimension from Bottom Brook to the north of the area to Fishels River south of the area. The body is approximately 12 miles across at its greatest width in the neighbourhood of Flat Bay Brook, and is approximately 175 square miles in area. The map-area crosses the middle of the body from the western almost to the eastern edge.

Four distinctive types of anorthosite, together with many gradational varieties, were recognized as follows: (1) Cairn Mountain type; (2) eastern border facies; (3) pink and brown varieties; (4) gabbroic types.

Cairn Mountain Type

Anorthosite of the Cairn Mountain type corresponds in general to that in the Adirondack region known as the Marcy type, described by Miller (24, p. 17) and Buddington (12, p. 21). It is typically light to dark grey, coarse grained, and composed of at least 90 per cent feldspar. The feldspar is usually basic andesine although some is labradorite.

Large, uncrushed crystals are as much as 7 inches long and crystals of the groundmass are from ⅛ to ¼ inch in diameter. The large crystals are usually dark grey whereas those of the groundmass are lighter coloured. Granulated plagioclase is common and may constitute from 10 to as much as 90 per cent of the rock. Granulation of the corners of the larger crystals and fractures within the crystals are commonly visible to the unaided eye. Curved cleavage faces and bent striations are common. No opalescent feldspars were observed.

Magnetite and small crystals of rhombic pyroxenes are accessory minerals in amounts usually less than 5 per cent of the rock. Microscopic inclusions are ubiquitous, but are more common in the large uncrushed crystals than in the finer grained groundmass. Some of the larger inclusions are identifiable as exsolution spots of orthoclase whereas others are thought to be magnetite, pyroxene, and spinel. The most common, however, are unidentifiable, dust-like particles.

Foliation is visible in most occurrences of this type of anorthosite. It may vary from that which is scarcely visible on close inspection to that which is obvious at a distance of 50 feet. The foliation is commonly due to an alinement of large uncrushed crystals of plagioclase, and such is beautifully shown in weathered surfaces near the fire tower on top of Cairn Mountain.

Eastern Border Facies

This facies is represented by medium- to fine-grained anorthosite composed almost entirely of white or very pale pink feldspar. The feldspar crystals are rarely more than 2 inches long and average about ⅛ to ¼ inch.

Little magnetite or pyroxene is present but rocks of this type are characterized by an abundance of dark green, chloritized inclusions that may represent altered inclusions of country rock. Crushing and granulation are not as obvious to the unaided eye as they are in rocks of the Cairn Mountain type but both are present in varying degrees.

Migmatites and injection gneisses are closely related to and continuous with anorthosites of the eastern border facies, and occur as green and white layered rocks of two types. One consists of green bands of altered mafic minerals varying from a fraction of an inch to a foot wide, between bands of injected anorthosite varying from a few inches to several feet wide. The green layers are commonly broken and strung out in a xenolithic manner but are more abundant as flattened lenses. The other type is a very finely banded injection gneiss, in which the dark minerals occur in bands a fraction of an inch thick separated by similar-sized bands of injected feldspars, the whole producing a greyish rock. This greyish injection gneiss occurs as bands in white anorthosite.

PINK AND BROWN ANORTHOSITE

Anorthosite of this type is about intermediate in appearance between that of the Cairn Mountain type and that of the gabbroic type to be described. The colour varies from light pink to dark red-brown. The groundmass of granulated feldspars is commonly lighter in colour than the larger crystals. As in the Cairn Mountain type granulated feldspar comprises from 10 to nearly 100 per cent of the rock. Rocks of this type are not as coarse grained as are those of the grey Cairn Mountain type although coarse, pegmatitic facies do occur. This type of anorthosite is common along Flat Bay Brook from Surveyor Brook to east of Lookout Brook. Magnetite in clots and masses, with or without garnet reaction rims, and accessory magnetite with minor pyroxene are characteristic of this facies.

GABBROIC TYPE

As the proportion of mafic minerals in the anorthosite increases to approximately 30 per cent, the rock becomes gabbroic in composition. This facies occurs along Flat Bay Brook and is particularly abundant south of the Bishop prospect. The essential minerals are plagioclase feldspar, pyroxene, magnetite, and, rarely, chlorite. The rock constituents commonly show some degree of parallel orientation. The pyroxenes, which sometimes have a reddish or purplish tint suggesting the presence of titanium, commonly have curved cleavage faces and may occur in irregular swarms of wedge-shaped crystals about 1 inch long. In some places they show a swirled arrangement, as if they had been stirred in a melt, as is well displayed just to the south of the southern corner of the Bishop claim. The gabbroic anorthosite commonly weathers to a crumbly, coarsely saccharoidal rock. The magnetite that in some places weathers out of the gabbroic anorthosite collects on the surface to form magnetite sand. An unusual type of gabbroic anorthosite occurs on Lookout Brook about a mile above its junction with Flat Bay Brook. The feldspars are dark red and pyroxene occurs in purplish crystals 1 inch to 4 inches long. The crystal faces of the pyroxene are commonly curved and many show multiple twinning.

MAGNETITE IN THE ANORTHOSITE

Magnetite occurs abundantly in the anorthosite as: (1) normal accessory magnetite; (2) deuteric magnetite; and (3) massive magnetite in pods and dyke-like masses. Normal accessory magnetite occurs as small subhedral masses with sharp boundaries, and as such does not constitute more than 3 per cent of the rock.

Deuteric magnetite occurs as small grains and masses that were introduced into the anorthosite during a late stage of magmatic activity. The magnetite is commonly surrounded by a halo of micas, garnet, and a fine, scaly mineral aggregate. It is usually irregular in outline and in many places appears to replace the feldspar of the anorthosite.

Pockets and lenses of titaniferous magnetite of the third class occur scattered through the anorthosite mass and some of them, of possible economic importance, are described in detail in a later section.

PEGMATITIC FACIES AND DYKES

Pegmatitic facies of the anorthosite and pegmatite dykes that are genetically related to the anorthosite occur at many places. Though small compared with the main mass of the anorthosite they are important in that they show that the original anorthosite magma was not a dry melt.

The rocks occur as pockets of very coarse crystals that grade into ordinary anorthosite. Crystals of plagioclase feldspar as much as 1 foot long, large crystals of pyroxene, and perthitic intergrowths were noted. Part of the main prominence of Skull Mountain on the south side of Flat Bay Brook opposite Hells Gulch is underlain by such a pegmatitic facies. Another small mass occurs in a south-facing cliff about 200 yards west of the middle of the northern Bishop prospect. At this latter place the crystals of feldspar appear on the surface as criss-crossing spikes 6 or 7 inches long with a few large pyroxene crystals interspersed. Several pockets of very coarse, pegmatitic anorthosite occur in the neighbourhood of the high falls on Lookout Brook.

Several dykes comprising coarsely crystalline pyroxene without feldspar were noted. One of such is about 700 feet north 20 degrees west of the northern boundary post of the Bishop claim. This mass, which is from 1 foot to 6 feet wide and approximately 50 feet long, contains individual crystals of pyroxene as much as 1 foot long, and the contact of the pyroxene with the wall-rocks is sharp. Another occurrence of the same type occurs about $\frac{3}{4}$ mile west-southwest of the northern prospect of the Bishop claim. Pockets and lenses 6 or 7 feet long and 1 foot to 2 feet wide occur commonly in the area and are particularly abundant in the region east of Hells Gulch.

Most of the dyke-like masses of pegmatitic material are later than the granulation of the main mass, as is shown by the enclosure of masses of granulated plagioclase in the large ungranulated pyroxene crystals. In other places large unbroken pyroxenes are completely surrounded by crushed feldspar. Because many of the masses trend in a north-south direction, it is thought that they were introduced after or simultaneously with the development of the regional structures.

Near known faults, large pyroxene crystals are rimmed with chlorite. It is probable that movement in these zones was accompanied by solutions that altered the borders of the pyroxene crystals. Some of these rimmed crystals occur in a small brook about 1 mile east of Hells Gulch and on the north side of Flat Bay Brook.

ORIGIN

The writer believes that the anorthosite was originally wholly or largely fluid for the following reasons: (1) inclusions of altered sedimentary rocks occur within the intrusion at several places, and their final position well removed from the borders of the mass suggests that they may have travelled considerable distances or at least that they have been completely enveloped by the anorthosite; (2) the border zones of the anorthosite show several instances of intimate injection of anorthosite into schistose rocks; (3) variations of the proportions of the dark minerals within the intrusion without any semblance of layering suggest some sort of liquid ancestry; (4) in the more gabbroic type of anorthosite crystals of pyroxene have been noted with a circular 'swirl' arrangement; granulation is not apparent and it may be assumed that movement occurred in the fluid state; (5) the occurrence of several different types of pegmatitic material in the anorthosite mass may be interpreted as indicating the former presence of mineralizing solutions; and (6) no other postulated condition satisfactorily meets all field evidence.

Nearly all theories that have been advanced to account for the origin of anorthosite agree that at some stage in their development magmatic differentiation has been important. Considerable divergence of opinion is met with, however, on the exact mechanism of differentiation and on the post-differentiation history of anorthosite.

The writer in 1943 (4) suggested an origin for anorthosite that called upon a process of differentiation, then refusion with mineralizers, and injection as a liquid. This is consistent with theories developed by Buddington (12, 13) as a result of research in the Adirondack anorthosite, and with the findings of Harrison (18) in southeastern Ontario.

Minor Intrusions

DIABASE DYKES

The anorthosite is cut in many places by dykes of common diabase that evidently represent the last stage of intrusive activity in the area. An east-west trending dyke occurs in the northern part of the northern prospect of the Bishop claim and cuts the magnetite. Fresh appearing diabase occurs in two dykes just below the lower falls on Three Brooks, about ⅓ mile above its junction with Flat Bay Brook. Several parallel diabase dykes crop out on the face of Cairn Mountain about 400 feet southeast of the forestry lookout cabin.

TRACHYTIC ROCKS

Two dyke-like masses of a fine-grained, reddish rock, approximately a trachyte in composition, occur about 800 feet above the lower falls of Three Brooks. The weathered surfaces of this rock are dark reddish brown, but the colour is much lighter on fresh surfaces. The rock comprises slender yellow needles of a much altered mineral, perhaps a rhombic pyroxene, set in a fine-grained groundmass of feldspars, mica, and pyroxene. A large amount of secondary calcite, and other alteration minerals, obscure most

of the detail of the rock in thin section. Magnetite is a common accessory mineral. The brick-red colour of the rock is apparently due to a fine dusting of hematite particles.

Two small bodies of bostonitic trachyte occur between the northern and southern magnetite prospects on the Bishop claim. The poorly exposed outcrops, in which no contacts are displayed, are covered with thin, weathered plates of light grey colour. In thin section secondary minerals completely obscure original structures and textures. If these rocks are related to the magnetites it is only in that they occur in the same general lines of movement or weakness.

Carboniferous Rocks

Adequate descriptions of rocks of Anguille and Codroy groups of Mississippian age have been published by the writer elsewhere (6, pp. 2-6), and by others, notably Bell (8) and Hayes and Johnson (17), and it is not proposed to give a detailed account of them here.

Rocks of these two groups outcrop in the banks of Sheep Brook and a tributary thereof from the north, and along Coal Brook. In both places the beds are structurally complicated by faulting, folding, and overturning near their contact with rocks of the Long Range, against which they are down-faulted.

In Sheep Brook an obscure succession of sandstone, shale, and siltstone with thin limy beds, some of which is overturned, occurs within ¾ mile of its junction with Flat Bay Brook. A massive bed of gypsum, more than 300 feet thick, is exposed and transected by Sheep Brook for about 3,000 feet parallel with and near the Long Range fault. The same gypsum bed was traced northward parallel with the Long Range front for another half mile at least and may extend farther. A thin-bedded limestone is exposed in a small south-flowing tributary brook about 2,000 feet north of its junction with Sheep Brook. This may be the Ship Cove limestone at the base of the Codroy beds. A conglomerate, thought to be the uppermost Anguille member, is exposed on Sheep Brook just below its debouchment from the Long Range. The Carboniferous rocks in Sheep Brook near the fault contact with those of the Long Range complex are mainly overturned.

Sheep Brook is one of the few places that the Long Range fault is actually exposed, with Carboniferous rocks on the west, separated by a zone of shearing, slickensides, and gouge from anorthosite of the Long Range complex on the east.

