GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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TERRA NOVA AND BONAVISTA MAP-AREAS, NEWFOUNDLAND

(2 D E½ and 2 C)

Stuart E. Jenness

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TERRA NOVA AND BONAVISTA MAP-AREAS, NEWFOUNDLAND

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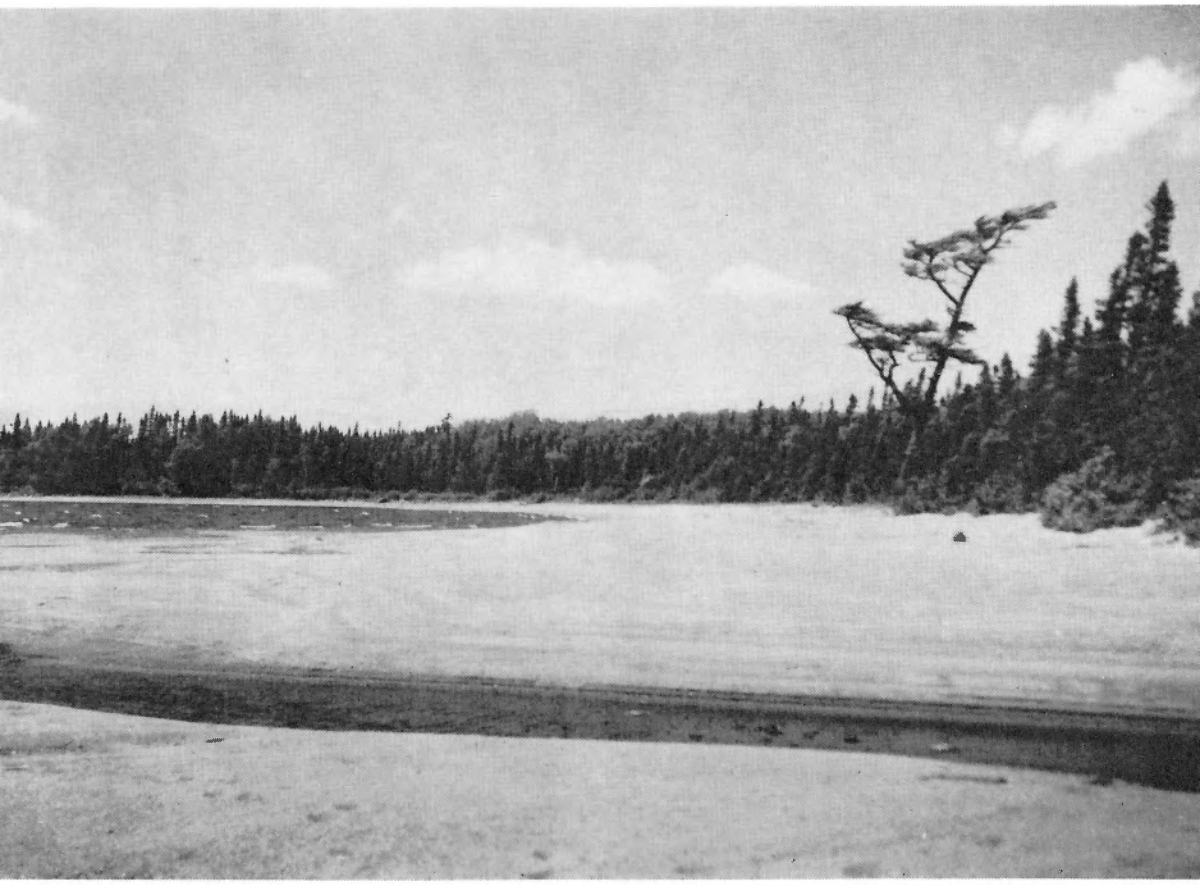

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Plate I. *Extensive sandy beach developed in outwash, Northwest Pond, near Port Blandford.*

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By

Stuart E. Jenness

DEPARTMENT OF
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PREFACE

Following the union of Newfoundland with Canada in April 1949, the Geological Survey of Canada undertook the reconnaissance geological mapping of a broad cross-section of the Island of Newfoundland. Towards this end, A. M. Christie mapped in Bonavista map-area during the summer of 1949 and parts of the summers of 1950, 1951, and 1952. S. E. Jenness mapped in the adjoining Terra Nova map-area during the summers of 1955 and 1956, and part of the summer of 1957, then re-examined parts of Bonavista map-area. This report contains the results of the two investigations.

The report contains much new information on the stratigraphy of a thick succession of Precambrian and Palæozoic rocks. It also contains the first potassium-argon ages determined on micas from Newfoundland granitic rocks. The Devonian age for the granitic rocks in Terra Nova and Bonavista map-areas is now confirmed.

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

OTTAWA, May 19, 1961

Memoir 327 — Kartenblätter Terra Nova und Bonavista (Neufundland).
Von Stuart E. Jenness.

Ein ausführlicher Bericht über präkambrische und frühpaläozoische Sediment- und vulkanische Gesteine in einem etwa 24 600 qkm grossen Gebiete des östlichen Neufundland. Auch devonische Granitgesteine, Glazialablagerungen und regionale Strukturen werden beschrieben.

Мемуар Но. 327 — Геологическая карта — Листы Терра Нова и Бонависта в Ньюфаундленде.
Автор: Стюарт Е. Дженнесс.

Подробный отчёт о докэмбрийских и ранне-палеозойских ссадочных и вулканических горных породах района в 9500 квадратных миль восточного Ньюфаундленда. Описаны также девонские гранитные породы, ледниковые месторождения и региональные структуры.

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TERRA NOVA AND BONAVISTA MAP-AREAS, NEWFOUNDLAND

Abstract

The two map-areas lie across the northeasternmost end of the Appalachian mountain system. Palæozoic and older rocks are well exposed in the hilly coastal regions, but are mainly concealed in the flatter interior, where Pleistocene deposits are more widely distributed.

Three geological subprovinces are recognized: (1) an eastern Precambrian belt consisting of three thick stratigraphic groups and including several erosional remnants of downfolded Cambrian and/or Ordovician sediments; (2) a western lower Palæozoic sedimentary and volcanic belt comprising the Gander Lake Group; and (3) a central belt of Devonian granite, which has intruded the sediments on both sides.

The oldest Precambrian rocks, the Love Cove Group, have been highly folded and regionally metamorphosed to greenschists. The next oldest, the Connecting Point Group, are a less deformed, typical greywacke-slate eugeosynclinal facies. These are succeeded by slightly deformed, continental red beds of the Musgravetown Group. Several strongly folded structural basins of Cambrian and Lower Ordovician shelf deposits occur within the Musgravetown Group in the Random Island region. The Gander Lake Group consists of greywackes and slates, of eugeosynclinal facies, and locally contains Middle Ordovician fossils. Its lower half has been regionally metamorphosed to the chlorite and biotite grades. Lenses of ultrabasic rocks occur along the middle stratigraphic unit of this group.

Porphyritic, pink biotite granite, the northern continuation of the Ackley batholith, lies athwart both the Gander Lake Group and the Precambrian rocks. Contact metamorphic aureoles occur along its west flank, granitized zones along its east flank. Biotite in the granite has been dated as 365±15 million years old.

Love Cove rocks were folded before Connecting Point time, and Connecting Point rocks were folded, at least locally, before Musgravetown time. Fold axes of the Musgravetown and younger rocks strike a few degrees east of north; those of older rocks strike more irregularly. Four fault systems have been outlined, the most important of which trends N15°E.

Metallic minerals are almost non-existent. Gravels and sands are plentiful, but at present have a very limited market. Water power could be obtained readily on Terra Nova River 1 mile east of Mollyguajeck Lake.

Résumé

Les deux régions à l'étude sont situées à l'extrémité nord-est du régime montagneux des Apalaches. Les roches paléozoïques et d'autres plus anciennes affleurent en abondance dans les régions accidentées de la côte, mais ces mêmes roches le plus souvent sont recouvertes dans la partie moins accidentée à l'intérieur des terres, où les dépôts pléistocènes prédominent.

La région peut se subdiviser en trois zones au point de vue géologique: (a) à l'est, une zone précambrienne, formée de trois épais groupes stratigraphiques, que

recouvrent les débris érodés de sédiments plissés d'âge cambrien et/ou ordovicien; (b) à l'ouest, une zone sédimentaire et volcanique du Paléozoïque inférieur comprenant le groupe Gander Lake; et (c) une zone centrale de granite dévonien qui fait intrusion au sein des sédiments de chaque côté.

Les roches précambriennes les plus anciennes, soit celles du groupe Love Cove, ont été fortement plissées et, en certains endroits, métamorphisées en schistes verts. Les roches du groupe Connecting Point, presque aussi anciennes que les premières, sont moins déformées et présentent le faciès eugéosynclinal grauwacke-ardoise. A celles-ci succèdent les couches rouges d'origine continentale, légèrement déformées du groupe Musgravetown. Plusieurs bassins structuraux fortement plissés et contenant des dépôts continentaux du Cambrien et de l'Ordovicien inférieur se rencontrent au sein du groupe Musgravetown, dans la région de l'île Random. Le groupe Gander Lake consiste en des grauwackes et des ardoises à faciès eugéosynclinal et, en certains endroits, il contient des fossiles de l'Ordovicien moyen. La moitié inférieure s'est métamorphisée par endroits jusqu'au faciès de la chlorite et de la biotite. Des lentilles de roches ultrabasiques se rencontrent en bordure de l'étage stratigraphique médian du groupe.

Du granite porphyritique à biotite, de couleur rose, qui prolonge vers le nord le batholite Ackley, gît à travers les roches du groupe Gander Lake et les roches précambriennes. Des auréoles de métamorphisme de contact sont reconnaissables le long du flanc ouest, et des zones granitisées, le long du côté est. On a établi que la biotite présente au sein du granite remonte à 365±15 millions d'années.

Les roches Love Cove ont été plissées avant l'époque Connecting Point tandis que les roches Connecting Point, tout au moins en certains endroits, l'ont été avant l'époque Musgravetown. Les axes de plissement des roches Musgravetown et des plus récentes sont orientés à quelques degrés à l'est du méridien mais ceux des roches plus anciennes sont orientés plus ou moins au hazard. On a repéré quatre réseaux de failles, dont le plus important a une orientation N15°E.

La région à l'étude ne contient à peu près pas de minéraux métalliques. Il y a des sables et des graviers en abondance, mais leur marché est présentement très restreint. On pourrait facilement mettre à profit l'énergie hydraulique sur la rivière Terra Nova, à un mille à l'est du lac Mollyguajeck.

Chapter I

INTRODUCTION

Location and Size of Areas

The two map-areas described in this report lie between north latitudes 48°00′ and 49°00′ on the northeastern coast of Newfoundland. Terra Nova (2 D E½) map-area is bounded by west longitudes 54°00′ and 55°00′. Bonavista (2 C) map-area adjoins Terra Nova map-area on the east, and is bounded by west longitudes 52°00′ and 54°00′. The two areas include approximately 9,450 square miles, of which 3,150 square miles lie in Terra Nova map-area. The Atlantic Ocean occupies more than half of Bonavista map-area.

Purpose and Duration of the Present Investigations

The field investigations on which the present report and geological maps are based were part of a general program undertaken by the Geological Survey of Canada in 1949 to complete the geological mapping of the Island of Newfoundland. They have permitted a re-evaluation of the geology of the frequently studied Bonavista and Trinity Bay areas, and extension of the resultant knowledge west into the relatively unknown interior of the island. The present report is based on reconnaissance mapping on a scale of 1 inch to 2 miles, published on a scale of 1 inch to 4 miles.

The writer mapped Terra Nova map-area during the summer months of 1955 and 1956, and for one month in 1957. He spent the remaining 2½ months in 1957 re-examining critical parts of Bonavista map-area, which had previously been mapped by A. M. Christie in 1949 and parts of 1950, 1951, and 1952.

Access and Travel Conditions

All parts of the coast of both map-areas are accessible by boat, although landings are difficult in many places because of rocky shores and rough water. A coastal steamer operated by the Canadian National Railways between St. John's and Lewisporte calls regularly during the navigation season at several communities in the Bonavista area. Fishing boats can be hired at almost any coastal village for transportation to other coastal localities.

Many coastal villages have only recently become accessible by road. Gravel roads now follow around much of the coast of Bonavista and Bay de Verde Peninsulas, and other roads are presently under construction to villages around the western shores of Bonavista Bay. These roads in turn are connected with the Trans-Canada Highway, which passes through the western half of Bonavista map-area northward from Avalon Peninsula, then veers westward across the northern

part of Terra Nova map-area. Only a few roads lie west of the highway. These are private roads, constructed and maintained by the Bowaters Pulp and Paper Company and the Anglo-Newfoundland Development Corporation.

Most of the southern third of Terra Nova map-area and a few places along its western side are accessible only by foot, float aircraft, or water routes. There are many lakes large enough to permit float aircraft landings, but few streams suitable for canoe travel, owing to shallowness, turbulence, and logging operations. Travel by foot is extremely tedious because of dense vegetation and the abundance of lakes, streams, and bogs.

Gander is the most accessible community in the two map-areas owing to the road, rail, and airplane routes that pass through it. It is also the largest settlement, with a population of about 5,000. All other communities lie irregularly distributed around the extensive coast line. There are no permanent settlements inland from the main road and railway.

Previous Geological Work

The earliest geological information is credited to William Cormack (1824) who, in 1822, walked across the southern part of both map-areas from Smith Sound, Trinity Bay, to the west coast of Newfoundland. His brief geological observations, where their localities can be identified today, are surprisingly accurate considering his youth (26 years) and conditions of travel.

J. B. Jukes (1843) undertook the first systematic geological mapping of parts of the present map-areas. He noted the similarity of the sedimentary formations in the Bonavista Bay area to those on Avalon Peninsula, and distinguished what are now known as Cambrian and Ordovician strata from the underlying Precambrian rocks. He published the first geological map of Newfoundland, indicating both his own and Cormack's geological findings.

In 1869 Alexander Murray (the first Director of the Newfoundland Geological Survey) visited Bonavista Bay, and reported (1881) on the "Laurentian" gneiss in the northwest corner of the bay, the slates, quartzites, and diorites exposed around Bloody Reach and on the Inner Gooseberry Islands, and the red sandstones and conglomerates along the south shore of Clode Sound. He also noted the intrusive relationship of the granite on Terra Nova Lake. During the same year, J. P. Howley examined the coast of Trinity Bay, and both Murray and Howley correlated the rocks now called Connecting Point and Musgravetown Groups with those in the Signal Hill Formation (Cabot Group) and underlying formations on Avalon Peninsula.

In 1874 Murray (1881) reached Gander Lake via Gander River, where he compared the slates with Upper Silurian slates in Sir Charles Hamilton Sound to the north, and recognized ultrabasic rocks within the slates.

Matthew (1899 a,b) published a section of Cambrian rocks in Smith Sound and descriptions of the Etcheminian (Lower Cambrian) fossils he found there. His account touched off a controversy, which continues to the present, as to the exact position of the base of the Cambrian in eastern Newfoundland.

The following year, Walcott (1900a) published a brief account of the Random Formation below the Lower Cambrian rocks near Clarenville; he regarded this formation as an upper Precambrian unit. He also published (Walcott, 1900b) an account of the Lower Cambrian units near Broad Cove in Smith Sound and near Hickman's Harbour on Random Island. This account still serves as a standard reference for the Lower Cambrian stratigraphy of Eastern Newfoundland.

In 1914 Van Ingen published a table dividing the Lower Ordovician strata in Bonavista map-area into six zones marked by index fossils, and included some condensed information on the lithology of the Cambrian strata. He did not include any criteria for the recognition of the Cambro-Ordovician boundary.

Dale (1915) published a detailed description of manganese-bearing beds at Smith Point, and four years later Buddington (1919) published some geological observations on Bonavista map-area in a report on the Precambrian rocks of Avalon Peninsula.

In 1926 Howell published a description of the Cambro-Ordovician stratigraphic column in southeastern Newfoundland, including the units in Bonavista map-area.

In Terra Nova map-area approximately half a century passed following Murray's 1874 excursion before any further geological work was undertaken. During the 1930's and 1940's members of the Newfoundland Geological Survey made several mineral studies of the ultrabasic rocks north and south of Gander Lake, but only that of Snelgrove (1934) was published.

In 1938 Snelgrove published a brief description of the abandoned Workington iron deposit near Lower Island Cove (in the southeast corner of Bonavista map-area) and the Hatchet Cove lead prospect (in the Southwest Arm of Random Sound).

In 1940 MacClintock and Twenhofel published an account of the surface features and Wisconsin glaciation of Newfoundland; this account included geological information on several localities in both Terra Nova and Bonavista map-areas.

Twenhofel (1947) studied the rocks along Gander Lake and proposed the name 'Gander Lake series' for the sequence of phyllites, slates, and quartzites he found there. Without fossil evidence, he related the series to the Silurian system on the basis of lithological similarity with Silurian strata on the islands in Sir Charles Hamilton Sound.

Hayes (1948) mapped the southern half of Bonavista map-area and recognized an angular unconformity within the Precambrian rocks. He named the rocks above this unconformity the Musgravetown Group, those below it the Connecting Point Group. The former he regarded as equivalent to the Signal Hill rocks (now part of the Cabot Group) of the St. John's area, and the latter as equivalent to the Conception slates and Harbour Main volcanic rocks of Avalon Peninsula. Working in conjunction with Hayes, Rose (1948) extended the two units southward towards Placentia Bay.

In 1948 Kemble Widmer, working for the Newfoundland Geological Survey, traced the distribution of the Musgravetown and Connecting Point Groups

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to the north, and reconnoitered into Terra Nova map-area, thereby recognizing the presence of a third major Precambrian stratigraphic unit, which he termed the 'Love Cove schists formation'. No report of his field work was prepared, but copies of his unpublished map have been made available to the writer from the files of the Geological Survey of Canada.

In 1949, A. M. Christie (1950) mapped the entire Bonavista map-area tracing the Precambrian units northward into the northwest part of Bonavista Bay. His report included the first details on the lithology of the Musgravetown and Connecting Point rocks and on the surficial deposits, but did not mention Widmer's Love Cove unit, although it occurs in a few places along the west side of his area. He re-examined the classical late Precambrian and Cambro-Ordovician localities in the Random Island area during parts of the summers of 1950, 1951, and 1952, and measured several sections.

In 1951 personnel of Photographic Survey Corporation Limited of Toronto undertook reconnaissance geological mapping from Bay d'Espoir northward, including part of Terra Nova map-area, for the Newfoundland Department of Mines and Resources. Their geologists discovered the first fossils in this area, and outlined the areas underlain by ultrabasic rocks. The following year Grady (1953, unpublished manuscript, Geological Survey of Newfoundland) and the writer (Jenness, 1958a) did more detailed mapping of the ultrabasic rocks, and members of the writer's field party discovered two fossil localities on Gander Lake. All the fossils are Middle Ordovician.

In 1953 the writer mapped an area between Clode Sound and Alexander Bay (Bonavista Bay) for the Geological Survey of Newfoundland (Jenness, 1958b). Much of this area, which lies partly in Bonavista map-area and partly in Terra Nova map-area, has now become Terra Nova National Park. This study confirmed the existence of Widmer's Love Cove unit, which was re-named the Love Cove Group, the existence of several distinctive features between the Musgravetown and Connecting Point Groups, and the presence of volcanic rocks within the Connecting Point Group.

Between 1953 and 1957 the Newfoundland and Labrador Corporation (NALCO) prospected and mapped in detail part of Terra Nova map-area. Their maps and reports have not been made public.

Acknowledgments

G. Klein, L. Franke, F. Nolan, D. Harris, and H. W. Dodge, Jr., each rendered capable service during the field season that they served as student assistants on the writer's field party. Reginald Bates of Happy Adventure, Bonavista Bay, proved invaluable as canoeman and assistant during each of the three summers, and his brother Bertram Bates, also of Happy Adventure, proved of great assistance in the same capacity in 1957.

The writer wishes to express appreciation to the following persons and their companies for assistance given him between 1955 and 1957: to the personnel of the Newfoundland and Labrador Corporation of St. John's, who provided the

writer with a reconnaissance geological map of part of Terra Nova map-area and permitted him to examine several of their suites of field specimens in 1955 and 1956; to the officials of the Anglo-Newfoundland Development Company who graciously permitted use of their facilities at Terra Nova and Gambo; and to the officials of the Bowaters Pulp and Paper Company at Benton and Glenwood, who kindly rendered many services and permitted use of their facilities.

The writer has benefitted greatly from discussions with D. M. Baird and W. D. McCartney concerning problems within the two map-areas. R. D. Hutchinson identified most of A. M. Christie's fossils, which all came from the Random Island area, and L. M. Cumming identified several of the writer's Gander Lake fossils.

The writer has had the benefit of an unpublished manuscript prepared by A. M. Christie on Bonavista map-area, and has drawn liberally on parts of it in the following pages. He has also had the benefit of examining manuscripts by R. D. Hutchinson (1962) and W. D. McCartney (in press) prior to their publication.

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Chapter II

PHYSICAL FEATURES

Relief

Most of Terra Nova and Bonavista map-areas lie within the Central Plateau of Newfoundland, a part of the Atlantic Upland physiographic division (Twenhofel and MacClintock, 1940, p. 1670). Only the Gander River drainage basin in the northwest corner of Terra Nova map-area lies outside the upland; it forms a part of the Notre Dame Bay Basin. No marked difference in surface appearance separates these two physiographic divisions. The most pronounced differences in surface appearance are between coastal and inland areas within the upland. In coastal areas relief is generally large with low elevations, whereas inland relief is relatively small, with higher elevations.

The surface of Bonavista map-area is hilly, although much of it lies below the 250-foot elevation. Higher hills occur only along the two subparallel south-southwest trending ridges between Freshwater Bay and the southwest corner of Bonavista map-area, and between Keels and the east end of Random Sound. Many hills along these two subparallel ridges have elevations between 500 and 750 feet; few are higher than this. The highest elevation in Bonavista map-area is 900 feet; it occurs 1½ miles west of the village of Adeyton. A narrow relatively low-lying plain underlain chiefly by Cambro-Ordovician shales trends northward from Hillview to Clode Sound. East and north of this the land is undulatory, with partly rounded rocky ridges separated by broad, gently shaped valleys. Small lakes abound in these hilly regions. Most of these lakes have small streams to carry their overflow seaward, but many of the streams dry up during the summer.