On Coal Brook Carboniferous beds are disturbed and structurally complicated, as is shown just west of the area of Figure 7. The lowermost Codroy gypsum bed is exposed on both banks of the brook, but a fault may intervene in the stream bottom. Just upstream from the gypsum are coarse conglomerates and interbedded buff and grey sandstones that are considered to be uppermost Anguille. These beds are overturned in part, if not wholly.

No other rock exposures were noted elsewhere on the Carboniferous lowland of the map-area.

MINERAL DEPOSITS

Magnetite

INTRODUCTION

Pods and lenses of magnetite of various sizes and shapes occur widely scattered throughout the anorthosite. Three of these, two of which are relatively large, are on what is known as the "Bishop claim", shown in Figures 7 and 8. These prospects are called in this report, "Bishop North", "Bishop South", and "Bishop III" respectively. Another occurrence, to the southwest of the Bishop, and near the north edge of the steep-walled valley of Flat Bay Brook is called "Hayes Prospect", and a fifth, on the south side of that valley and about 2 miles downstream from the Hayes, is called the "Hudson Prospect".

BISHOP CLAIM

Accessibility

The Bishop claim near the headwaters of Sheep Brook, as shown on Figure 7, is reached by a poorly marked trail that leaves Flat Bay Brook road at Hells Gulch Brook, approximately 10 miles from St. Georges. The trail follows Hells Gulch for ¾ mile, and then continues across country for about another mile to the southern and northern Bishop prospects.

Two possible routes for roads into the Bishop claim may be considered should the area be developed. The better route would join with the present road from St. Georges, about 1 mile east of its crossing of Dribble Brook, and from there trend eastward to a small draw just north of where Sheep Brook issues from the Long Range scarp. From there the road would join Sheep Brook Valley and follow it eastward to the claim. This route would require the construction of approximately 6 miles of new road and would make a total haulage of a little less than 9 miles to the railway or tidewater at St. Georges.

An alternate route would leave the present road along Flat Bay Brook at Hells Gulch Brook, about 10 miles from St. Georges, trend northward up the gulch to Sheep Brook tributaries then eastward to the deposits. It would involve construction of approximately 3½ miles of new road in some difficult terrain and would result in a total haulage of almost 14 miles to St. Georges.

General Geology

The country rock is mainly the gabbro type of anorthosite. It is rich in hypersthene, which occurs in thin tabular or wedge-shaped crystals that are commonly oriented parallel with the regional foliation. Magnetite, with small masses and rims of garnet, is common in small grains and irregular masses as much as 1 foot long. White weathering anorthosite notably low in mafic minerals occurs as local patches that are common adjacent to the main magnetite showings. The grain size of the anorthosite is coarser along the margins of the magnetite masses. Pockets of pyroxene crystals as much as 1 foot long, dykes of pyroxene, dykes of coarse feldspar and pyroxene, and other rock types indicative of pegmatitic action occur near the magnetite bodies. The general relationships of rock types in the Bishop claim area are shown on Figure 8.

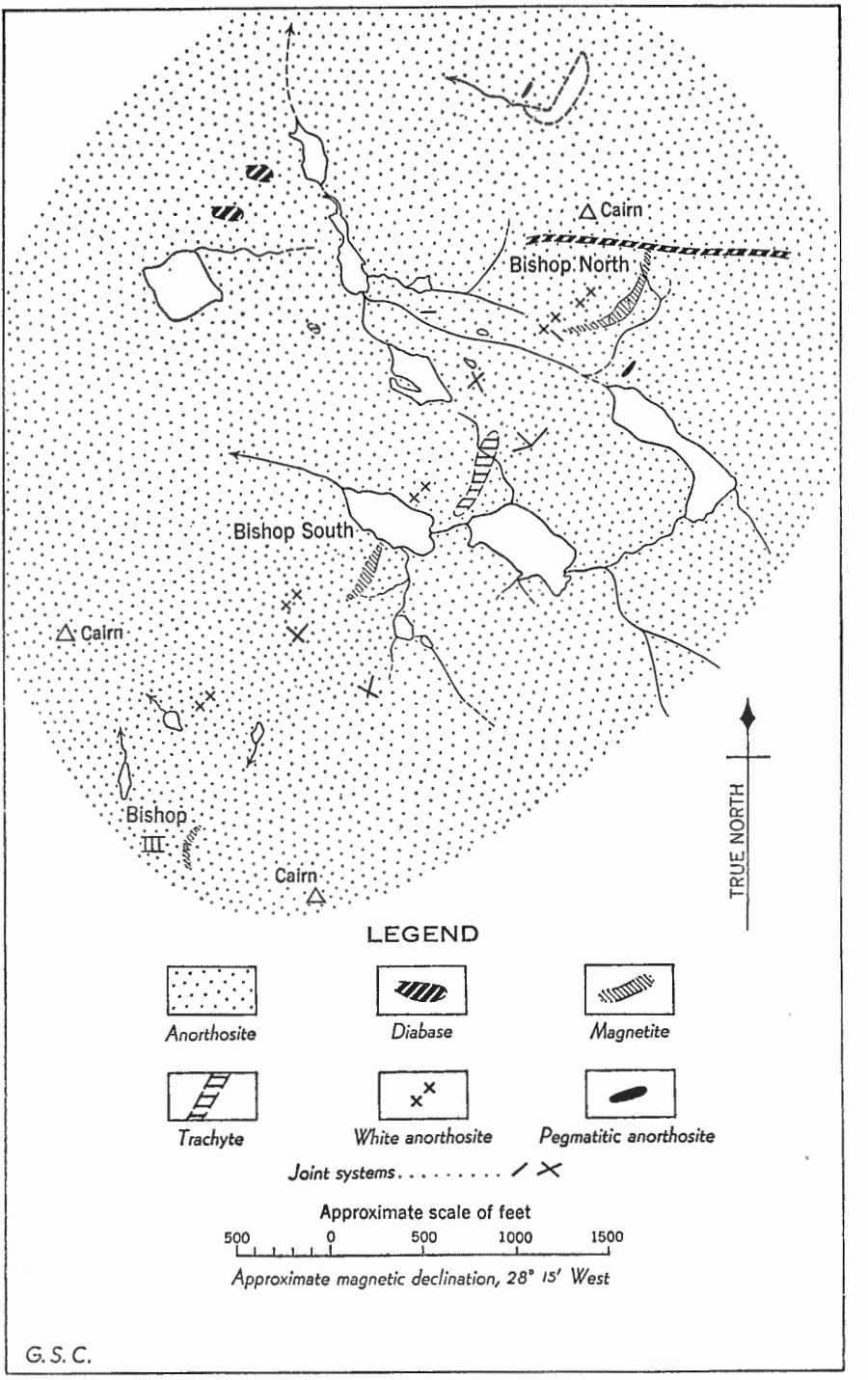

Figure 8. Geological map of Bishop claim area.

Bishop North

Figure 9 shows rock exposures and the assumed extension of map-units at the Bishop North prospect. Chunks and fragments of magnetite in a matrix of limonite-rich debris occur on the surface between the magnetite outcroppings. The contacts of the magnetite body are not well exposed, but supplementary information gathered from trenches and from results of magnetic surveys apparently indicate the presence of a lenticular mass of magnetite that trends east and northeast, and is believed to dip steeply to the west.

Geology. The contact between the magnetite and the anorthosite is generally sharp, and commonly is marked by a marginal rim of deep red garnet. The feldspar crystals in the anorthosite were noted to be generally coarser near the contacts with magnetite, and such anorthosite is generally bleached in a zone 2 to 20 feet wide that grades into normal country rock.

A diabase dyke occurs at the northern end of the ore zone, as shown on Figures 8 and 9. It has been traced by small patches of bedrock for about $\frac{3}{4}$ mile and trends nearly east with an apparent vertical dip. It cuts the magnetite body nearly at right angles, as shown on Figure 8. The rock is fresh, grey-green diabase, the colour of which is due to plentiful bright green augite and to greenish alteration products. In thin section the rock is seen to be composed of laths of plagioclase, augite, and minor biotite, and contains a considerable, but variable, amount of magnetite, which in some instances weathers out and lies on the surface as magnetite sand. The dyke is almost certainly later than the magnetite and independent of it genetically.

Dip-needle Surveys. Traverses were run in the vicinity of the orebodies on the Bishop North prospect using a Gurley dip needle and recording the vertical magnetic intensities. The results of this work are incorporated in Figure 9, in which variations in vertical magnetic intensity are shown by means of contours. As a result of this survey, some conclusions may be drawn, as follows: (1) that part of the magnetite body exposed in outcrop is probably the most important; (2) the orebody extends considerably to the north of known exposures; (3) an extent to the south is not well indicated; (4) the orebody is assumed to dip to the west, inasmuch as readings of intensity decrease slowly in that direction, and abruptly to the east; and (5) depression contours near the widest part of the orebody may indicate an involved horse of country rock.

Mineralogy. The ore is massive, coarsely crystalline magnetite, containing 1 to 2 per cent of dark green spinel. The magnetite crystals are about $\frac{3}{4}$ inch long on the average, but specimens as much as $1\frac{1}{4}$ inches are not uncommon. They display excellent octahedral cleavage. On surfaces exposed to the weather the magnetite has a bright metallic appearance but breakage reveals considerable limonite along cleavage planes and between crystals. On etched, polished surfaces of the magnetite minute plates and needles of ilmenite are visible parallel with cleavage directions. These tiny plates appear in polished section to average 1·0 mm. in length and approximately 0·04 mm. wide, and thus it would appear unlikely that any practical method of mechanical separation can be devised that would eliminate this titanium-bearing mineral from the magnetite, especially inasmuch as some residual ilmenite would remain dissolved in the magnetite (Singewald, 29).

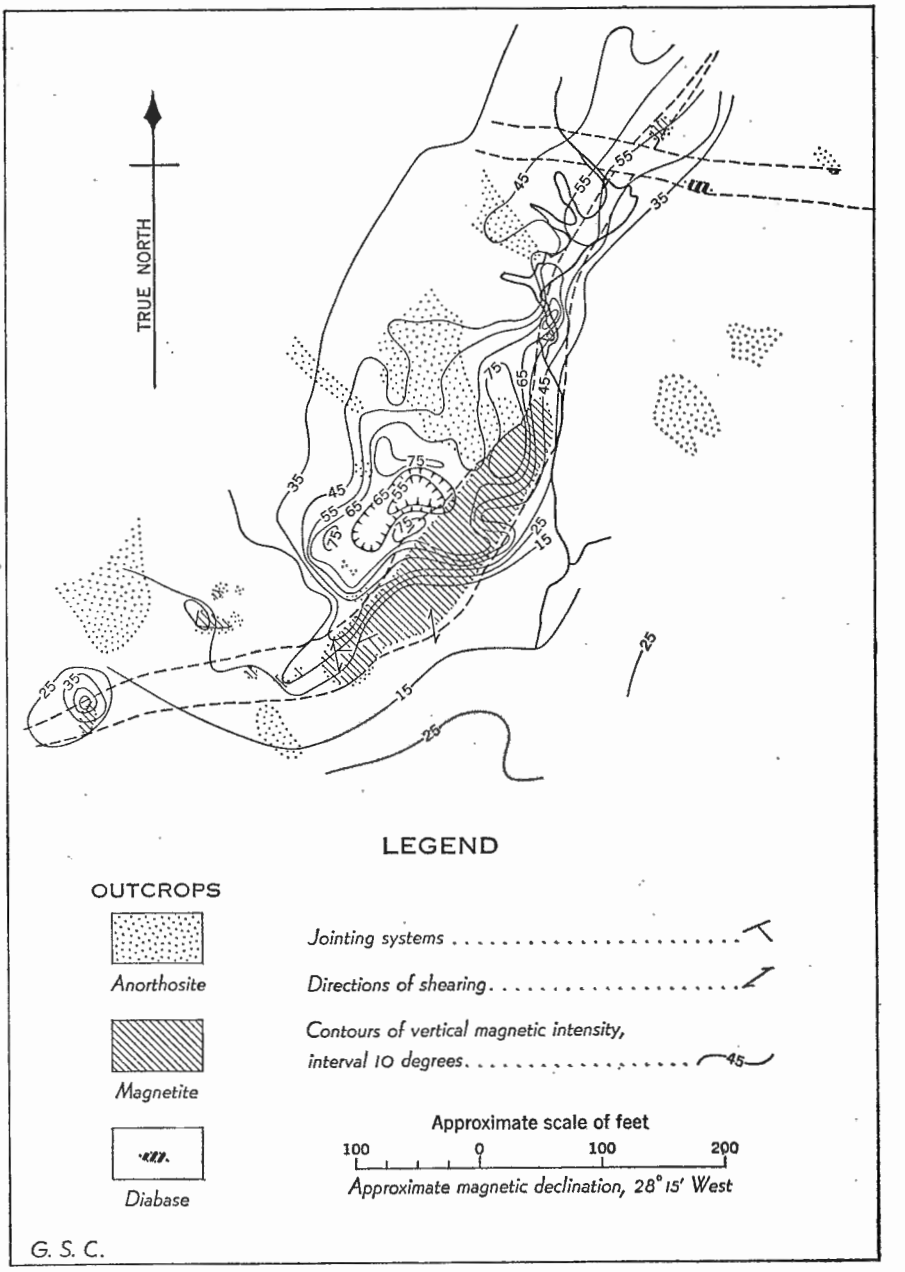

Figure 9. Map showing geology and vertical magnetic intensity of Bishop North prospect.