The surface of Terra Nova map-area is relatively flat and lies chiefly above the 500-foot elevation. Several river valleys carve into this surface, locally producing relief of between 300 and 600 feet. Elevations north and east of Gander Lake are generally less than 300 feet above sea-level, but south of the lake they increase; at first abruptly on the south shore of Gander Lake, then fairly gradually towards the higher terrain near the south coast. Near the southern boundary of Terra Nova map-area a major east-trending height of land separates the streams that flow to the north or northeast coast from those that flow to the south coast (Figure 1). Elevations of 750 feet above sea-level are common along this height of land. Still higher elevations occur along a secondary height of land that separates the Gander River drainage basin from the drainage basins of Terra Nova River and Gambo Pond. Despite its elevation, however, most of the terrain south of Gander Lake is only gently undulant.

A more rugged type of terrain occurs in the southeastern corner of Terra Nova map-area. There a relatively narrow band of acidic to intermediate compositioned volcanic rocks projects rather abruptly above the surrounding countryside

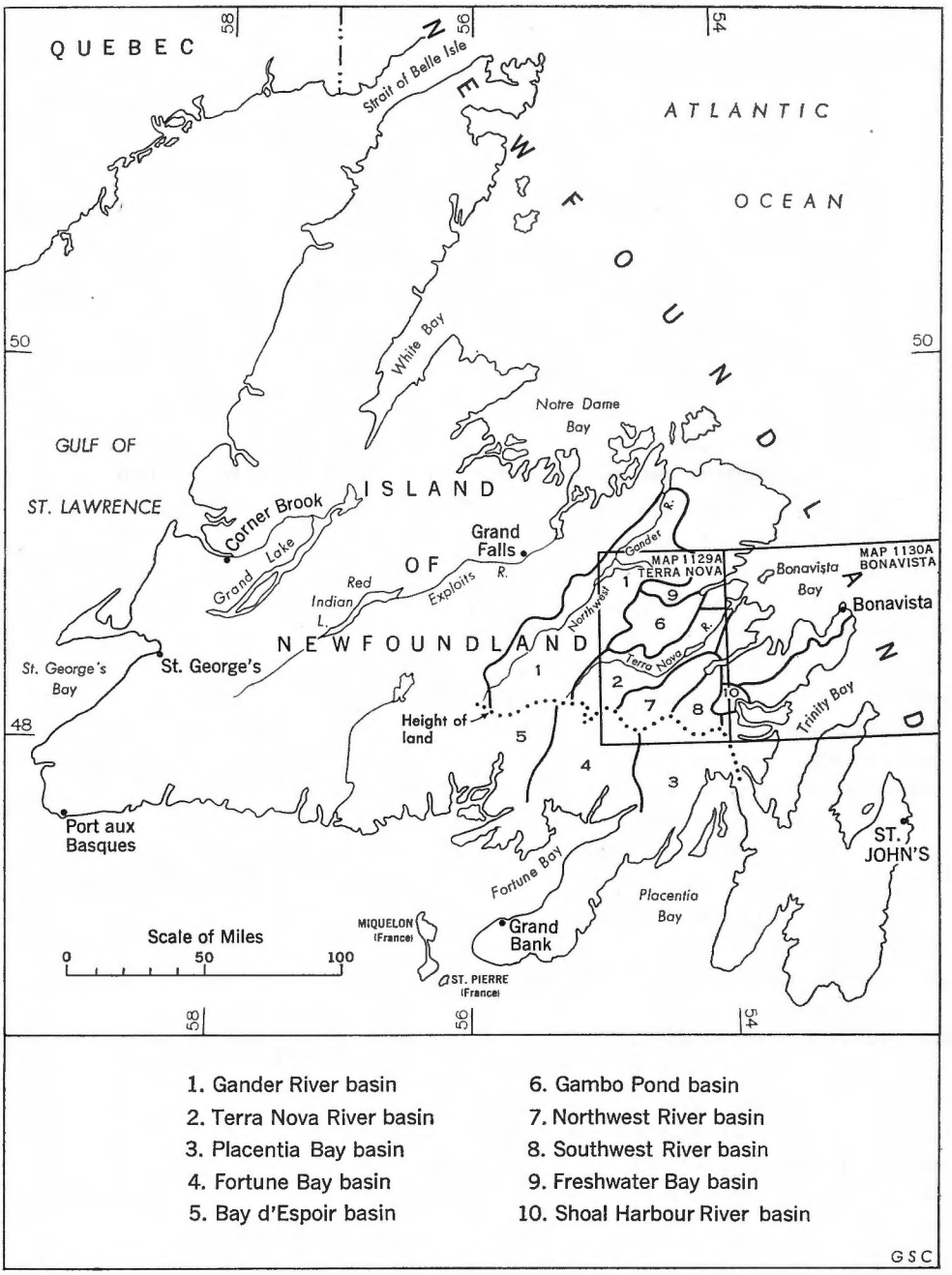

Figure 1. ***Principal drainage basins within the Terra Nova and Bonavista map-areas and the immediately adjoining areas.***

to form a roughly triangular-shaped ridge straddling both Black River Pond and Tug Pond, and converging northward to the valley of Shoal Harbour River. Near-vertical cliffs several hundred feet high flank the Shoal Harbour River valley at this point. The highest elevation of both map-areas (1,300 feet) is found along the eastern side of this triangular-shaped ridge, 3½ miles north of Tug Pond. West of the ridge the land flattens out for many miles, and much of it, especially around Meta Pond, has a relief of little more than 100 feet, despite an elevation of between 500 and 600 feet above sea-level.

Drainage and Post-Glacial Drainage Changes

The presence of their many rivers and streams might suggest that the two map-areas are well drained. This is not the case, however, for there is much poorly drained boggy terrain, especially south of Gander Lake, for instance in the region around Meta Pond (N. Lat. 48°05′, W. Long. 54°50′). In such regions high precipitation, low evaporation, and relatively low relief prevent the existing drainage courses from removing the surplus water. Even in areas of higher relief where drainage is more active and effective, such as around the coast, patches of bog occur between hills and even in small depressions on the sides and tops of the hills. As a consequence, the water table lies near the surface in most of the two map-areas.

Two rather large drainage basins and several smaller ones occur in Terra Nova map-area. Most of these are oriented northeastward, largely as a result of the coincidence of the northeasterly slope of the terrain and the northeast structural trend of the underlying rocks. The streams in these basins drain to the north, northeast, and east coasts. Two drainage basins are oriented southward, and their streams drain into Placentia and Fortune Bays on the south coast. These two basins are separated from the rest by the east-trending height of land that lies a few miles inland from the south coast (Figure 1). No important drainage basins lie within Bonavista map-area, owing largely to the short distances to the coast from any place within it.

The drainage basins of Gander River and Terra Nova River control the largest volumes of water in eastern Newfoundland. They also contain the largest rivers and the largest and greatest number of lakes in eastern Newfoundland.

The Gander River drainage basin is the largest (about 2,500 square miles) in eastern Newfoundland, but only a part of it (about 600 square miles) lies across the northwest corner of Terra Nova map-area. This part, however, is a major element in the Gander River drainage system, for it includes Gander Lake, the third largest lake in Newfoundland, which acts as an important local reservoir for the heavy spring run-off of water.[1] The surface of the lake fluctuates 6 to 8 feet between spring run-off and the summer dry season. The amount of water thus

[1] The following figures give some indication of the quantity of water contained by Gander Lake: it is about 35 miles long, 1 mile to 2 miles wide, and part of it is 900 feet deep (as determined by soundings made by the Canadian Department of Transport in 1955 at Gander). Other parts of the lake are said to be even deeper. Near the southwestern corner of the lake, just a few hundred yards beyond the mouth of Southwest Gander River, where one might expect the lake to be shallow because of filling by the river sediments, measurements made by Bowaters Pulp and Paper Company employees have shown a depth between 400 and 500 feet.

temporarily held back by the lake is estimated to be more than 50×10^8 cubic feet, an amount which otherwise would subject the lower part of Gander River to violent flooding each spring. Despite the withholding action of the lake, the lower part of the river does rise several feet, and some flooding does occur.

The second largest drainage basin is that controlled by Terra Nova River, covering about 750 square miles, two thirds of which lies within Terra Nova map-area (Figure 1). Like the Gander River basin, this basin also contains a large lake that serves as a local withholding basin for spring run-off waters. This is Terra Nova Lake, a triangular-shaped body, with the river and a stream entering its two western apices, and the river flowing from its third, eastern apex. Its depth is not known, so that no estimate of the volume of water withheld is possible. Three fairly high waterfalls occur along the river; one, about 30 feet high, is 10 miles upstream from Terra Nova Lake; the other two, about 25 and 40 feet high respectively, are several miles downstream from the lake.

Several other drainage basins are shown on Figure 1; some of these cover a considerable area, but none contains sufficient water to maintain a river of significant size.

Two post-glacial drainage changes appear to have occurred in Terra Nova map-area. The first of these was the diversion of the outlet of Gander Lake, from an east-trending valley leading to Freshwater Bay to its present course down Gander River Valley. Glaciofluvial deposits now exposed between the east end of Gander Lake and Freshwater Bay indicate the route taken by former glacial meltwaters. This eastward course may even have been the original pre-glacial route for rivers draining central Newfoundland. Cause of the diversion to its present channelway in Gander River Valley is tentatively attributed to the rise of the Freshwater Bay spillway by post-glacial upwarping. The spillway area has risen 100 feet relative to sea-level since the last deltaic outwash was deposited at Middle Brook South, near Gambo.

The second drainage diversion affected the water flowing out of what is now Gambo Pond. The occurrence of glacio-fluvial deposits extending from Gambo Pond east into the Northwest Arm of Alexander Bay indicates that glacial meltwaters following down the valley of Gambo Pond formerly flowed in this direction. This route may have been the preferred outlet of the glacial meltwaters because of ice blockage in Freshwater Bay, or because of damming by glacio-fluvial deposits entering Freshwater Bay from Gander Lake. In any case, the overflow from Gambo Pond ultimately was diverted north into Freshwater Bay, again possibly as a result of local post-glacial crustal movements.

Other smaller scale drainage changes probably have occurred elsewhere within the two map-areas, but have escaped recognition so far.

Coast-Lines and Evidence of Emergence

There are well over 200 miles of coast-line in the two map-areas, most of which is rocky, precipitous, and deeply embayed. Ice abrasion during the period of Pleistocene glaciation and slow development of soil because of cold climate

have left large sections of the shore as bare rock. All headlands are rocky, and most are practically devoid of vegetation. Long embayments such as Freshwater Bay, Clode Sound, Smith Sound, and Random Sound, penetrate deeply towards the interior of Newfoundland. Along much of the coast the land surface rises steeply from the sea to elevations between 200 and 300 feet; locally, high ridges such as Mt. Stamford in Newman Sound, rise 600 to 700 feet above the shore.

Good docking harbours are few in both map-areas because of the abundance of rock outcrops around the shore and because many of the long bays face east or northeast and are exposed to heavy North Atlantic seas. Furthermore, although most of the large bays are deep (as much as 600 feet in some places), heads of bays are generally shallow—e.g. Freshwater Bay, Random Sound, and Smith Sound. This condition has been brought about by the dumping of glacio-fluvial sands and clays at the mouths of rivers entering these bays. The dumping of glacial debris is discussed further in Chapter III.

Beaches are rare. Most are small and consist of beach shingle that is composed of the pebbles of local resistant rock types. There are a few exceptions. Two sand beaches, each more than ½ mile long, occur at the head of Eastport Bay, and a third one at Sandy Cove nearby (Plate II A and B). All three are backed by 50- to 100-foot sand banks, marking the position of former deltas. Another sandy beach extends along shore for ½ mile in the Northwest Arm of Clode Sound. Small sandy beaches flanked by rock exposures have been observed in other parts of the coast, but these are only suitable haven for small fishing boats.

The coast-lines of Bonavista Bay and the west side of Trinity Bay are rising relative to sea-level at the present time. Evidence of this rise is: (1) elevated deltaic sediments at the mouths of rivers flowing into the heads of many of the larger bays, (2) small elevated gravel and sand accumulations in bays, and (3) the occurrence of rocks now above low tide that were submerged 40 to 50 years ago.

Deltaic sediments with their upper surfaces now approximately 100 feet above sea-level occur at the following places in Bonavista Bay[1]: (1) at Middle Brook South, near Gambo; (2) in the Northwest Arm of Alexander Bay; (3) at Eastport; (4) at Sandy Cove (*see* Plate II B); and (5) at Traytown. Deposits of a somewhat similar appearance and the same upper surface elevation occur at Port Blandford, at the junction of the two streams that flow into the southwest corner of Newman Sound, and at Plate Cove. Fluvial deposits with a slowly rising gradient extend inland from some of these deposits. The elevated deltas mark a coastal uplift in this area of approximately 100 feet.

Small sand and gravel deposits with upper surfaces believed to mark former positions of sea-level have been observed in many small embayments around the coast of Bonavista and Trinity Bays. The highest of these have their upper

[1] Elevations above sea-level mentioned in this section are close approximations rather than exact values. They are probably within 5 feet of the exact elevations. Measurements on many were made as accurately as possible by means of a metallic tape, but are subject to the above limits of accuracy owing to the difficulty of establishing the exact position of sea-level and the exact top of the deposit.

surfaces between 45 and 55 feet above sea-level. Deposits in this group occur in the following places: (1) at the southwest corner of Eastport Bay (approximately 55 feet) (*see* Plate II A); (2) at the southwest corner of Newman Sound (approximately 50 feet); (3) at Port Blandford (50 feet); (4) at Shoal Harbour (55 feet); (5) at the mouth of North West Brook in the Southwest Arm of Random Sound (45 feet); and (6) at Long Beach, also in the Southwest Arm of Random Sound (48 feet). All six appear to be deltaic deposits at the mouths of small stream valleys and are presumably of more recent age than the 100-foot deltas. Two similar deposits terraced at about 50 feet, but not apparently related to any stream

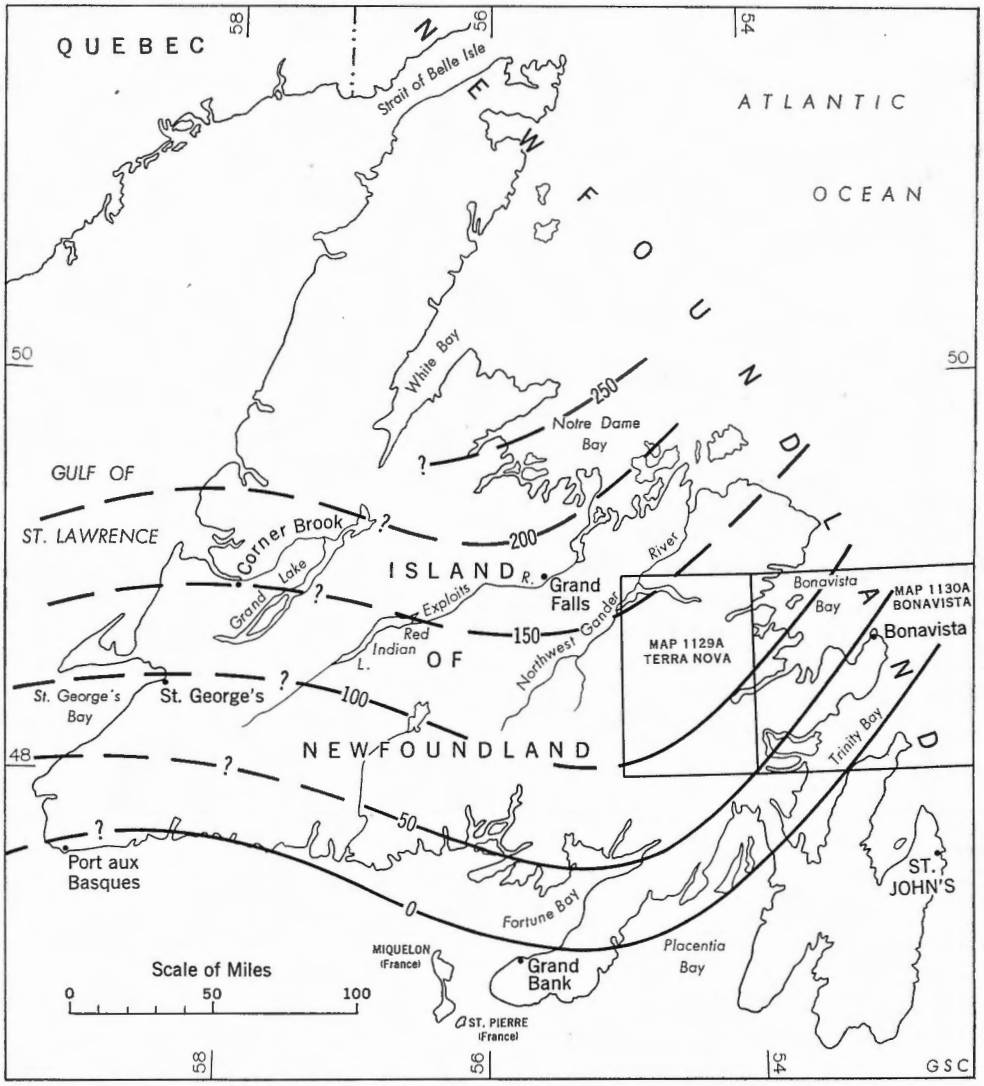

Figure 2. *Isobases in eastern Island of Newfoundland based upon upper levels of outwash deltas (from Jenness, 1960).*

valley have been observed in Clode Sound, one at Jamestown, the other at Bunyan's Cove. Varved clays and silts appear in the lower 10 to 15 feet of the 50-foot Port Blandford deposit, and have been noted also near Shoal Harbour, as basal deposits to sandier sediments (Hayes, 1948).

Poorly stratified gravels with elevations of 35 to 40 feet above sea-level form a terrace at Keels (near Cape Bonavista), and a smaller deposit on the west side of a small point 5 miles west of Hickman's Harbour in Random Sound. These deposits are not related to existing stream valleys and are presumably of marine origin. Smaller gravel and sand deposits, beach-like in appearance, occur 15 to 25 feet above sea-level in small embayments in Clode Sound and Newman Sound, presumably marking yet another former position of sea-level.

Elderly fishermen at several coastal communities around Bonavista Bay have observed over the past 40 to 50 years the slow emergence of shoreline features, such as rocky shoals, which would be dangerous to their boats. These observations confirm the belief that the coastal areas around Bonavista Bay are emerging at the present time. Estimates as to the extent of emergence obtained by the writer from such fishermen agree with the statement of Hayes (1948) that the upward movement has been at a rate of between 1 foot and 2 feet in the past 50 years. This rough estimate is of the same order of magnitude as the more quantitative tide-gauge data at St. John's, Newfoundland, which suggest a rate of *sinking* at St. John's, of almost 2 feet per century. A hinge line (marking a zone of neither emerging nor sinking shoreline) is believed to occur between the St. John's area and the Bonavista Bay region (Figure 2), passing through the centres of Placentia and Trinity Bays.

These elevated features are discussed in another publication (Jenness, 1960) wherein the writer concluded, from similar features in adjoining areas, that the east coast of Newfoundland west of Trinity Bay is emerging relative to sea-level, but not equally around the rest of the coast. Emergence along the south coast appears irregular, and on the north coast appears even greater than around Bonavista Bay. Provisional isobases drawn on the levels of the upper deltaic flattened surfaces are shown on Figure 2. Differential warping upward towards the northwest is indicated.

Chapter III

GLACIAL GEOLOGY

Both map-areas were glaciated during Pleistocene times. Deposits of glacial till have been observed in almost all parts of the two areas, and their presence is responsible for much of the gentle rolling aspect of the terrain. Both areas appear to have a veneer of till ranging from a few inches or less to 20 or 30 feet thick.

The existence of two drift zones in eastern Newfoundland has been recognized (Jenness, 1960), mainly on the basis of deposits within the present two map-areas (*see* Figure 3). These zones are separated by a discontinuous end moraine that encircles all but the west side of Terra Nova map-area, a few miles within its borders. As the exact relationship of the two drift zones is not yet fully understood no specific name has been given to either, but the terms 'outer drift zone' and 'inner drift zone' have been used to simplify discussion (Jenness, 1960). Nowhere within the two map-areas have deposits of more than one drift been recognized together. Deposits in the outer drift zone are principally residual ground moraine, but include several large bodies of glacial outwash that were derived from the inner drift zone and which lie along river valleys to the ocean. The deposits in the inner drift zone also include ground moraine, but the more diagnostic deposits and glacial features are the end moraine, eskers, kames, and kame terraces.

Direction of Ice Movement

Glacial striations, indicator boulders, stoss-and-lee shaped ridges, and the general distribution of glacial deposits within the two map-areas indicate that the last advance of the Pleistocene ice-sheet across the two map-areas was in a coastward direction (Figure 3). Thus the movement of the ice in the northwestern corner of Terra Nova map-area is but a few degrees east of north, the direction of the nearest coast, whereas farther eastward the movement of the ice turned increasingly eastward towards Bonavista Bay. In the southern half of Bonavista map-area ice movement directions were south of east, whereas they were almost southerly in the southwest corner of Terra Nova map-area. The ice apparently radiated from a centre west of the two map-areas (Figure 3).