Green spinel occurs as irregular patches, usually less than an inch in diameter and having no definite crystal outline. Delicate, feathery growths of magnetite occur in most of these patches, and small stringers occupy cracks in others.

Vanadium, shown in the assays in very small quantities, probably occurs dissolved in the magnetite, perhaps replacing iron to produce coulsonite. Small amounts of pyrite are present. One specimen taken from rubble showed what appeared to be magnetite brecciated on a minute scale and cemented with a talc mineral.

Hand specimens of the magnetite ore show that it is composed of grains of three colours: dull black magnetite; magnetite with a decided bluish cast; and reddish or brownish magnetite.

It is believed that the variety of colours exhibited is only one of a series of ranges of physical properties resulting from a difference in composition such as the proportion of minor constituents dissolved in the magnetite.

Structure. The trend of the ore in the northern prospect conforms to that of the regional foliation, to that of the other orebodies, and to the strike of a zone of white anorthosite. The magnetite itself shows the results of strong shearing in a direction essentially parallel with the long, east-west trending, structural valley to the south of the prospect. This shearing produces a vertically dipping, sheety structure in the otherwise massive magnetite.

Individual crystals in the massive magnetite are difficult to outline, but where they are visible they seem to have interlocking relationships with their neighbours. No evidence of preferred orientation was observed on the rock surfaces.

Bishop South

Introduction. The magnetite prospect known as Bishop South occurs in a rounded hill about 2,000 feet southwest of the northern prospect, as shown on Figure 8 and in detail on Figure 10. The hill is bare or covered with low bushes except on the northern and northwestern flanks, which have a dense growth of small spruce.

The deposit is well exposed on the northern slope of the hill, where it is seen to be massive magnetite covered in part with fragments of magnetite in a limonite matrix, with a horse of coarse-grained anorthosite within the magnetite. Farther down the northern slope of the hill similar magnetite includes at least two anorthosite horses and is broken into small blocks by fracturing.

Fragments of magnetite intimately mixed with limonitic, earthy material cover most of the rest of the presumed area of the magnetite body, and some of this mixed debris suggests that the magnetite is not massive as is usual but is a mixture of feldspar and magnetite in almost equal proportions.

A westward dip for the magnetite body is postulated on evidence of the shape of the outcrop and the attitude of a small exposure of contact on the eastern flank of the body.

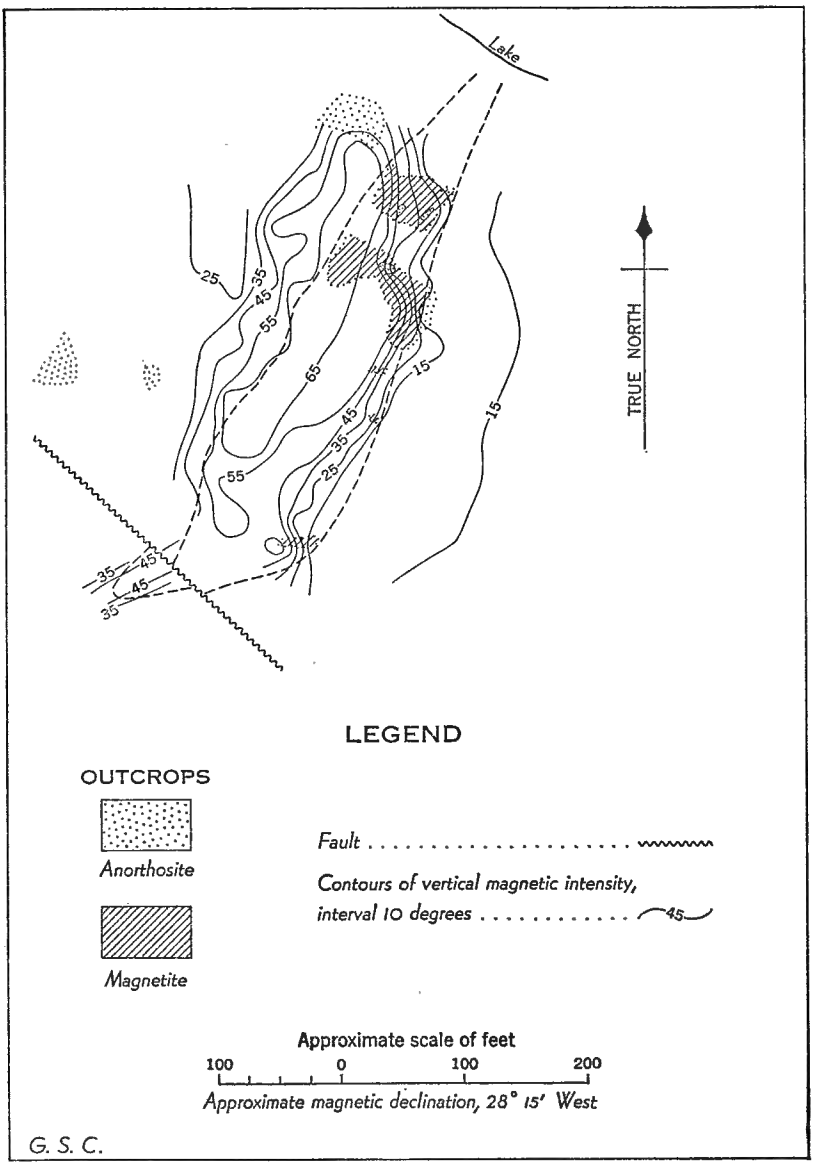

Figure 10. Map showing geology and vertical magnetic intensity of Bishop South prospect.

Dip-needle Survey. The vertical magnetic anomalies as recorded by the dip needle, and shown on Figure 10, correspond well with information secured from outcrops, and indicate, as at Bishop North, that the orebody dips to the west.

On the east of the orebody, an area of low vertical intensity is due, perhaps, to two factors: first, that the observations were made topographically below the magnetite; and second, that they are to the east of outcrop of a westward dipping orebody.

The dip-needle results show that there is probably no great extension of the orebody beyond where there are outcrop indications.

Dip-needle readings were taken along a line transverse to the strike of the ore across the sharp little gully to the south. There is only one high reading and its position seems to indicate a swing in the strike of the orebody and a rapid pinching out of the ore. There may well have been a displacement along a fault, of which the gully is a surface indication.

Across the lake to the northeast of the orebody readings were taken on a long east-west line, to determine whether or not the magnetite zone continues under the lake to reappear on its line of strike. There were no major disturbances recorded, which suggests that the magnetite ends before reaching the northern shore of the lake.

From exposures and dip-needle surveys, it would appear that the ore zone is about 400 feet long and 70 feet wide.

Lithology and Mineralogy. The wall-rock is anorthosite of the same general character as that of the northern prospect, and shows bleaching, coarsening of the feldspar crystals, and the development of some garnet rims.

The ore likewise is similar to that of the northern deposit, and is coarse-grained magnetite in which the crystals average about ½ to ¾ inch in length. Green spinel is present in much the same proportions. Magnetites of different colours are present, but the dark red-brown variety is not as common as at Bishop North. Titanium occurs as ilmenite in plates and needles along crystallographic planes in the magnetite. These minute plates of ilmenite are similar in size to those of the northern prospect.

Structure. The ore zone is a lens that trends about north 30 degrees east and dips approximately 65 degrees to the west. The emplacement of the ore was controlled by a structural line of weakness the trend of which is common to other ore deposits of the region, and of which the exact nature and mechanism is not known.

The magnetite is cut by numerous, closely spaced fractures and by more massive jointing as well. Slickensiding on some joint faces shows that movement occurred. Most of the fracturing is parallel with the Long Range fault and is, therefore, considered to have developed at a similar, post-Carboniferous, time.

Bishop III

Massive magnetite outcrops in a mound on the western side of a swampy area about 1,700 feet south 35 degrees west from the Bishop South prospect. The magnetite, about 20 feet long and 10 feet wide, is bounded on the west by light-coloured anorthosite that extends at least 100 feet farther west. Elsewhere the magnetite is bounded by swamp.

A survey with a Gurley dip needle showed vertical magnetic anomalies in a zone about 500 feet long and 30 feet wide. The results were very irregular and not uniformly high. Such results suggest that the deposit is a zone of magnetite and anorthosite with local pockets of massive magnetite such as in the one large exposure.

This deposit cannot be considered of any economic interest unless the two larger masses to the north are developed. The very small proportion of outcrop makes any estimate of reserves hazardous, but it is considered that at best the total reserves must be only a small fraction of that of Bishop North.

HAYES PROSPECT

Introduction

Magnetite occurs on the brow of a south-facing cliff about ½ mile north of Flat Bay Brook, and about half-way between Surveyor Brook and Hells Gulch. The prospect may be reached by a trail that leaves Flat Bay Brook road about ½ mile east of Surveyor Brook.

Figure 11 shows the outcrop distribution and vertical magnetic intensities in the vicinity of the prospect. Three outcrop zones delimit the deposit. The southernmost is a dyke-like mass of magnetite with a rim of partly amphibolitized pyroxene about 50 feet long that extends from the crest of a south-facing cliff northward onto the flat top of the hill. Twenty feet to the north the second zone consists of an intimate mixture of magnetite and partly altered pyroxene in a tabular, dyke-like mass. Stripping nearby displayed other masses rich in amphibolitized pyroxene. Some 280 feet to the north the third zone, which has been uncovered mostly by stripping and trenching, is a magnetite lens about 80 feet long and averaging about 6 feet wide. It is bordered on the west side by amphibolitized pyroxene rock. In addition to these occurrences, stripping has revealed a few square feet of magnetite and pyroxene about two-thirds of the way up the trail from the river road to the main prospect.

The magnetite in all these exposures is similar to that of the Bishop North prospect except that the variations in colour of the magnetite are more noticeable.

Dip-needle Survey

A survey was run with a Gurley dip needle and the results are shown on Figure 11. From study of these results it is concluded that there is little prospective ore beyond that indicated by the outcrops; that the southern and northern masses are related but not continuous; and that the 45-degree contour corresponds well with the magnetite as shown in outcrop.

A similar survey made near the small occurrence on the trail to the Hayes prospect showed no magnetic disturbance beyond the stripped area, and it appears that the deposit is not of any importance.

Wall-rock and Structure

Wall-rock characteristics of the Hayes prospect are similar to those of the Bishop claim, except for the abundance of rock rich in partly amphibolitized pyroxenes that occurs with the ore at several places. Bleaching and coarsening of the feldspars of the adjacent anorthosite are notable near the magnetite.

The magnetite bodies of the Hayes prospect were emplaced in linear lenses parallel with the foliation of the area and with the magnetite lenses of the Bishop claim, 1¼ miles to the northeast.

Prominent jointing occurs in both the magnetite and the adjoining anorthosite toward the southern end of the ore outcrop, but that of the magnetite is slightly different in direction from that of the anorthosite.

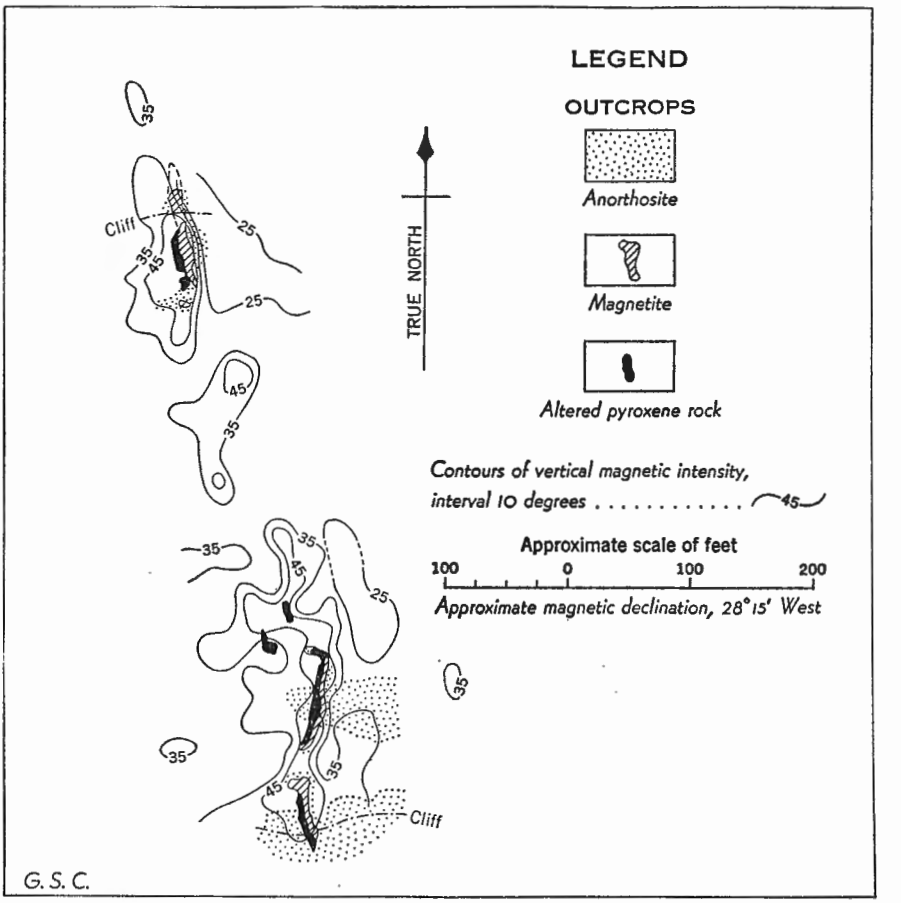

Figure 11. Map showing geology and vertical magnetic intensity of Hayes prospect.

The northern magnetite body of the Hayes prospect is also jointed, with joint faces 1 foot to 5 feet apart. In addition to joint faces, shear planes are visible in the magnetite with striated faces, and in some places the boundaries of the magnetite and anorthosite are offset slightly by such planes.

Conclusions

The magnetite of the Hayes prospect is not considered to be of economic interest. The magnetite body at best contains not much more than 10,000 tons. Its occurrence as a thin, steeply dipping body would make mining expensive, and transportation down the steep hillside to the river road would be difficult

HUDSON PROSPECT

The Hudson prospect is on the south side of Flat Bay Brook, and is best reached by following Menduwagi Brook about ¼ mile above its mouth to a right angled turn in the stream from whence a blazed trail leads directly up the steep hillside to the outcrop.

The prospect is on a heavily wooded hillside that slopes to the west. Exposed is about 400 square feet of anorthosite and 100 square feet of magnetite.

The country rock is a fine-grained grey anorthosite that shows results of granulation. The magnetite appears dark against the anorthosite, and weathers a rusty colour. The contact is sharp and does not show the usual bleaching of the anorthosite or the usual coarsening of the feldspar crystals. Small clots of biotite occur at some places along the contact.

The magnetite is a dark, metallic colour but contains bright pyrite in irregular masses, which may form as much as 20 per cent of the body. Chalcopyrite is present in small quantity and evidently was the latest mineral to be introduced. The grain size varies from very fine grained to ¾ inch in greatest dimension.

The high proportion of pyrite, and, therefore, of sulphur, makes this prospect an unlikely source of iron ore.

OTHER PROSPECTS

Several small bodies of magnetite, the largest about 8 feet long by 2 feet wide, occur in a zone of about 300 square feet on the eastern crest of Hells Gulch, about ¼ mile back from Flat Bay Brook. The contacts are sharp and show the usual coarsening and bleaching of the adjacent anorthosite, and prominent garnet rims.

A dyke-like body of magnetite, about 15 feet long by 1½ feet wide, occurs in white weathered anorthosite that is quite free from mafic minerals, about 500 yards east of Hayes prospect. The magnetite is coarse grained and garnet is developed along the edges.

ORIGIN OF THE MAGNETITE

That the magnetites were introduced after the consolidation of the anorthosite is indicated by the conformity of the bodies to the structural trends of the region, by the sharp contacts of the bodies by the wall-rock alteration, and by the absence in the magnetite of some of the structural features of the anorthosite. The obvious genetic relationship suggests that they were introduced shortly after consolidation.

The manner of introduction of the magnetite in anorthosite bodies the world over has been long discussed. The evidence in this map-area is not compatible with the theory that the magnetite was introduced as a simple melt. On the other hand, emplacement by hydrothermal means does not satisfactorily fit the evidence. The following points of evidence bear on the origin of the magnetite: (1) sharp contacts and narrow sill or dyke-like forms are characteristic of the magnetite; (2) the ore is neither foliated nor granulated and shows an intergrowth of crystals with serrate, interlocking boundaries; (3) feathery growths and crack-fillings of magnetite in green spinel of irregular outline are common. Pyrite and chalcopyrite,

both later than the magnetite, occur in several of the deposits. Rare crack-fillings of calcite are present in the magnetite of Bishop North; (4) the magnetite is very coarse grained and shows no evidence of chilled margins or other systematic variation, even in masses only 4 inches wide; (5) the genetic association of magnetite and coarse-grained, pegmatitic, amphibolitized pyroxene is evident at many places. Some of the large crystals of the latter project into the anorthosite without evidence of granulation. In several places the magnetite forms dyke-like masses of crystals that average several inches in greatest dimension; (6) the wall-rock shows marked effects of the introduction of the magnetites. Garnet rims as much as 3 inches thick are formed. A coarsening of the crystals of the anorthosite and hydrothermal alteration to a white weathering, scaly aggregate is characteristic. In some places the anorthosite shows these same hydrothermal effects without magnetite so that it was evidently a process of general distribution not necessarily accompanied by magnetite emplacement. In such wall-rock zones as those described above mafic minerals are absent or present in small quantities and rimmed with chlorite.

The writer concludes, therefore, that the magnetite was introduced by a combination of hydrothermal agents and magmatic injection, perhaps as a liquid by virtue of a heavy charge of water and other mineralizers and followed by a flood of pegmatitic and hydrothermal activity.

Assays

Assays were run by the Government Laboratory at St. John's on ore samples from the two large prospects on the Bishop claim and from Hayes. The iron content was unfortunately not properly evaluated due to the difficulty in getting part of the iron in the magnetite into solution. The assays do indicate, however, that the titanium content is variable and that it averages about 6 per cent on Bishop North and Bishop South and approximately 5 per cent on Hayes. Silica is less than 1 per cent and sulphur averages about 0·30 per cent. Vanadium was found in all samples and averaged 0·20 per cent. Phosphorus is small.

Gypsum

Gypsum is present in the area as one of the lowermost stratigraphic members of the Codroy group. These rocks occur to the west of the Long Range fault and are separated thereby from the anorthosites previously described. Gypsum exposures were noted on Sheep Brook, a northern tributary of Flat Bay Brook, and on Coal Brook, a southern tributary of the same stream.

SHEEP BROOK

Gypsum occurs in a steeply tilted bed about 300 feet thick 1 mile above the mouth of Sheep Brook. The brook cuts diagonally across the stratum and exposes the gypsum in long cliffs that are as much as 100 feet high.

The gypsum is pure white or light grey. Anhydrite is present in varying proportions in the lower zones but included carbonaceous material is uncommon. The margins of the mass show fine ribbon banding and include some limy layers. The interior of the mass is uniformly layered with only minor colour variations from zone to zone.

Bedding within the gypsum is irregular; the zone, however, strikes about north 25 degrees east and dips in general to the southeast. Cross-bedding in adjacent beds and areal distribution of formations show that the whole sequence is overturned and that tops are to the northwest. The gypsum bed does not show the intricate folding and crumpling of the laminations that are characteristic of many gypsum deposits farther south in this district, and although the gypsum is broken by a multiplicity of small slip- and shear-planes, there is no evidence of large-scale faulting.

COAL BROOK

Gypsum occurs in cliff exposures on both sides of Coal Brook about 4,500 feet above its mouth, and just within the area delimited on Figure 7.

On the north bank, limited exposures of gypsum are scattered along the steep valley side. Related sink-holes can be followed in a direction about north 40 degrees east for half a mile along the crest of a ridge. The sink-holes are rarely more than 10 feet in diameter and are closely spaced. Farther to the northeast, along this line, no further evidence of gypsum beds was encountered as far as the gypsum exposures on Sheep Creek.

The banding in the gypsum strikes north 30 to 40 degrees east and dips about 60 degrees to the southeast, in which attitude the beds are assumed to be overturned. Where visible, the gypsum is of a pure white, fine-grained type with but little included carbonaceous material. No recognizable anyhdrite is present.

Cliffs of gypsum occur at one locality on the south bank of Coal Brook and are very conspicuous. The outcrops are covered with thin flakes and chips of gypsum debris, which repose at about 45 degrees, and solid gypsum lies a few inches below this surface. The gypsum is everywhere white with scarcely any organic matter and no visible anhydrite.

The occurrence of a characteristic conglomerate of the Anguille group a short distance upstream indicates that this gypsum bed is in the basal zone of the Codroy group.

THE IRON DEPOSITS OF INDIAN HEAD AREA

By Allen V. Heyl and John J. Ronan

INTRODUCTION

GENERAL STATEMENT

The region of Indian Head, a promontory on the northeast shore of St. Georges Bay, western Newfoundland, has long been known to have occurrences of iron ore, the possible value of which had never been adequately ascertained. In 1942 the Geological Survey of Newfoundland sent two parties into the region to investigate the possibilities of these occurrences. The iron-bearing terrain, which extends inland some 10 miles from Indian Head, was divided roughly in halves, A. V. Heyl, assisted by Benjamin F. Leonard, examining the southern half of the region, and J. J. Ronan, assisted by James Vine, the northern half. Mention has been made on page 1 of this volume of Ronan's untimely death in October 1942 when the *S.S. Caribou* was torpedoed. This report is, of necessity, entirely the work of the first-mentioned author, and incorporates both his first-hand knowledge of the southern part of the area, and material gleaned from Ronan's field note-books relative to the northern part.

The field work consisted of geologically mapping an area of pre-Carboniferous rocks roughly 10 miles long by 3 miles wide, extending northeast from Indian Head on St. Georges Bay, and of prospecting both by surface methods and by geophysical surveys for hitherto unknown deposits of iron ore minerals.

The identification of many rocks in the area was made from thin sections by Professor A. F. Buddington of Princeton University, and is gratefully acknowledged; as is the assistance extended by Dr. A. K. Snelgrove, Adviser to the Geological Survey of Newfoundland; by Mr. Claude Howse, Chief Geologist, Geological Survey of Newfoundland; and by the Messrs. House of Dominion Steel and Coal Corporation Limited.

LOCATION

Indian Head is a rugged, rocky headland jutting into St. Georges Bay about 4 miles west of Stephenville Crossing on the Canadian National Railways (*See* Figure 1). From the headland, a ridge extends northeasterly some 10 miles, and is a series of rocky, forest-covered hills, bounded on the northwest and southeast by areas of low relief. Field work for this report was confined to this ridge.

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GENERAL GEOLOGY

GENERAL STATEMENT

Within the region of investigation igneous and metamorphic rocks of pre-Carboniferous age are flanked by Carboniferous sedimentary rocks and overlain by Pleistocene and Recent unconsolidated sands and gravels (*See* Figure 12). The pre-Carboniferous rocks that underlie the aforementioned ridge include anorthosite, soda granite-gneiss, norite-gneiss, pyroxenite, hornblende-plagioclase gneiss, hornblende-microperthite-granite-gneiss, microcline-biotite granite-gneiss, norite-gneiss with inclusions of biotite gneiss, and granite-pegmatite, peridotite, and doleritic basalt dykes. All of these rocks except possibly the inclusions of biotite gneiss in the norite-gneiss are considered to be of igneous origin (*See* Figure 12).