The ice moving out of central Newfoundland across the two map-areas evidently terminated its forward progress when it reached the sea (Jenness, 1960). Thus it is improbable that it passed beyond Trinity Bay on the southeast. The direction of ice movement on the northern end of Carbonear Peninsula (in the southeast corner of Bonavista map-area) is not well known, but appears to have been coastward from the higher central parts of the narrow peninsula. The ice that occurred in this area was probably of local origin. A. M. Christie has recorded (unpublished 1949 field notes) a seemingly anomalous direction of S70°E on a smoothly polished bedrock surface just south of Grates Point at the northwestern

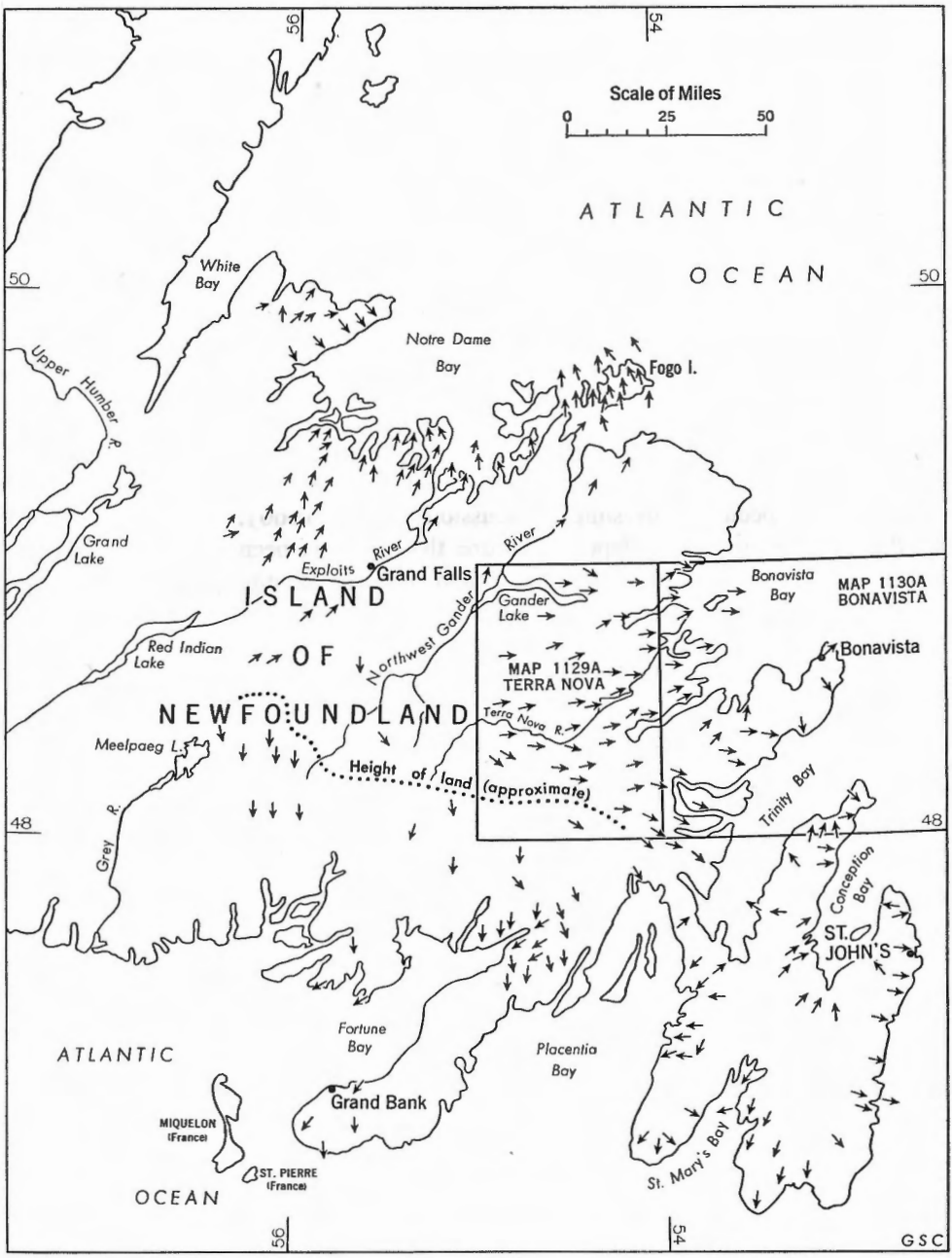

Figure 3. *Orientations of glacial striations and grooves in eastern Island of Newfoundland (after Jenness, 1960).*

end of this peninsula. This direction is completely opposite to all other readings on this peninsula, in that it is on-shore rather than off-shore, and suggests that some of the central Newfoundland ice-sheet may have succeeded in crossing Trinity Bay.

The writer has compiled a list of 204 glacial striation and groove observations; 52 from Bonavista map-area and 152 from Terra Nova map-area. (*See* Appendix A.) Many but not all of these are represented on the geological maps accompanying this report.

Two sets of striations have been observed on a few outcrops in both map-areas, but in each instance the dominant set is regionally coastwards, and the lesser set (which is presumably older because it is crossed by the dominant set) is oriented at a small acute angle to it. No important change of direction of ice movement is indicated in any of these outcrops.

Glacial Deposits and Features

Glacial deposits and features identified to date include ground moraine, end moraine, indicator boulders, eskers, kames, kame terraces, outwash, and outwash deltaic sediments. All of these have been recognized within Terra Nova map-area; as yet, however, no end moraines, eskers, kames, or kame terraces have been recognized in Bonavista map-area.

Ground Moraine[1]

Ground moraine occurs almost everywhere in the two map-areas. It forms a thin veneer over most of Terra Nova map-area, with the result that there are few outcrops. In Bonavista map-area, on the other hand, it is generally restricted to the lower regions between the many hills. The till comprising the ground moraine in both map-areas can be seen along the banks of many of the brooks and streams, in isolated deposits in burned-over country, and in many road cuts. Deposits more than 20 feet thick are exposed in only a few places, such as on the highway between Gander and Glenwood, on the roads near Bonavista, on the highway south of Clarenville, and along the private road west of Terra Nova.

The composition of the till comprising the ground moraine typically reflects the nature of the underlying bedrock. Thus it is a clayey till where it overlies the slates of the Gander Lake Group and in the large Cambro-Ordovician basin north of Clarenville, whereas it is a sandy or gravelly till in areas underlain by sandy rocks of the Musgravetown Group, or by granite. The till in some of the granitic areas, especially around Meta Pond, is stony. Large boulders clog many of the small stream channels in both areas.

End Moraine

One of the most important of the glacial deposits in the two map-areas is the end moraine that encircles much of Terra Nova map-area, separating the

[1] Used here for a "moraine having low relief devoid of transverse linear elements" (Flint, 1957, p. 131).

inner and outer drift zones in eastern Newfoundland (Figure 4). Despite its importance to regional glacial interpretation, however, the end moraine is generally so inconspicuous on the ground that it is readily overlooked in many places. Knowledge of its existence came about indirectly through recognition first of the radial pattern of the various glacial outwash deposits and then of the occurrence of small boulder-strewn hills or hillocks along the inland limits of the outwash deposits. Such boulder-strewn hillocks have been observed on the highway just south of Gambo, at the east end of Maccles Lake, along the railway just north of Terra Nova, and at the west end of Salmon Pond. In each locality granitic rocks lie immediately to the west, thus accounting for the coarse nature of the material. Subsequent field investigations revealed the presence of similar features in a few localities just south of Gander Lake, around the east end of Gander Lake, along the west side of Square Pond a few miles to the south, and about the west ends of Shoal Harbour Pond and Andrews Pond. A line joining all these localities coincides remarkably with a line separating the numerous eskers (which lie on the concave side of the line, towards central Newfoundland) and the glacio-fluvial outwash deposits (which lie on the convex or coastal side of the line) as shown on Figure 4.

The internal composition and structure of the end moraine has been observed only in a few roadcuts along the Trans-Canada Highway about 6 miles southeast of Gambo. There boulders of granitic material as much as 20 feet in diameter are piled in small hillocks along with finer-sized debris, completely unsorted and unstratified.

Indicator Boulders

Glacial boulders of certain rock types within the two map-areas have proven useful in showing the direction of ice movement, in giving some indication of the distance material was moved by the ice, and in estimating the thickness of the ice-sheet. They have also in places proved useful in mapping contacts. Rock types that have yielded valuable indicator boulders are: the pink porphyritic granites; the biotite-quartz paragneisses with large pink feldspar porphyroblasts; the red Musgravetown sandstone; and the pink Smith Point limestone. Of these four the first two are the most widespread and useful.

Granitic boulders have served to verify the direction of ice movement by their spread in large numbers ('shadow effect') for a mile or so, and as isolated boulders for many miles, beyond the eastern boundaries of granite contacts. They also have provided some indication of the distance of ice transport, for although most boulders are within a few miles of their source, 2- to 3-foot boulders of the type of granite found west of the railway tracks at Alexander Bay station have been observed alongside the road between Eastport and Salvage at least 24 miles east of their place of origin.

The indicator boulders have also provided a little information on the thickness of the ice-sheet that overrode eastern Newfoundland. Such boulders have been found at or near the tops of all high hills in both map-areas, including the highest hill (1,300 feet above sea-level and about 600 feet above nearby terrain)

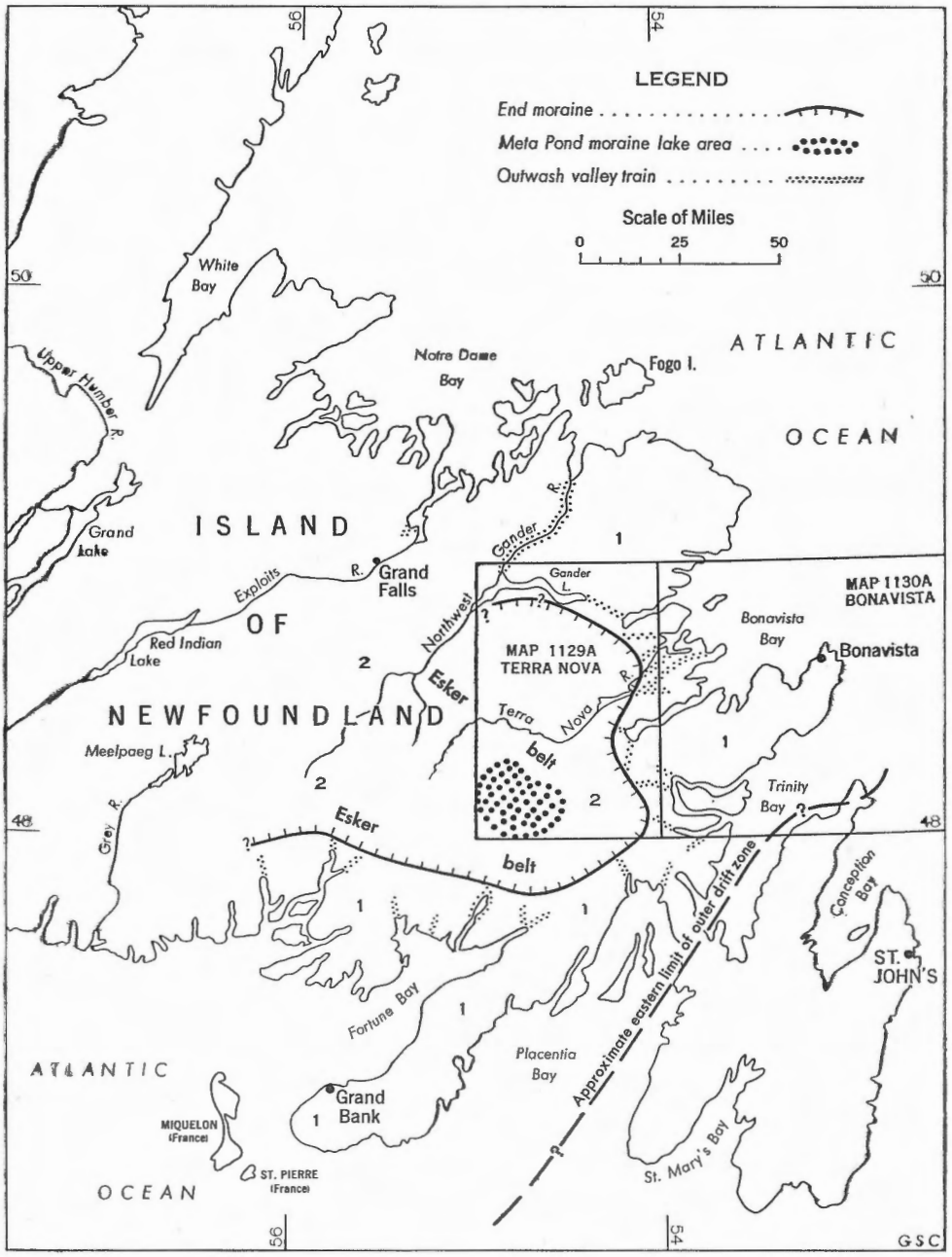

Figure 4. *General distribution of glacial deposits in and adjoining the map-areas covered by this report. End moraine separates inner drift zone (2) from outer drift zone (1).*

just north of Tug Pond, where a boulder of Musgravetown red sandstone lies almost at the crest of the hill. Thus the last major ice-sheet was thick enough to override relief features at least 600 feet high.

Eskers

To date twenty-five eskers have been recognized in Terra Nova map-area, but none in Bonavista map-area. All occur within a belt 20 to 30 miles wide that lies immediately inside the end moraine (Figure 4) and most of them occur within or alongside granitic terrane. The eskers range in length from a few tens of yards to 7 miles.

The longest esker lies along the south side of Mint Brook, between North Pond and Masons Pond, a distance of 7 miles. It is generally 30 to 40 feet high, 50 to 100 feet wide, and somewhat discontinuous, and conforms with slight changes in the surface topography. It provided the local base for the pulp road into North Pond constructed by the Anglo-Newfoundland Development Company.

Another lengthy discontinuous esker forms a sandy projection into the northwest end of Terra Nova Lake, then appears again (in longitudinal section) along the south shore of the same lake a mile to the southeast. The dip of the crossbedded sands within this esker indicates that the sands were deposited by eastward-flowing water. Screen analysis of a sample of the crossbedded sands revealed that 94 per cent of the material falls between 0.125 and 2 mm, indicating fairly good sorting. Quartz, pink feldspar, and rock fragments derived from the sedimentary rocks to the west constitute the bulk of the material in this esker.

Another esker with a known length of about 4 miles is intersected by a private road leading west from Terra Nova, about a mile west of Lake St. John. This and the previous two eskers are the only ones that occur in easily accessible locations. The remaining twenty-two eskers are readily recognizable on aerial photographs. Many of these are small, some only a few hundred yards long.

The occurrence and distribution pattern of the eskers in Terra Nova map-area indicate: (1) that the eskers were most readily formed in or immediately adjoining areas of granitic bedrock (presumably because of the plentiful supply of sands and gravels eroded from the medium- to coarse-grained granites); (2) that the orientation of the eskers fairly closely matches the regional direction of ice movement established by glacial striations; and (3) that the eskers, end moraine, and outwash deposits were probably formed at about the same time during the waning of the Newfoundland ice-sheet.

Kames and Kame Terraces

The writer has recognized only three kames in Terra Nova map-area, and none in Bonavista map-area. One of the kames is a small circular knoll about 25 feet high a mile north of Terra Nova, where it is partly exposed in a railway cut. It consists of quartz and feldspar sands and granite pebbles, with no visible stratification. The other two kames, almost circular in shape and between 15 and 20 feet high, occur in the middle of a bog a mile east of the south side of Esker Pond.

Neither of these is exposed in section. Other kames may exist[1], but heavy vegetation hinders their detection.

Gravel bodies regarded as probable kame terraces are perched on the sides of fairly steep hills at two widely separated localities, one 5½ miles south of Gander Lake, the other just west of Gambo. Both occur at about the position where the end moraine should be, but is as yet unrecognized. The first of these occurs at the junction of the east and west branches of Southwest Gander River, more than 200 feet above the valley floor and about 400 feet above sea-level. There a 20-foot section exposed alongside the Bowaters Pulp and Paper Company private road shows a gravel composition, with the coarse fraction ranging from pebbles near the base to boulders (up to 1 foot in diameter) near the top. Stratification is fairly good, with some tonguing of sands in gravel layers, and cut-and-fill type crossbedding.

The second probable kame terrace is exposed in two large pits on the southeast side of the ridge behind the village of Gambo. The upper surface of both terraces is about 150 feet above sea-level. A 100-foot section of one of the two pits occurs along the railway just north of Gambo. The material consists of fairly well-sorted and stratified pebbly sands and gravels. Several thin clay bands occur in the upper part of the section, but the rest of the material is much coarser, being chiefly coarse sands, pebbles, and cobbles up to 4 inches in diameter, with very little fine or medium sand. The beds dip to the east or southeast at about 4 degrees. The other pit lies alongside the Trans-Canada Highway about a mile to the southwest, and a few yards downhill from the connecting road into Gambo. This pit contains a 50-foot cliff of gravel, poorly exposed because of slumpage, but appearing to consist of poorly sorted sands with subrounded pebbles, cobbles, and boulders. Clay content is small. Several small gravel pits occur along the ridge between these two large pits, indicating the continuity of the terraced deposits.

Outwash Deposits

Deposits of outwash sands and gravels occur in many of the valleys leading from the interior of Terra Nova map-area to the sea. Most of these lie entirely within this map-area, but a few extend into Bonavista map-area. Many terminate in sandy deltaic deposits, the tops of which are tens of feet above sea-level. The general locations of thirteen outwash valley fills within the two map-areas are shown in Figure 4. They occur in valleys or at the mouths of valleys; most are terminated by deltaic deposits at the coast. Brief descriptions of the principal outwash deposits follow.

Gander Lake-Middle Brook South Deposits

Thick deposits of sands and gravels lie along the valley leading from the southeast end of Gander Lake to Freshwater Bay at the village of Middle Brook South

[1] Since this manuscript was submitted for publication, E. P. Henderson has reported probable kames and a kame terrace along the valley west of Northwest Arm of Alexander Bay, southeast of Gambo (*in* Lord, C. S. and Jenness, S. E.: Field work, 1960; Geol. Surv., Canada, Information Circular No. 4, 1961).

(just north of Gambo). They are best exposed in a series of pits at the east end of Gander Lake, a few hundred feet northeast of the highway bridge, where their upper surface is about 155 feet above sea-level. They consist of fine to coarse, well-stratified sands more than 50 feet thick, which in places display excellent cut-and-fill structures, typical of stream deposits. Pebbles in the sands are subrounded and consist chiefly of grey, fine-grained argillaceous and arenaceous rocks similar in type to the rocks exposed south and west of Gander Lake. Most of the sand-sized particles are subangular grains of quartz and feldspar, but the sands also include many tiny fragments of slate, fine-grained mica schist, granite, and ultrabasic rocks. The deposits now occur as isolated residuals along the sides of the valley leading east from Gander Lake.

Sand and gravel belonging to this outwash train are also exposed 6 miles to the southeast at Butts Pond, in an abandoned pit alongside the railway tracks. The upper surface of this deposit is about 135 feet above sea-level, marking an apparent drop of approximately 20 feet from Gander Lake. Its sands are pebbly but well stratified. This pit was formerly quarried by the railroad for road ballast.

From Butts Pond the outwash deposits can be traced to Freshwater Bay 4 miles to the southeast, where they terminate on the south side of the valley in a steep bluff overlooking the bay. A broad terrace extends upvalley for more than a mile from the bluff. Its upper surface at the bluff is 100 feet above sea-level, and the elevation rises slightly to the northwest.

A drop in elevation from the uppermost level of the deposits at Gander Lake (155 feet approximately) to 100 feet at the mouth of the outwash valley at Middle Brook South marks a fairly steep original stream gradient—55 feet in 9 miles. The outwash may have originally filled the valley to these elevations, and subsequently been dissected, following a change in stream regimen, by a stream with considerably more water volume than that of the small streams now flowing along the valley.

Gambo Pond-Alexander Bay Deposits

Large sand and gravel deposits are exposed along the Trans-Canada Highway 2 miles southeast of Gambo, where they lie between the drainage courses of the east-flowing Northwest Brook and two small streams flowing west into Gambo Pond. The sands are well-stratified and crossbedded, and have a flat upper surface at approximately 115 feet above sea-level. Similar deposits occur to the east at irregular intervals between the highway and the Northwest Arm of Alexander Bay, where they terminate 3½ miles down the Arm in a steep sandy deposit that appears to be a delta. The upper surface of this deposit is approximately 100 feet above sea-level. A general decrease in grain size and elevation from west to east has been observed in these deposits.

The outwash deposits in the valley between Gambo Pond and Alexander Bay probably accumulated because of blockage of the Gambo Pond outlet to Freshwater Bay. Subsequently, as was the case in the deposits between Gander Lake and Freshwater Bay, these deposits were extensively dissected and today they remain as only scattered residual patches along the valley floor and sides.

Terra Nova River-Traytown Deposits

Outwash deposits of sand, gravel, and clay occur along the valley of Terra Nova River. They are most readily seen about 8 miles above the mouth of the river, where they form a sandy terrace at an elevation of approximately 120 feet. The terrace continues upstream for about a mile and is deeply channelled by the river.

The deltaic deposits at Traytown are believed to be the seaward terminus of the outwash in Terra Nova Valley. Terra Nova River now empties into Alexander Bay at Glovertown, but the train of sandy sediments that crosses a small saddle in the ridge along the east side of the valley and then continues to Traytown appears to indicate the former course of the outwash stream flowing down Terra Nova Valley. The upper surface of the deltaic sediments at Traytown is 100 feet above sea-level. Ice blockage of the narrow outlet to the Southwest Arm of Alexander Bay was probably at least part of the cause of the outwash waters flowing from Terra Nova Valley toward what is now Traytown. The deposits are now extensively dissected and occur chiefly as small residual patches along the valley sides.

Southwest Tickle-Eastport Area Deposits

Outwash deposits occur along the valley into the Southwest Tickle (an embayment in the northeast arm of Alexander Bay), a few miles south of Traytown, and from there eastward to Eastport. Thick deposits of pebbly sands have been exposed on the Trans-Canada Highway just west of the Tickle, and a 25-foot section is exposed in a small pit ½ mile west of the mouth of the Tickle. The sands and gravel in this pit are well stratified and display cut-and-fill type crossbedding, as well as layers or lenses of pebbles and fine sands. The crest of this deposit lies approximately 120 feet above sea-level.

A probable remnant of outwash forms a small island at the mouth of the Southwest Tickle. It consists of about 15 feet of pebbly sands, and is presently undergoing erosion by long-shore currents.

Well stratified and crossbedded fine sands overlain by coarse sands and small boulders are exposed in a small road cut on the east side of the village of Sandringham, 4 miles east of the Southwest Tickle. The top of this exposure is approximately 110 feet above sea-level. These deposits are probably the eastward continuation of the outwash in the Southwest Tickle. Sandy deposits underlie much of the farm land at Sandringham, and almost all the land between Sandringham and Eastport (farther east). The maximum elevation of the deposits at Eastport is just over 100 feet. The following features indicate a glacio-fluvial origin for these deposits and a source west of the Southwest Tickle: (1) a decrease in elevations of their upper surfaces east from the Southwest Tickle; (2) a general decrease eastward in the grain size of the sands and pebbles; (3) better sorting of the material toward the east; and (4) an eastward direction of flow as indicated by the attitude of the crossbedding. These outwash deposits terminate at Eastport and Sandy Cove in impressive elevated deltas (*see* Plate II A and B).