The degree of metamorphism found in these rocks is considerable although not of the most intense type. The rock suite is markedly similar to that found by Buddington in the Precambrian of the Adirondack Mountains (1, pp. 2-3)[1]. Buddington states: "At Indian Head and to the northeast is a horst of pre-Cambrian comprising anorthosite, mafic gabbro, mafic syenite, soda granite and granite. The nature of the complex rocks suggests by analogy with the Adirondacks that they may constitute the western border of the St. George's anorthosite massif (20 miles east of Indian Head). The ilmenite-magnetite gabbro of Indian Head resembles that of the Split Rock mine in the Adirondacks. The green gneiss in the Indian Head horst where the road crosses it from Stephenville . . . . is a mafic hypersthene syenite resembling Goldschmidt's mangerite and the mafic syenite of the Adirondacks". The similarity between the Indian Head rocks and those of the Long Range to the east and northeast is strongly suggestive that Indian Head is a disconnected western part of the Long Range massif.

Walthier (10) shows that to the north of the Indian Head area these metamorphic rocks may be in faulted contact with early Palæozoic beds, but in no place could he observe the contacts or the inferred faults. The unmetamorphosed Carboniferous red shales and sandstones lie unconformably as unfolded beds on the contorted and metamorphosed gneisses at Seal Cove Point on the south shore of Indian Head. The relationship proves that the Indian Head rocks are pre-Carboniferous in age. No more definite age can be shown although the marked affinities to the Long Range rocks and to those of the Adirondacks suggest that their age may be pre-Cambrian rather than Palæozoic.

In general the dark, more basic rocks are in the southwesterly and central parts of the area, and more acidic types predominate in the region surrounding Gull Pond and in the northeastern half of the area.

[1]Numbers in parentheses refer to Bibliography, page 42.

DESCRIPTION OF ROCK TYPES

Commencing with the oldest, a brief description of each of these types follows.

Hypersthene Diorite- and Norite-gneiss with Biotite Inclusions. This complex rock is formed by injection and replacement of sedimentary beds by hypersthene diorite and norite, thereby altering the former to biotite and biotite schist. Rocks of this type occur in a rough triangle near the middle of the area. Sedimentary bedding is recognizable as such in the larger inclusions of biotite schist. Such beds are between 1 inch and 2 inches thick, and, on petrologic evidence, are believed to have been thin-bedded siltstones and impure quartzites. The bands of hypersthene diorite and norite are considered to be genetically related to the granoblastic norite-gneiss that lies to the southwest.

The rock is dark grey, weathering to brown, and is mottled with dark grains of biotite and hornblende. In general, banding is prominent and displayed by alternating dark norite and light diorite. The dark bands consist mainly of small crystals of biotite, hypersthene, and labradorite, whereas the lighter ones are mainly andesine feldspar, hypersthene, and a little orthoclase. Locally, scattered grains of magnetite may be seen, and, more rarely, small garnets.

Hornblende-plagioclase Gneiss. This rock occurs as dykes and small stocks, mainly in the central and northern parts of the area. It ranges in composition from a highly altered gabbro to quartz-hornblende diorite, weathers black, is characterized by a regular banding, and, on fresh surface, is mottled with altered white to light grey feldspars and shiny black recrystallized hornblendes. Locally, small areas of basic pegmatite occur, but most of the rock is medium grained. The northernmost body, at the top of the first ridge to the north of Long Gull Pond, has concentrations of magnetite.

Granoblastic Norite-gneiss. Norite-gneiss occurs mainly in the central and southern parts of Indian Head Ridge. It forms a rim around anorthosite on the point of Indian Head, and extends northward to the south and east shores of Gull Pond.

The rock is pale olive-green, and is composed of green hypersthene (locally augite), and labradorite in varying proportions. Magnetite is rare, and was observed as scattered grains, small bunches of grains, and veinlets. The grain size varies from 1 inch near the anorthosite contact to 1 millimetre near Gull Pond. The rock was injected and replaced by anorthosite, pink soda granite-gneiss, pegmatite, and basic dykes. Much of the rock near Gull and Oxback Ponds can be described as a partly granitized and replaced norite-gneiss, the mineral grains of which are oriented into prominent gneissic platy bands, within which a well-defined lineation is commonly visible that trends north 45 degrees east and plunges from 15 to 30 degrees toward the northeast. This rock is slightly older than the anorthosite and may represent the marginal chill zone phase of the original magma from which the anorthosite was differentiated. It is one of the two rock types in the area that contain commercial magnetite deposits.

Hypersthene Pyroxenite. This rock was observed only in three small areas. The largest of these is directly southeast of Labrador Pond, the second is about 800 feet east of the Indian Head mine; and the smallest is

about ½ mile north of Gull Pond. The Labrador Pond body may have been much greater in pre-anorthosite time, as small inclusions of the rock are found throughout the younger anorthosite.

The rock is dark green to black and composed almost wholly of hypersthene. The rock is of interest in that parts of it are a low-grade magnetite ore, in which the mineral occurs as scattered grains, clots, and numerous small veins, the iron content of which may be as high as 25 per cent. The rock intrudes the norite-gneiss and is intruded by anorthosite and younger rocks.

Anorthosite. This rock forms cliffs at the tip of Indian Head and underlies the interior upland to the north and west of Labrador Pond. It is white to light grey with large, isolated crystals of mafic minerals. The grain is coarse and crystals up to 6 inches across occur. In composition it is almost wholly labradorite with minor amounts of hypersthene, hornblende, and magnetite. The rock locally displays a coarse flow-banding of relatively pure labradorite 1 foot to 3 feet thick, alternating with bands of labradorite in which are large crystals of hypersthene. Near its boundaries the rock is white and finer in grain as a result of recrystallization, crushing, and alteration.

The anorthosite occurs in a stock-like body that plunges to the northeast beneath the rim of norite-gneiss at an angle of between 15 and 30 degrees. The rock is similar to anorthosite exposed along Flat Bay Brook in the Long Range 15 miles to the southeast (*See* previous report page 25).

Pink Soda Granite-gneiss. Rocks of this type form a band ½ to 1 mile wide that extends from the southeast shore of Indian Head to the south side of Long Gull Pond.

The rock is light to deep pink in colour, has a fine-grained granitic texture, is generally low in mafic minerals, and is characterized by a strong and regular gneissic banding. In composition it is a soda granite composed mainly of oligoclase and quartz. Pyroxene and hornblende in general are rare, but are more common near contacts. Magnetite and hematite occur as minor constituents. Locally the gneiss is pegmatite or graphic granite that is composed only of quartz and feldspar with minor magnetite.

The gneiss replaces and injects hypersthene diorite- and norite-gneiss, gabbro, hornblende-plagioclase gneiss, norite-gneiss, and hypersthene pyroxenite. Much norite-gneiss near Gull and Oxback Ponds has been partly granitized by it. Most of the iron ore lenses to be described later have been found within this rock.

Granitic Gneisses. In the northern half of the area, fringing Long Gull Pond and extending north to White Sail Lake, is a large area of granite-gneiss that may be divided into three lithological types, and as such is shown on the map, Figure 13. The three classifications are microcline-biotite granite-gneiss to the immediate north of Long Gull Pond; hornblende-microperthite granite-gneiss to the south of White Sail Lake; and hornblende augen-gneiss to the south of Long Gull Pond. These rocks are younger than the pink soda granite-gneiss described above and differ from it in that they are typically granitic and have microcline as their major essential constituent. The microcline-biotite gneiss is pale pink, medium fine grained, and well banded. It resembles somewhat the pink soda granite-gneiss but differs in that much biotite and abundant

microcline are present. Epidote and chlorite are common secondary minerals. The hornblende-microperthite granite-gneiss is moderately coarse grained, even textured, shows only minor banding, and is composed of microcline, quartz, and hornblende. The hornblende augen-gneiss is salmon-pink in colour and has large phenocrysts of microcline an inch or more in diameter embedded in a groundmass of microcline, quartz, and hornblende with some biotite. The phenocrysts have been rounded and elongated due to crushing to form large eye-like masses. The rock intrudes microcline-biotite gneiss. All three of these rocks contain scattered grains of magnetite, particularly in the coarser phases, but at no place were important concentrations observed.

Granite-pegmatites. Granite-pegmatites are numerous throughout the area except in those parts underlain by anorthosite on Indian Head. Such rocks are particularly numerous within and near the borders of the body of pink soda granite-gneiss. The pegmatitic phases range in size from narrow dykelets and concentrations along gneissic planes to dykes 20 or more feet wide. Probably many if not all of these pegmatites were derived from the same magmatic source as that of the rocks they cut. Most of these pegmatites are simple in composition; quartz, plagioclase, microcline, and commonly biotite are their major constituents, and magnetite is frequently found as an accessory mineral.

In addition to these simple pegmatites, two other types were noted: magnetite-bearing pegmatites, and rare-earth bearing pegmatites. The former are common and range in composition from normal pegmatites with scattered grains of magnetite to magnetite veins with scattered grains of feldspar. It is, therefore, concluded that such pegmatitic magmas introduced and deposited most if not all of the concentrations of iron ore minerals. The second type of pegmatite was noted only at a sharp curve of the highway south of Oxback Pond. Here the rock is very coarse grained, with crystals ranging up to 8 or 10 inches across, and has a dominant graphic texture and large plates of biotite. Accessory minerals are beryl, black tourmaline, zircon, uraninite, gummite, magnetite, and an undetermined grey-black mineral, possibly tantalite. Probably none of these are in commercial quantities.

Basic Dykes. The youngest intrusions in the area are a series of basic dykes, which extend for considerable distances but are, on the average, only 8 or 10 feet wide. In composition the rocks are mainly aphanitic doleritic basalts, but at least two lamprophyres are known and one large dyke of peridotite.

These dykes generally are intruded along faults or joint planes. Most of them trend approximately north 20 degrees east and follow the planes of the principal faults. The rocks are fresh and have been observed to cut all other intrusive rocks in the district. In some places secondary movement along the fissures of intrusion has sheared and altered the dykes after their emplacement.

Carboniferous Strata. Red sandstones, shales, and conglomerates of Carboniferous age are exposed on the east side of Seal Cove, and in a very small area about 4,500 feet west of the west end of Long Gull Pond. At the first-mentioned locality, these gently dipping beds unconformably overlie pre-Carboniferous rocks. The basal beds are coarse limestone conglomerates,

on which lie an undetermined thickness of coarse- to fine-grained red sandstones and sandy shales, in which fossils of plant fragments are abundant. Very probably these latter rocks can be referred to the Upper Carboniferous Barachois Series (6). Similar Carboniferous rocks probably underlie the valleys to the west and east of Indian Head but are not exposed.

Pleistocene Glacial Deposits. Indian Head was entirely covered by Pleistocene continental glaciers. Local patches of glacial till fill the hollows and larger valleys of the ridge, and almost completely cover the lowlands to the west and east of Indian Head. South of Long Gull Pond the main glacial movement was westward across Indian Head from the high plateau of the Long Range to the east. A series of low rolling hills extending east from Noels Pond across Long Gull Pond as islands, and into Harrys Brook Valley, mark a late Pleistocene terminal moraine. This moraine marks the southernmost advance of a glacial front whose centre was in the Lewis Hills to the north.

STRUCTURAL GEOLOGY

Banding in the gneisses of the area dips at low angles. In general the gneisses have the structure of an elongated dome of which the longer axis trends to the northeast, with the anorthosite mass near its centre. The west and south sides of this dome are not exposed as they lie beneath St. Georges Bay, and thus the apparent structure is anticlinal. This visible structure is a low broad arch with shallow dipping limbs that plunges between 15 and 30 degrees to the northeast, as is shown by well-defined lineations. The central part of the structure has been broken by a complex series of radial fractures that have their vortex at the south end of Labrador Pond. In addition, a number of north trending sheared faults are probably due to compressive forces from the northwest and southeast, as are some minor northeast trending, open folds that were developed in the gneisses and are evident to the east and northeast of Long Gull Pond.

In general, the horizontal component of movement along the shear fault planes was greater than the vertical component. The fault blocks in some places moved northward and in some others southward. The vertical movement, though less than the horizontal, was still considerable, and in general the west side of a fault block was moved upward and the east side moved downward.

In the northern part of the area the deep valley of Long Gull Pond marks a line of major east trending thrust faults that dip northward at low angles. Several are exposed along the north side of Long Gull Pond, but the principal thrust fault is nowhere exposed and can only be inferred. This main thrust fault very probably underlies and follows the drift-filled valley of Long Gull Pond. Toward the east the strike of this main fault plane may bend northeastward and follow the northwest side of the valley of Harrys River. This change in the fault trend is suggested by the northeastward curve of the subsidiary thrusts in this part of the area. The displacement along this main thrust zone could not be determined, but as the rocks change abruptly across Long Gull Pond Valley the displacement must be considerable and in the order of several thousand feet, the overlying rocks having moved southward.