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Shoal Harbour River Deposits

Several deposits of sand and gravel are exposed along the railway tracks in the steep-sided valley of Shoal Harbour River, northwest of the village of Shoal Harbour. They are best exposed in a large pit, about 3 miles from the village, that was formerly worked by the railway for road ballast. The upper surface of this pit is about 180 feet above sea-level. A 30-foot section of pebbly sands, fairly well bedded, was exposed at the time of the writer's visit in 1955. The sands are medium to very coarse grained, show some crossbedding, and include many fragments of orange-pink feldspar and pebbles of red sandstones, grey aphanitic (arenaceous ?) rocks, and granitic material, all of which have their place of origin a few miles to the west. This deposit is believed to be at least 50 feet thick. Similar but smaller deposits are exposed in several places upstream along both the railway and the river, as far as the connecting valley into Andrew Pond. These outwash deposits are believed to have originated near the eastern sides of Andrew and Shoal Harbour Ponds, the approximate position of the former ice-front.

The exact seaward terminus of the Shoal Harbour River valley outwash is not yet known. It may be a few hundred yards east of the village of Shoal Harbour, where the railway cuts through a well-bedded sand deposit with a flattened upper surface approximately 55 feet above sea-level. The sandy beds in this exposure are capped by a sharply undulant contact and at least 3 feet of unstratified cobble gravel. Gravelly deposits a few hundred yards to the west at somewhat higher elevations may be part of the same deposits. The 55-foot upper level of these sands may indicate marine bevelling of originally higher deposits. Certainly it would seem to be too low, in relation to the 180-foot elevation of the sands in the railway pit 3 miles upstream, for this to be the seaward terminus. Alternatively, the terminus may be on Random Island opposite the mouth of the Shoal Harbour River, where Hayes (1948) reported the presence of varved clays that might be deltaic bottom-set beds. This deposit was not seen by the writer.

Other Outwash Deposits

Sands and gravels, which appear to be outwash deposits on the basis of their distribution and composition, have been observed along the sides or at the mouths of several other river valleys. They include: (1) the deposits along the valley immediately west of Glovertown, probably including the gravel quarry on the hillside on the west side of the town; (2) the thick deposits intersected by the Trans-Canada Highway in the valley of the brook (locally known as Saltons Brook) leading into the northwest corner of Newman Sound; (3) similar large deposits leading into the southwest corner of Newman Sound along Big Brook; (4) deposits terminating with the delta 2 miles northwest of Port Blandford in Clode Sound; (5) deposits along Southwest Brook, which presumably are related to the extensive gravels near Port Blandford station; (6) deposits in the valley emptying into Smith Sound at Georges Brook, where Hayes (1948) reported the occurrence of varved clays; (7) deposits in the valley leading into the Southwest Arm of Random Sound at North West Brook village, where two terraced

deposits are prominent; (8) deposits in the narrow valley leading into the same body of water at Long Beach, 7 miles to the east (this deposit is actually just a few yards south of Bonavista map-area); (9) deposits in the valley leading into Bonavista Bay at Plate Cove, where stratified sands and gravels have a flat upper surface 100 feet above sea-level.

In all of the above localities the streams now flowing in the valleys are much smaller than the streams from which the sands and gravels must have been deposited. Again, all the deposits have been strongly dissected, and only small remnants of what may have been quite extensive valley fills are now to be found. The distribution of the deposits around Bonavista Bay and Random Sound (as well as in Placentia and Fortune Bays to the southwest) forms a distinct pattern, which suggests a common time of origin for most of them.

Deltaic Deposits

Deltaic deposits occur at the seaward ends of four outwash valley trains, and probable deltaic deposits occur at the ends of several others. Most of them lie within Bonavista map-area. They form a part of a group of deltaic deposits, now 35 to 100 feet above sea-level, that occur around the north, east, and south coasts of Newfoundland west of Avalon Peninsula. Descriptions of the main deltaic deposits follow.

Eastport-Sandy Cove Deltas

The most impressive deltaic deposits in eastern Newfoundland occur at Eastport and Sandy Cove (Plate II B). They consist of two deltas derived from a single train of outwash. Both deposits are exposed in 100-foot bluffs facing the open sea, with extensive sandy beaches at their bases. Both have been partly dissected, the deposit at Eastport having been cut through to sea-level by a stream, that at Sandy Cove having been somewhat eroded along its eastern side.

No complete stratigraphic section is visible at either Eastport or Sandy Cove, but a generalized section can be obtained by piecing together small sections of each delta that become exposed at infrequent intervals by marginal slumping. In general, the lowest 15 to 20 feet (above sea-level) of each delta consists of fine sands, silts, and clays in fairly distinct thin beds. Most of the clay bands are less than 4 inches thick and grade downward into silts and fine sands. These clays, silts, and fine sands are essentially horizontally bedded, and are interpreted as bottom-set beds. They are overlain by about 75 feet of seaward-dipping sands that constitute the fore-set beds. The grain size of these sands coarsens upwards, though not gradationally, and the dip of the beds shows a corresponding increase upwards in the section to a maximum of about 15 degrees. The top 10 feet of the delta at Sandy Cove consist of almost flat-lying, partly stratified pebble gravels that truncate the underlying fore-set beds, and which probably constitute the top-set beds of the deposit. Both deltas show considerable headward erosion.

Another sandy deposit, which appears deltaic, lies on the southwestern side of Eastport Bay, between the two 100-foot high deposits just described. It is terraced at only 50 feet above sea-level (*see* Plate II A). The lowest 16 feet consist of inter-

layered fine reddish sands and grey clays. Above these lie 30 feet of sands and silts in thin distinct beds, with a few clay bands. The clay bands become more abundant upwards and are the dominant facies in the uppermost part of the 30-foot section, where they contain a few pebbles and lenses of fine sand and silt. Above this lie 4 feet of pebbly, clayey sand, with small boulders and thin intercalated bands of clays and fine sands, all of which are topped by a thin cover of grey gravelly soil. The stratigraphy thus differs considerably from that of the higher deltas nearby. This deposit appears to be a small delta, but if so, it is of later origin than the adjoining two. It may be approximately the same age as the 50-foot delta at Port Blandford.

Middle Brook Delta

A deltaic deposit lies about 100 feet above sea-level at the east end of the Gander Lake-Middle Brook South spillway in Freshwater Bay. About 70 feet of this delta occur on the west side of the road between Middle Brook South and the adjoining village of Dark Cove, but only the upper 50 to 60 feet are exposed in section. A clay seam 18 feet above the road acts as an impermeable layer for downward-percolating surface waters, which seep along the top of the seam. The sands above this seam coarsen upwards, although not gradationally for considerable variation in grain size occurs at all elevations.

The sands consist of subangular to subrounded grains of quartz and pink feldspar, with some mica flakes and a few micaceous rock fragments. Size sorting and mineral sorting are better than in the related outwash deposits towards Gander Lake, indicating downstream winnowing during transport. Boulders that have tumbled to the roadside from various levels in this deposit belong to rock types that outcrop to the west around Gander Lake.

Only the fore-set beds are exposed in this deposit, but the appearance of clay bands in the lower part and the general decrease in grain size downwards suggest that the bottom-set beds are not far below the visible section.

Port Blandford Delta

The remnant of a small delta lies in the Northwest Arm of Clode Sound 3 miles north of Port Blandford, and extends inland to the railway tracks ¼ mile distant. This delta has a flat upper surface 50 feet above sea-level. Fore-set and bottom-set beds are exposed at several places around the shore, the former consisting of gently seaward-dipping, fine to coarse sands, the latter of varved clays, silts, and sands. The sands of the fore-set beds coarsen upwards in the section, and cobbles up to 4 inches in diameter occur at the top. The sands consist of grains of quartz and pink feldspar, with some biotite, epidote, and fragments of chloritic schist, all of which probably originated within a few miles to the west of the delta. The fore-set beds dip between 3 and 4 degrees to the southeast. The base of the fore-set beds lies about 10 feet above the shoreline and is marked by the occurrence of numerous water seeps, which flow out along the top of the clayey bottom-set beds. These clays appear to be flat-lying and are varved. Ten varves were counted in a well-exposed 30-inch section, which suggests (by extrapolation over the 10-

foot probable thickness of these bottom-set beds) a total of approximately 40 varves in the deposit. This is a small number compared with the 1,600 or more varves reported to occur near the mouth of Conne River in Bay d'Espoir (Widmer, 1950). The Port Blandford delta is believed to represent the seaward terminus of outwash that followed down the valley of Northwest River. This route is suggested by the presence of extensive coarse sand beaches and sandy shoals on Northwest Pond (*see* Frontispiece), features rarely found in other lakes in Eastern Newfoundland. The varved basal sediments imply deposition in fresh water. A body of fresh water may well have existed at the west end of Clode Sound at the time of deposition, caused by ice blocking the Sound farther east, perhaps at the narrows. The elevation of the delta indicates it formed later than the 100-foot deltas following partial uplift of this part of the coast.

A thick sand and gravel deposit with a flat upper surface about 100 feet above sea-level occurs near the centre of the village of Port Blandford, facing the southwest end of Clode Sound. Alluvium now clogs the head of the Sound at the mouth of the Southwest Brook in the same manner as outwash has clogged the head of Newman Sound to the north. No stratigraphic section of this deposit has been obtained, as the exposed bluffs (just north of the railway station) are strewn with slumped debris, but the deposit might be a residual part of a delta built by outwash carried down the Southwest Brook into Clode Sound.

Other Deltas

Deposits similar to recognized elevated deltas in eastern Newfoundland have been observed by the writer at the following locations: Traytown (upper surface about 100 feet); Northwest Arm of Alexander Bay (upper surface about 100 feet); Plate Cove (upper surface about 100 feet); Shoal Harbour (upper surface about 55 feet); Northwest Brook in the Southwest Arm of Random Sound (upper surface about 45 feet); Long Beach in the Southwest Arm of Random Sound (upper surface about 50 feet). All the deposits occur at the mouths of fairly lengthy valleys that contain only small streams today. Examination of small sections near the tops of some of these poorly exposed deposits revealed well-bedded, medium to very coarse sands, composed in most locations of quartz, mica, feldspar, and rock particles. According to their stratigraphic position in the respective deposits, these sands have been interpreted as either fore-set or top-set beds.

The occurrence of varved clays at Georges Brook and on Random Island (Hayes, 1948) suggests bottom-set beds of a fresh-water deltaic deposit similar to the one at Port Blandford. These have not been studied by the writer.

Outline of Late Pleistocene Events

Recognition of the various glacial features described on the foregoing pages supplements earlier glacial information sufficiently to permit a tentative outline of glacial events in eastern Newfoundland. Much additional information is needed, however, to formulate the complete sequence of events.

Sequence of Glacial Events

The following sequence of glacial events in Terra Nova and Bonavista map-areas is postulated.