Fault zones may be parallel with Indian Head Ridge on the east and west sides, although no direct evidence for such zones was observed in the area. Walthier (10) has inferred such faults to the north of the mapped

area but he did not observe them. The exposed unconformable overlap of Carboniferous sediments at Seal Cove suggests that these faults, if they exist, had ceased their major movements by the time the Carboniferous beds were deposited. However, faulting may be expected along the flanks of an anticlinal dome such as that of Indian Head, which structurally resembles the Basin and Range structures of southwestern United States (4, 8).

The period of this deformational movement is not clearly defined, but it probably extended over a long range of geologic time from that of formation of the structural dome until some time after the emplacement of the basic dykes. The relieving of stress did not take place continuously but was renewed from time to time inasmuch as fault planes in places show indications of movement in more than one direction; this would indicate that the fault blocks were acted on by forces from different directions, and thus at different times.

IRON DEPOSITS

GENERAL STATEMENT

The iron deposits of the Indian Head area are mainly nearly flat-flying lenses rich in magnetite and hematite that have considerable areal extent but no great thickness. Their average thickness is about 2 feet, but it may be as much as 10 feet or as little as ½ inch. The lenses of iron ore minerals are generally conformable to the gneissic bands, but, rarely, as at the Upper Drill Brook mine, are in crosscutting relationships to the gneissosity.

The iron ore lenses have been noted mainly in rocks of two types, the norite-gneiss, and the pink soda granite-gneiss. They were emplaced near the end of the period of granite-pegmatite invasion and are considered to be genetically related to these latter rocks.

TYPES OF DEPOSITS

The iron ores are composed of magnetite (Fe_3O_4) and hematite (Fe_2O_3), which, in this area, are very similar in appearance and are often intimately associated, but may, by careful inspection, be distinguished. The magnetite is coarse grained, strongly magnetic, black in colour, with a black streak, and generally has a fresh and greasy looking surface. The hematite is coarse grained but has a more steel-grey colour; it is non-magnetic, has a dark red streak, and is duller and more dusty in appearance. The magnetite is more abundant, inasmuch as hematite is common only in the area north and northwest of Long Gull Pond and in the immediate vicinity of the Hawk's Nest Ore east of the Indian Head mine. The hematite bodies are generally confined to deposits within the pink soda granite-gneiss, whereas magnetite bodies are more common in the norite-gneiss; bodies of mixed mineralogy, such as that at Drill Brook, are near the contact of the two rocks.

The most abundant accessory minerals in the iron deposits are plagioclase feldspar, quartz, hypersthene, garnet, chlorite, a little apatite, and in a few places, as at the Lower Drill Brook mine, the sulphides pyrite, chalcopyrite, and molybdenite. At this mine, pyrite forms a detrimental impurity, whereas chalcopyrite and molybdenite are rare.

A less important type of iron deposit occurs associated with the hypersthene pyroxenite, in which low-grade deposits of magnetite have been observed. In one such deposit on the southeast side of Labrador Pond, titaniferous magnetite occurs throughout much of the pyroxenite. The grade of this material is, however, too low to be of present economic interest.

PREVIOUS WORK

Historical Résumé. The actual date of discovery of the iron deposits of Indian Head is not known, but it was apparently prior to 1920. The deposits were prospected by trenching and some diamond drilling about 1923 by the Reid Newfoundland Company Limited (9, p. 57). Hatch (5) described nine tabular or lenticular bodies located by the Reid Company. In 1931 a brief examination was made by the Princeton University Geological Expedition and the general geology and petrology of the area were studied. In 1939 Buddington (1) briefly studied the area in connection with an examination of the titaniferous magnetite prospects east of St. Georges. He gave a brief but clear description of the geological relationships, and notes the similarities between the rocks of Indian Head and those of the Long Range east of St. Georges. In 1941 a prospecting program was begun by Dominion Steel and Coal Corporation Limited (DOSCO) of Sydney, Nova Scotia. Some mining of iron ore was commenced by that company in 1941 and continued into 1943. The properties have been idle since then.

Geophysical Prospecting. In 1941 a number of prospects in the Indian Head area were surveyed geophysically by Professor A. E. Flynn of the Nova Scotia Technical College. Both the Hotchkiss Superdip magnetometer and the Megger instrument were used, and surveys were made of the Cliff mine, and of a larger area extending from 400 feet west of the Indian Head mine east to the Stephenville road (*See* Figure 13). The latter survey delimited several areas of high magnetic attraction, particularly in the eastern part.

In the summer of 1942 geophysical surveys were conducted by the Geological Survey of Newfoundland in six places where surface indications were considered favourable. Four of these areas were surveyed by Reuben Skinner with a Gurley dip needle, and two areas by James Vine with a Hotchkiss Superdip magnetometer. The areas are listed and indicated on Figure 13. In all of these except one some favourable results were obtained. Where the ore is known to be predominantly hematite, and, therefore, non-magnetic, no results will be obtained from a magnetometric survey.

Areas of high vertical magnetic intensity were delimited by such surveys, but as the hematite content of the ore varies in each deposit, no conclusions can be drawn from magnetic data alone as to the richness of the deposits. Such surveys should be considered, therefore, to indicate only those areas in which further prospecting by trenching or diamond drilling should be carried out.

Diamond Drilling. Core drilling was conducted in the Indian Head area by the Geological Survey of Newfoundland during 1942-43. The first ten holes, to the north and east of the two Drill Brook mines (*See* Figure 13), cut several lenses of iron ore at depths of between 28 and 100 feet, and a lens 4 feet thick at a depth of 239 feet. Details of this drilling are described in the account of the Drill Brook mines.

PROSPECTING

As the pegmatites are genetically related to the iron deposits, in prospecting for other such deposits in the area one should concentrate on regions in which pegmatites are abundant. They are generally more common within and near the borders of the pink soda granite-gneiss.

A second factor of importance is the association of the iron-bearing bodies with the zones of fracture and faulting in the region. Almost all of the major deposits are near one of the major faults or in a zone of numerous minor faults and fractures. The movement along the faults apparently took place over a long period of time, and it is probable that the fracture zones near them served as conduits of easy access for the ore-bearing solutions. Practically all of the deposits are at or near the contacts of the norite-gneiss and the pink soda granite-gneiss; where the norite-gneiss has been partly replaced by granite-gneiss; or where inclusions of norite-gneiss exist in the latter. This is true even of the orebodies at Cliff mine, for although that prospect is at a distance from the actual contact, many remnantal bands or masses of what originally were norite-gneiss still exist in, and partly replaced by, the granite-gneiss.

DESCRIPTIONS OF THE IRON LENSES

Indian Head Mine. The workings on this property consist of an east-trending open pit about 150 feet long and 25 feet wide, dug in 1941 by DOSCO on a large surface outcrop of rich iron ore. The results of this work were very disappointing as the ore was found to be only a few inches to 1½ feet thick. After a few hundred tons of ore were mined, operations were transferred to the Cliff mine.

The ore occurs as thin lenses, the largest 18 inches thick, that lie parallel with the gneissic banding in the norite-gneiss. The norite was cut by numerous thin stringers of soda granite-gneiss and granite-pegmatite, and was fractured and faulted during these injections, a process that continued until after the emplacement of the ore. These minor faults have broken and separated the magnetite lenses into many small, isolated segments, a few inches or feet apart. Originally the main ore lens, about 1 foot thick, lay parallel with the banding of the norite-gneiss and dipped northward, almost parallel with the slope of the hill, at an angle of between 15 and 30 degrees, and the other, thinner lenses also follow this general trend.

The quantity of ore exposed at the Indian Head mine is not large. A few hundreds or thousands of tons of high-grade ore might be obtained by careful shallow stripping of cap rock and soil above the main ore lens, which appears to extend for a radius of 100 to 300 feet at shallow depths from the present open pit. Probably a 1-foot thick ore band exposed in a U-shaped trench 300 feet to the west of the main pit is part of the same lens. A hill slope just to the northeast of the mine beyond the small brook valley is suggested as a site for further prospecting. Large float boulders of good ore were found here and indicate the possibility of locating a workable band of magnetite. Flynn's (1941) magnetometer survey indicated magnetic material at this place.

"500" Prospect. This project is located 500 feet southeast of the Indian Head mine where a band of ore at least 1 foot thick is partly exposed in fine norite-gneiss. The ore lens strikes north 75 degrees east and dips 30 degrees northeast. Because the true width is not exposed and the ore is of good grade, further trenching is advised.

"950" Prospect. Nine hundred and fifty feet south 60 degrees east from the Indian Head mine trenching has exposed a 1-foot thick lens of magnetite above which is a second 3-inch lens separated from the first by a few inches of rock. The lenses are in norite-gneiss and strike north 68 degrees west and dip 38 degrees northeast.

"800" Prospect. About 1,000 feet east of the Indian Head mine are two prospects 156 feet apart in large masses and small stringers of magnetite in pyroxenite. The pyroxenite is high in magnetite and is in continuous outcrop between the two pits. At the more westerly prospect the ore is exposed in the bed of a small creek and at the other the ore is exposed by trenching. An area of strong magnetic attraction was indicated by Flynn's geophysical survey of 1941 in the rock-capped area between the two prospects.

Hawk's Nest Ore. A new occurrence was discovered by members of the field party in 1942, about 300 feet southeast of the "800" prospect. A band of hematite in replaced norite-gneiss was exposed by trenching and found to range in thickness from 18 inches to 3 feet. The strike of the band is north 53 degrees west and the dip 26 degrees northeast. Large loose blocks of ore were noted about 100 feet northwest of this outcrop, and may indicate the minimum lateral extent of the hematite band.

"1800" Prospect. This prospect is in an area surveyed with a Hotchkiss Superdip magnetometer by the Geological Survey of Newfoundland in 1942 about 1,750 feet southwest of the Indian Head mine. A high magnetic attraction was noted, but prospecting exposed only small lenses of ore. As soda granite-gneiss has replaced norite-gneiss in this area, as granite-pegmatites are abundant, and as thin lenses of iron ore are numerous, it is suggested that this area should be more thoroughly prospected by either deep trenching or diamond drilling.

Stephenville Road Prospect. Several 3- to 4- inch lenses of magnetite were noted on the east bank of the Stephenville road at the southern loop of an S-turn. The lenses are parallel with the gneissic banding, strike north 35 degrees east, and dip 28 degrees northeast at the contact between norite-gneiss and soda granite-gneiss. Small test pits had been sunk on the west side of the road and some ore was found near them in 1942 by the prospectors of the Geological Survey of Newfoundland.

Cabin Brook Prospects. Several lenses of iron ore have been reported from Cabin Brook Valley south of the Stephenville road. Pits and trenches near the top of the east side of the valley, within area No. 7 on Figure 13, disclosed some magnetite as bunches and lenses in norite-gneiss. Intrusive stringers of pyroxenite are parallel with the foliation and joints in the norite. A dip-needle survey of the area revealed several zones of high magnetic attraction, the largest of which encompasses those lenses exposed at the surface. It is suggested that additional trenching and some diamond drilling might be advisable here.

Late in 1942 a promising iron ore lens was found by prospectors of the field party about 350 feet southwest of Cabin Brook bridge. This lens is reported to be extensive and several feet thick, but was not seen by the writers. About 2,000 feet southwest of the same bridge are two prospects where small lenses of iron ore were noted.

Cliff Mine. This mine comprises a large open pit about 400 feet long and 60 feet wide that is located on the slope of the hill that follows the north shore of Gull Pond, and is about 125 feet vertically above the pond. The orebody was first prospected by the Reid Newfoundland Company Limited in 1923, and was opened and operated as a mine by DOSCO in 1941 and 1942. Two parallel, nearly horizontal lenses of iron ore are exposed in a face of soda granite-gneiss, in which, locally, there are small areas of partly digested norite-gneiss. A shear fault is visible at the west end of the pit, which strikes 19 degrees east and dips 85 degrees southeast. The fault is right handed and has a greater lateral than vertical component of movement. Striæ indicate that movement was in a plane inclined 24 degrees to the horizontal. This fault cuts off any known western extension of the two iron lenses.

The two iron lenses strike east and dip between 15 and 20 degrees to the north. The lower band is about 8 feet thick and the upper ranges from between 1 foot and 3 feet in thickness. They are separated by approximately 10 feet of pink soda granite-gneiss. The lower lens pinches out about 30 feet from the terminal fault; the upper, however, has a length along the face of approximately 430 feet. The ore is a relatively pure, coarsely crystalline hematite with practically no admixed magnetite.

An adit, 28 feet in length, has been driven north into the face about 20 feet east of the west end of the open pit. The lower ore band, which is 8 feet thick at the adit portal, extends about 10 feet to a zone of mixed rock and ore. The face shows 1 foot of mixed ore and rock at the floor, above which is 4 feet 3 inches of norite-gneiss, overlain at the roof by 9 inches of mixed ore and rock. It is apparent that this lens shortly pinches out to the north.

The upper lens appears to continue northward into the hill, but as its average thickness may be less than 2 feet, it will probably not be economical to mine it much farther north in a direction of thicker overburden.

Drill-holes to the north of the face would indicate whether either band widens out again to a mineable width. There is little hope of finding the displaced parts of the lenses west of the terminal fault.

Northwest Prospect. About 1,250 feet northwest of the Cliff mine, on the north side of a small brook, is an occurrence of coarsely crystalline hematite similar to that at the Cliff mine, in two parallel flat-lying lenses in soda granite-gneiss. The lower ranges in thickness from 2 to 15 inches, and is separated by about 3 feet of rock from the upper, which is from 1 foot to 3 feet thick. The lenses are parallel with the gneissosity, and both strike north 66 degrees east and dip 18 degrees northwest. Both the rocks and the ore bands are crushed and fractured by numerous minor faults. The plane of a larger fault is visible in the stream banks to the south of the occurrence, and strikes north 30 degrees east and dips 75 degrees southeast. The ore lenses probably are cut off to the southeast by this fault.

The North Prospects. On the top of a hill 3,250 feet north 18 degrees east from the Cliff mine several small trenches expose thin lenses of hematite ore in soda granite-gneiss. None of these lenses are more than several inches in thickness and all are intensely fractured and faulted. Probably the Cliff mine fault passes through the area, and such is suggested by the magnetic contour pattern derived from the geophysical survey made here. This survey, made with the Hotchkiss Superdip magnetometer, did not indicate any marked magnetic anomalies.

Skinner Prospect. About 850 feet north 20 degrees east from the Cliff mine, a hematite lens was found by Reuben Skinner, prospector for the Geological Survey of Newfoundland during the summer of 1942. Ore occurs immediately east of the Cliff mine fault, in soda granite-gneiss. The lens is exposed for 50 feet, is from 10 to 18 inches thick, and is nearly pure hematite, as is indicated by the following grab sample assay[1].

	Per cent
Iron	70·2
Titanium	0·08
Vanadium	trace
Silica	2·37
Sulphur	0·05
Phosphorus	*nil*

The tonnage exposed is small, but the ore could be easily recovered, and there is a possibility that the lens extends farther to the east.

Mountain Ore Prospect. About 1,000 feet east of the Cliff mine, an iron ore lens is intersected by a trench 1,500 feet long, excavated by the Reid Newfoundland Company Limited in 1923. The ore is high-grade hematite, 1 foot to 2 feet thick, and is exposed in the trench about 700 feet from its southern end. The lens strikes north 55 degrees east, dips 18 degrees northeast, and is exposed for a distance of 100 feet west, and 75 feet east, of the trench. A hole drilled by the Reid Company 100 feet north of the exposure in the trench intersected the lens. An assay made at the Newfoundland Government Laboratory of a composite of grab samples taken at 15-foot intervals along the ore lens is as follows:[2]

Grab Sample, Mountain Ore

	Per cent
Iron	59·18
Titanium	0·63
Vanadium	*nil*
Silica	10·17
Sulphur	0·033
Phosphorus	0·22

This lens shows some promise.

Summit Ore. A second smaller lens of hematite in soda granite-gneiss occurs 1,000 feet up the hill from the south end of the trench just described, and about 400 feet north of the Mountain Ore lens. It is exposed for 10 feet, is from 1 foot to 1½ feet thick, and strikes north 70 degrees east with a dip of 14 degrees to the northeast. This prospect is not considered of value

[1] Analyst, E. P. Conroy, Newfoundland Government analyst, 1942.
[2] E. P. Conroy, Analyst, 1942.

as the lens pinches out a short distance to the northwest. A grab sample of this ore assayed by the Newfoundland Government Laboratory gave the following results:[1]

	Per cent
Iron	59·18
Titanium	0·46
Vanadium	*nil*
Phosphorus	0·061
Sulphur	0·034
Silica	5·89

Falls Brook Prospects. Two prospect pits were excavated by the Reid Newfoundland Company Limited on ore lenses outcropping along Falls Brook. The more western prospect is about 500 feet upstream from where the brook crosses the Cliff mine road. At the top of a small falls over soda granite-gneiss are several small lenses of hematite that range from 2 inches to 1 foot thick, and strike north 55 degrees west with a dip of 25 degrees to the northeast. Two 3-inch bands of hematite 6 feet long were noted about 40 feet to the northeast in a cliff 20 feet high of mixed norite- and soda granite-gneiss.

Another prospect pit is 1,250 feet upstream from the road, and 45 feet north of the brook. It is 15 feet long in soda granite-gneiss, and displays several very thin bands of hematite in a 3-foot section of rock. Practically all of the ore had already been removed in the prospecting.

Lower Drill Brook Mine. An open pit mine was worked by DOSCO during the spring and summer of 1942 on the north side of Drill Brook, which joins Oxback and Gull Ponds. The open pit is in the slight depression through which Drill Brook formerly flowed, before having been diverted to the south. It is about 200 feet long in an east direction and 100 feet wide.

Ore occurred as shallow rolling lenses on both sides of the old creek bed, and apparently capped the axis of a small open anticline that pitches to the northeast at about 15 degrees. Minor flexures occur within the larger fold and the thickness of the ore lenses varied.

The ore is a mixture of magnetite and hematite with pyrite as a common accessory. Chalcopyrite (Cu,FeS) and molybdenite (MoS_2) are minor sulphide constituents. Large phenocrysts of plagioclase occur isolated in the magnetite, and in places thin rims of garnet or flakes of chlorite were observed. Ground water has caused extensive oxidation of the sulphides to form limonite with stains of copper oxide (cuprite) and copper carbonate (malachite).

Representative samples of Lower Drill Brook mine ore were assayed at the Government Laboratory in St. John's.[1]

	East Face	*West Face*
	Per cent	Per cent
Iron	64·05	60·50
Titanium	4·32	3·48
Vanadium	0·38	0·07
Sulphur	0·44	3·80
Phosphorus	*nil*	*nil*
Silica	0·47	0·47

[1] E. P. Conroy, Analyst, 1942.

Ten diamond drill-holes were bored by the Newfoundland Government to the north of both the Lower and the Upper Drill Brook mine along a line trending approximately south 70 degrees east, and are shown on Figure 13.

Condensed logs of the cores are given below, but geological details are lacking owing to Ronan's untimely death. The elevations are relative to the shore of Gull Pond, which is zero elevation.

G.S.N. Drill-hole No. 1

Collar elev.: 224 Angle of hole: 70° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	71	rock
71	80	iron ore
80	80·5	mineralized rock
80·5	82·5	iron ore
82·5	83	mineralized rock
83	142	rock

Analyses of Core (in per cent)

Depth	SiO_2	Fe	P	TiO_2
71–74	2·00	59·94	0·35	5·50
74–77	2·50	60·26	0·47	5·50
77–80	4·68	58·80	0·03	5·50
80–83	21·50	37·60	0·05	6·05

G.S.N. Drill-hole No. 2

Collar elev.: 231 Angle of hole: 75° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	69	rock
69	78	iron ore
78	78·5	mineralized rock
78·5	80·5	iron ore
80·5	81·5	mineralized rock
81·5	200	rock

Analyses of Core (in per cent)

Depth	SiO_2	Fe	P	TiO_2
69–72	4·54	60·62	0·32	6·05
72–75	2·45	63·34	0·12	5·50
75–78	4·65	57·67	0·27	6·05
78–81	29·20	30·30	0·00	2·68

G.S.N. Drill-hole No. 3[1]

Collar elev.: 249 Angle of hole: 75° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	83	rock
83	84·5	iron ore
84·5	88·5	rock
88·5	90	iron ore
90	93	rock
93	96·5	iron ore
96·5	97	rock
97	97·8	iron ore
97·8	108	rock

Analyses of Core (in per cent)

Depth	SiO_2	Fe	P	TiO_2
83–86	3·70	58·97	0·08	6·16
86–91	7·80	56·30	0·03	6·60
91–94	13·40	49·70	0·18	6·60

G.S.N. Drill-hole No. 4

Collar elev.: 224 Angle of hole: 82° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	44·5	rock
44·5	47·5	iron ore
47·5	52	mineralized rock
52	99·5	rock
99·5	102·5	iron ore
102·5	151·5	rock

Analyses of Core (in per cent)

Depth	SiO_2	Fe	P	TiO_2
44·5–46·5	7·12	58·43	0·16	7·15
99·5–102·5	7·00	55·65	0·41	5·50

[1] A comparison of the log and analyses shows that they do not closely correspond, and, therefore, one or the other may be inaccurate.

G.S.N. Drill-hole No. 5

Collar elev.: 223 Angle of hole: 72° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	28	rock
28	32	iron ore
31	36	iron ore and rock
36	86	rock

Analyses of Core (in per cent)

Depth	SiO_2	Fe	P	TiO_2
28–31	10·34	54·32	0·14	5·50
31–34	7·36	54·97	0·06	5·50

G.S.N. Drill-hole No. 6

Collar elev.: 179·5 Angle of hole: 77° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	109	rock
109	109·5	iron ore
109·5	111·5	rock
111·5	114·5	iron ore
114·5	116·5	rock and iron ore
116·5	118	mineralized rock

Analyses of Core (in per cent)

Depth	SiO_2	Fe	P	TiO_2
109–112	22·00	34·56	0·00	0·00
112–115	10·20	49·38	0·00	5·28
115–118	39·00	11·95	0·00	0·00

G.S.N. Drill-hole No. 7[1]

Collar elev.: 166 Angle of hole: 68° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	129	rock
129	129·2	iron ore
129·2	130·1	rock
130·1	137·7	rock and iron ore
137·7	150	rock

[1] No analyses were provided for holes 7, 8, 9, 10.

G.S.N. Drill-hole No. 8

Collar elev.: 305 Angle of hole: 90° Direction of hole: vertical

Depth in feet		Description
From	To	
0	130	rock
130	149	mineralized rock
149	150·3	iron ore (broken core)
150·3	153·3	iron ore and rocks
153·3	317	slightly mineralized rock

G.S.N. Drill-hole No. 9

Collar elev.: 273 Angle of hole: 74° Direction of hole: N.69°W.

Depth in feet		Description
From	To	
0	33	rock
33	35	mineralized rock
35	45	highly mineralized rock
45	45·5	iron ore
45·5	93	highly mineralized rock
93	98	rock
98	99	rock and iron ore
99	150	rock

G.S.N. Drill-hole No. 10[1]

Collar elev.: 286·3 Angle of hole: 90° Direction of hole: *nil*

Depth in feet		Description
From	To	
0	239	rock
239	243	iron ore
243	247	rock

Holes Nos. 4, 6, and 7 were drilled north of the Lower Drill Brook mine. Only holes Nos. 4 and 6 cut mineable thicknesses of ore, and as there is a 44-foot difference in elevation between the ore zones cut by these holes, this probably indicates that two separate small lenses were cut. The ore zone cut by hole No. 4 is probably that exposed in the east face of the Lower Drill Brook mine.

Upper Drill Brook Mine. A second open pit is about 300 feet east of the Lower Drill Brook mine on a rock bench 50 feet above and 100 feet north of the northwest corner of Oxback Pond.

The ore occurs in a series of three lenses that range in thickness from 6 inches to 3 feet. Several smaller lenses and crosscutting veins follow small faults or joints from the main lenses. The major lenses pinch and swell

[1] Hole not completed December 1942.

and are mostly parallel with the gneissic foliation, which is here contorted and broken by several minor faults, folds, and flexures. The general strike is north 84 degrees east and the dip ranges between 15 and 30 degrees to the north.

The country rock is fine-grained norite-gneiss with numerous small injections of granite-pegmatite. The drilling indicates that soda granite-gneiss underlies this cap of norite-gneiss and that pegmatites from it were intruded upward into the norite.

The ore is magnetite with only small local concentrations of those sulphide minerals that are common at the Lower Drill Brook mine. Large phenocrysts of plagioclase and minor quantities of garnet and chlorite are, however, associated with this ore. An analysis of a grab sample of the ore from this mine as determined by the Newfoundland Government Laboratory is given below:[1]

Analysis of Upper Drill Brook Mine Ore

	Per cent
Iron	64·40
Titanium	2·99
Vanadium	0·23
Sulphur	0·07
Phosphorus	*nil*
Silica	1·86

Drilling by the Government diamond drill, to the north and east of this mine and described earlier, was quite successful. Holes Nos. 1, 2, 3, 5, and 10 cut workable thicknesses of iron ore. Holes Nos. 8 and 9 cut wide zones of mixed magnetite and rock. Holes Nos. 1, 2, 3, 4, and 5 probably cut the same iron ore lens that is a thicker north extension of the northernmost lens in the open pit. An estimate of possible ore is permissible. The total area included between the ore face in the open pit and holes Nos. 1, 2, 3, 4, and 5, with extension towards Nos. 8 and 9, is about 48,300 square feet. This multiplied by the average thickness, which is 7·7 feet, gives 371,900 cubic feet of ore, or 57,000 tons with an average grade of 54·8 per cent iron.

The ore intersected in hole No. 10 is probably too deep to be a part of one of the main lenses. Further drilling might profitably be done on this band to establish whether a mineable orebody exists.

Several iron ore prospects were located by geophysical and surface prospecting on the narrow land between Oxback and Gull Ponds. The area was prospected with a Gurley dip needle. Seven areas of strong vertical magnetic intensity were observed, and at three of these surface prospecting revealed some magnetite.

"32" Prospect. Near the eastern corner of the southernmost cove of Gull Pond and about 50 feet above the pond is a prospect referred to as such because it lies on line No. 32 of the local magnetic survey. A strong vertical magnetic anomaly was observed, but relatively few fragments of loose magnetite were noted in the vicinity of the anomaly. A vertical left-handed shear fault trends northward through the area of anomaly, and is marked by a 25-foot wide basic dyke. Further prospecting might be of value. The rock is pink soda granite-gneiss and strikes north 46 degrees west with a dip of 17 degrees to the northeast.

[1]E. P. Conroy, Analyst, 1942.

Reid No. 1 Prospect. Two hundred feet south and a little east of the "32" ore prospect, the Reid Newfoundland Company Limited dug a prospect pit that exposes an outcrop of mixed magnetite ore and rock estimated to have an average content of 35 to 40 per cent iron. The dip-needle readings near this prospect are as high as 65 degrees, and further prospecting seems warranted.

Meuse Prospect. One hundred feet south of Reid No. 1 prospect and 180 feet east of the shore of Gull Pond are four small iron ore lenses, 1 foot to 2 feet thick, arranged *en échelon* one above the other. They occur in pink soda granite-gneiss, and both the gneiss and the ore lenses strike north 4 degrees west with a dip of 39 degrees to the southwest. A Hotchkiss Superdip magnetometer survey normal to the strike indicated that the lenses extend at least 50 feet eastward into a cliff face. Only a small, but easily mineable, tonnage of ore is indicated here. The ore is mixed magnetite and hematite.

High Knob Prospect. Three hundred and thirty feet southwest of the Meuse prospect, at the summit of a small hill, a strong vertical magnetic anomaly was observed. Trenching on the hilltop by prospectors attached to the party exposed small concentrations of iron minerals in the rock. The strong local attraction may indicate the presence of a larger deposit beneath this hill. The country rock is norite-gneiss the banding of which strikes approximately north and dips 35 degrees east. At the surface magnetite is scattered throughout the norite in veinlets and bands, which are parallel with the gneissic banding. The rock is sheared but no faulting is exposed. This prospect should be explored below the surface by drilling. It is considered to be potentially one of the most promising in the area although relatively little magnetite is exposed.

"22" Prospect. An intense local vertical magnetic anomaly about 130 by 50 feet was indicated on survey line No. 22, about 300 feet southeast of the southern cove of Gull Pond. Two bands of mixed magnetite and hematite have been exposed by prospecting within this area. The lens near the north end of the anomaly strikes about north 15 degrees west and dips 30 degrees northeast, and is in soda granite-gneiss. It is exposed for 50 feet, and is from 1 foot to 2 feet thick. Thirty-five feet to the west of this lens is a second and smaller lens of mineralization.

South Shore of Oxback Pond. Several small lenses were located by surface prospecting on the hill slope to the south of Oxback Pond, after which a magnetometer survey was made to investigate their possibilities. An area of slightly higher than normal vertical intensity was defined.

Labrador Pond Area. Two deposits of magnetite lie between the south shore of Labrador Pond and St. Georges Bay. One is on the south shore of the southeast cove of the pond. The second is about half-way between the pond and the shore of the bay.

The northern is in hypersthene pyroxenite that strikes northerly and dips 15 degrees to the east. Several small pits and trenches have been dug in the deposit. The ore is low grade, containing about 25 per cent of iron in disseminated grains, small veins, and masses. The grade is probably more or less uniform over an exposed area about 500 feet square. Similar

mineralized outcrops are found elsewhere in the pyroxenite, and supposedly the total mineralized area is much greater. The magnetite is low in titanium. Analyses of samples of this ore are as follows:[1]

Labrador Pond Prospect (along shore of the pond):

	Channel sample (W. side)	Grab sample (E. side)
	Per cent	Per cent
Iron	24·25	25·70
Titanium	0·48	3·21
Vanadium	0·02	0·14
Sulphur	0·045	0·106
Phosphorus	*nil*	*nil*
Silica	35·90	28·96

Low-grade magnetite deposits of this "taconite" type are being successfully recovered by crushing, magnetic separation, and concentration in New Jersey, New York, and Michigan. Possibly this deposit is of considerable size, but extensive trenching and sampling would be required to mark the surface limits, and drilling to determine the depth of the ore. Anorthosite may possibly underlie the pyroxenite and cut off the ore at a shallow depth.

A thousand feet to the south a similar, low-grade, disseminated deposit occurs in norite-gneiss. The ore occurs as thin veins and lenses in the strongly banded gneiss that strikes north 43 degrees east and dips 22 degrees southeast. The outcrop of the exposed ore lens is about 100 by 53 feet. The ore is magnetite and is slightly lower in grade than the deposit to the north.

A magnetic survey was made of these two prospects. Moderate intensities were recorded where magnetite was actually seen.

North of Long Gull Pond. At the summit of the first ridge to the northeast of Long Gull Pond is an elongated mass of hornblende-plagioclase gneiss, which contains scattered grains and local concentrations of magnetite. In no place was the magnetite in sufficient quantity to be worth further exploration.

OTHER MINERAL DEPOSITS

ANORTHOSITE

A quarry for anorthosite was in operation by the United States Government in 1942 on the northwest point of Indian Head (Figure 14). The anorthosite was used for coarse rock fill, some dimension stone, and railroad ballast. The rock is well jointed and takes a good polish, according to Snelgrove (9). Other excellent potential quarry sites exist along the shores of Indian Head.

MANGANESE

Small oval nodules of pyrolusite and other black manganese oxides were observed in red Carboniferous sandstone along the northwest shore of Seal Cove. The deposits are not of economic value, but further search in these rocks elsewhere in the area might locate other larger deposits.

[1] Analyst, E. P. Conroy, Newfoundland Government Analyst, 1942.

COPPER

Small quantities of chalcopyrite accompany the pyrite and a little molybdenite at the Lower Drill Brook mine. It is not present in economic quantities.

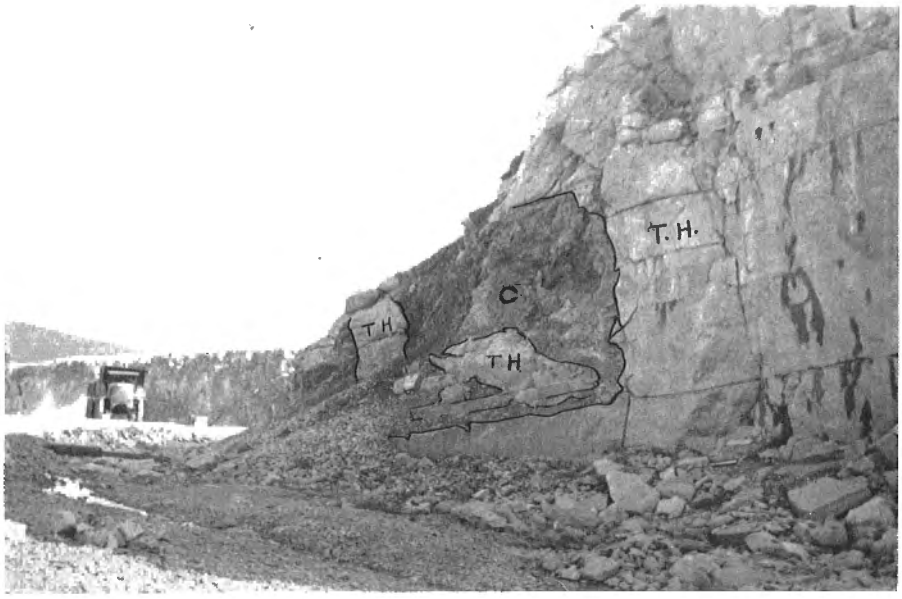
On the shore of Labrador Pond east of the iron deposit is an area of hypersthene pyroxenite impregnated with pyrrhotite and pyrite. A selected grab sample yielded small quantities of copper, as follows:[1]

	Per cent
Copper	0·50
Nickel	*nil*
Platinum	*nil*

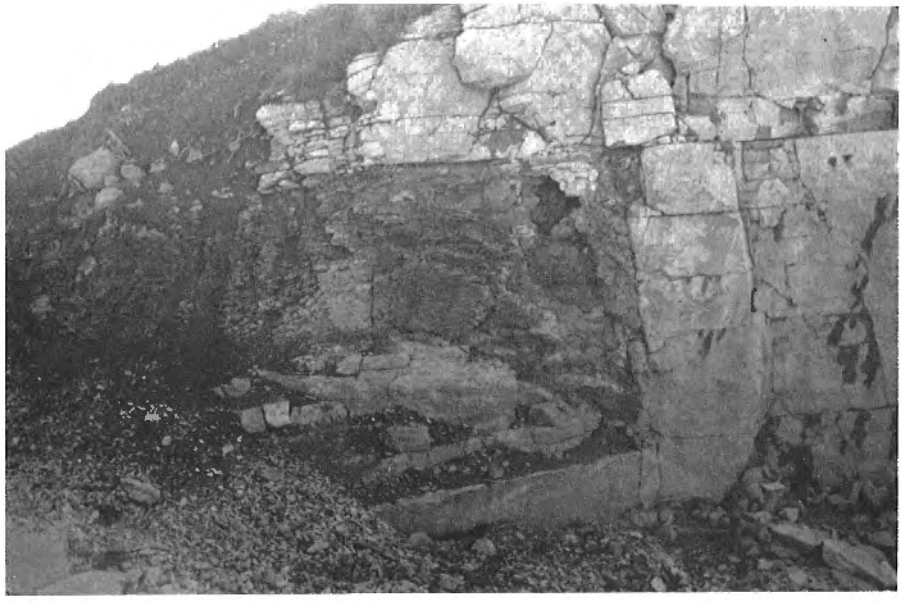
GRAVEL

Glacial till gravels were being removed in 1942 from a gravel pit on the Stephenville highway near the crest of Indian Head Ridge and used for local road materials. Many other potentially usable deposits of this type exist in the area if needed.

[1] Analyst, E. P. Conroy, Newfoundland Government analyst, 1942.



A. Cave filling at the "Narrows" of Aguathuna quarry. Codroy fossiliferous limestones (C) fill cave in Table Head strata (T.H.). Pillar and part of collapsed roof can be seen at left and centre of photograph. (Pages 6, 9.)



B. Detail of cave filling, showing unbroken Table Head limestones forming roof, side wall, and floor of cavern. Depositional contact shows above cave level. (Pages 6, 9.)

PLATE III

A. Bishop North prospect. Shows how massive magnetite breaks readily into plates and blocks along joints and shear planes. (Page 32.)

B. Glaciated massive magnetite on Bishop North prospect. The white spots are magnetite crystals that reflect the sun's rays. (Page 32.)

PLATE IV

A. View of southern end of Hayes prospect showing dark magnetite in white-weathered anorthosite. Flat Bay Brook in distance. (Page 37.)

B. Stripping near southern end of Hayes orebody. Massive magnetite weathers in relief above anorthosite. (Page 37.)