1. Late Pleistocene ice from west of Terra Nova map-area advanced across the two map-areas to the ocean. The direction of movement was north-northeast at the west end of Gander Lake, east throughout much of Terra Nova map-area, but southeast along its southern margin, and generally with an eastward component on Bonavista and Carbonear Peninsulas, where local topographic lineaments governed the final direction of movement. The ice flowed beyond the northern and southern boundaries of the two map-areas, but halted to the east in Trinity Bay. During its advance across the two map-areas, the ice scoured the tops of many high ridges and smeared debris across the low-lying terrain, locally producing distinct residual lineaments that are readily visible on aerial photographs. This advancing body of continental ice probably produced much of the rounded appearance of the terrain in the two map-areas.

2. Subsequent climatic warming resulted in the retreat of the ice-front inland from the coast, leaving most of Bonavista map-area covered with relatively unstratified till. The mixed nature of this debris suggests that the frontal retreat may have taken place relatively rapidly.

3. A new and final ice-front then formed inland from the coast, partly encircling the north and east sides of Terra Nova map-area. The position of its outer edge is indicated by an extensive although discontinuous end moraine, the existence of which has been established with reasonable certainty at nearly a dozen places between Gander Lake and Tug Pond. It is not yet known, however, whether this moraine marks the position of a prolonged stopping point during the general inland retreat of the ice-front or whether it represents the outermost edge of a second advance of the ice from some point of retreat farther inland. In any case, its presence indicates a fairly lengthy interval of cooler climate than existed during the earlier rapid waning of the ice-sheet.

4. A second climatic warming then brought about the more or less simultaneous development of many of the glacial deposits in Terra Nova map-area. These include the discontinuous end moraine, the many eskers that lie inside its arcuate margin, the probable kame terraces at Gambo and along Southwest Gander River, the kames lying inside the end moraine, and the extensive outwash sands and gravels that lie along most of the valleys between the end moraine and the coast. Many of these outwash bodies terminate at the coast as deltas, particularly between Freshwater Bay and Clode Sound.

5. The final, apparently rapid, melting of the ice-sheet then followed, resulting in the release of large volumes of meltwaters, which produced extensive erosion of all the valley fills. The vast quantities of material thus eroded now form broad sandy shoals off the mouths of each major stream valley in the two map-areas.

6. Crustal adjustment to the release of the ice load commenced at some time during the final waning of the ice (stage 4 above), with the coastline around Bonavista Bay rising relative to sea-level. (It is probable that sea-level was also rising as a result of the vast amount of water released by the melting ice-sheets in

the northern hemisphere.) Fresh-water lakes probably developed at the heads of Clode Sound and Random Sound, because of the presence there of varved clays and silts. These deposits now lie 50 to 55 feet above sea-level. Ice blocking the narrow headlands to these sounds would have permitted the development of such fresh-water lakes.

7. Gravel beaches and terraces developed in many small bays during subsequent temporary stands of the sea-level. These deposits now occur at elevations between 15 and 35 feet above present sea-level. The coast-line of Bonavista Bay continues to rise today.

Time of Glaciation

In 1940 MacClintock and Twenhofel suggested on the basis of the unweathered nature of till found throughout the island, that glaciation in Newfoundland occurred in late Pleistocene (Wisconsin) times. Since their paper was published no new information has been reported that would modify this age. Much information on post-glacial dates and climates could be obtained from a study of carbonaceous material in the numerous bogs in the map-areas, as has been done in Cape Breton (Livingstone and Livingstone, 1958). Carbonaceous material at the base of a peat bog near St. John's, southeast of the present areas, yielded a Carbon-14 age of 7,400±15 years (Olson and Broecker, 1958), which provides a rough measure of the length of time since deglaciation.

Chapter IV

GENERAL GEOLOGY

Terra Nova and Bonavista map-areas comprise a fairly substantial part of northeastern Newfoundland, extending from the Atlantic Ocean westward almost to the centre of the island. Within their boundaries is a good cross-section of the northeastern end of the Appalachian mountain system, including Precambrian to lower Palæozoic sedimentary rocks and large intrusive granitic bodies of Devonian age.

The two map-areas can be divided into the following three geological sub-provinces: (1) a folded and faulted Precambrian sedimentary rock belt in the east; (2) a belt of dominantly argillaceous rocks of Ordovician age to the west; and (3) a belt of granitic rocks that separate and intrude the other two. There are in addition four small basins of Cambrian and Ordovician rocks, which are folded and faulted into the Precambrian rocks around Random Sound and at Keels in Bonavista Bay.

The Precambrian rocks consist largely of clastic sediments, but include abundant volcanic rocks in some places. They have been divided into three stratigraphic groups, all of which are locally strongly deformed and cut by high-angle faults. Each group is less deformed, however, than the preceding one. These rocks underlie almost all Bonavista map-area, and about one quarter of the southeastern part of Terra Nova map-area.

The lower Palæozoic bedded rocks comprise a north-northeast trending belt of steeply folded, argillaceous and arenaceous sediments, known as the Gander Lake Group. They include greywackes, slates, and minor volcanic rocks, and represent a fairly typical eugeosynclinal facies. Middle Ordovician fossils have been collected from a few beds in the middle and upper parts of the group. The sediments show a regional increase in metamorphic grade towards the east, and in addition have been locally contact metamorphosed and granitized by the extensive bodies of granitic rocks along their eastern flank. They are not in visible contact with the Precambrian rocks to the east.

Lying between the Gander Lake Group and the Precambrian rocks is a broad belt of granitic rocks that can be traced across Newfoundland from the south to the north coasts. The two map-areas lie across the central part of this north-northeast trending belt. The granitic rocks are generally pink to red, coarse-grained biotite granites, with large euhedral phenocrysts or porphyroblasts of potash feldspar in many exposures. The granites are intrusive bodies of fairly homogeneous composition, except along their eastern flank, where extensive feldspathization, migmatization, and granitization have produced mixed rocks.

Three small structural basins of Cambro-Ordovician rocks lie within the Precambrian rocks in the Random Sound region, a fourth in the Keels area near Cape Bonavista, and a possible fifth basin by Lockers Flat Island in the

northwest part of Bonavista map-area. These rocks are marginal shelf facies, locally rich in fossils, and consist predominantly of shaly units. They occur immediately above the well-known Random Formation, which lies between the late Precambrian Musgravetown red beds and the Lower Cambrian shales. The shales are preserved in steeply folded, locally overturned and much faulted basins. Lithologically they are similar to the Cambro-Ordovician rocks on Avalon Peninsula, and differ markedly from the Ordovician strata in the Gander Lake Group to the west.

Unconsolidated glacial sediments of Pleistocene age truncate all the above units. They include widespread deposits of till and outwash.

Table of Formations[1]

Era	Period (or Epoch)	Rock Units (Thickness in feet)	Lithology
Cenozoic	Pleistocene	Unconsolidated glacial deposits (0–100)	Stratified clays and silts, sands and gravels; glacial till, boulders
		Angular unconformity	
Palæozoic	Devonian or younger		Diabase
		Intrusive contact	
	Devonian		Aplite dykes Leucogranite Ackley batholith; flesh-red, coarsely porphyritic granite; locally contains granitized members of the Gander Lake and Love Cove Groups
		Intrusive contact (into Gander Lake Group)	
	Late Ordovician (?)		Pyroxenite, serpentinite, talc- and quartz-carbonate schists

[1] During the summer of 1962 members of a Geological Survey of Canada field party under the direction of H. Williams discovered Silurian rocks in the northwest corner of Terra Nova map-area. These rocks are red and grey quartzitic sandstones and shales, with minor limestone, and locally contain fossil brachiopods and corals. Four fossil localities were discovered: one in the brook at Lat. 48°54.2′, Long. 54°59.4′, one in the brook at Lat. 48°55.5′, Long. 54°59′, and the other two in Salmon Pond Brook at Lat. 48°59.9′, Long. 54°53.5′. Middle (?) Ordovician graptolites were discovered also in rocks in the same three brooks within half a mile (to the east) of the Silurian rocks. The Silurian rocks belong to the Botwood Group, which Williams (pers. com.) has traced southeastward from Bay of Exploits. They dip steeply eastward, with tops to the west, near their contact with the Ordovician rocks. Williams has interpreted the calcareous strata in Salmon Pond Brook (1 mile west of Glenwood) as basal members of the Botwood Group. His assistants also discovered several outcrops of granite on Salmon Pond Brook at Lat. 48°57.8′, Long. 54°59′-55°00′, and quartz dioritic rocks within a mile to the north.

Table of Formations—continued

Era	Period (or Epoch)	Rock Units (Thickness in feet)	Lithology
	Intrusive contact (into Gander Lake Group)		
Palæozoic (cont'd.)	Middle to Late Ordovician (?)		Diorite, gabbro
	Intrusive (?) contact (into Gander Lake Group)		
	Middle Ordovician	Gander Lake Group (25,000 +)	'*Upper Unit*': shales, argillites, dominantly grey, but some red and green bands; minor graptolitic black argillites and greywackes; locally contact metamorphosed to micaceous schists south of Gander Lake. '*Middle Unit*': greywacke, fossiliferous calcareous argillite and siltstone, black slate, basic lava, tuff; locally contact metamorphosed to mica and amphibolite schists south of Gander Lake. '*Lower Unit*': greywacke, argillaceous and thinly laminated quartzite, some pyritiferous black slate and grey slate; regionally metamorphosed to chlorite and mica schists, mica quartz paragneiss, minor amphibolite; locally contact metamorphosed to micaceous quartzites, cordierite, andalusite, and garnet hornfels; locally feldspathized, migmatized, and granitized.
	Not in contact		
	Late Cambrian to Early Ordovician	Harcourt Group (>488<3,100) Elliott Cove and Clarenville Formations (>393<3,000)	Grey to black shale or slate, siltstone, locally grey to black cone-in-cone limestone concretions
	Middle Cambrian	Manuels River Formation (95)	Grey to black shale or slate; a few thin bands of grey to black limestone

Table of Formations—continued

Era	Period (or Epoch)	Rock Units (Thickness in feet)	Lithology
	Conformable contact		
Palæozoic (cont'd.)	Middle Cambrian	Adeyton Group (1149 +)	
		Chamberlain's Brook Formation (332 +)	Green and red shale or slate, with minor thin bands of pink and grey limestone; thin manganiferous zone at base.
	Early Cambrian	Brigus Formation (343–360)	Red and green shale or slate, with thin bands of red or green limestone; limestone nodules in some shale beds near base.
		Smith Point Limestone (24)	Pink-red limestone, generally massive; minor interbedded red shales with pink limestone nodules
		Bonavista Formation (450–650)	Red and green shales or slates, some thin beds of grey, green, or pink limestone; limy nodules in some shale beds; thin white calcareous granule sandstone at base
	Erosional (angular ?) unconformity		
Precambrian		Random Formation (265–360)	White, greenish grey and pink quartzite, locally crossbedded, and sandstone; grey shale
	Conformable contact		
		Musgravetown Group (10,000 +)	
		Crown Hill Formation (2,500 +)	Red pebble conglomerate, sandstone, some red siltstone; green sandstone
		Rocky Harbour Formation (1,000 +)	Yellowish green crossbedded sandstone
		(Undifferentiated middle unit) (1,000 +)	Grey, green, and red sandstone and siltstone; grey to brown pebble conglomerate
		Bull Arm Formation (>1,600)	Acid and basic lavas, red and grey sandstone and conglomerate, minor pyroclastic rocks
		Cannings Cove Formation (100 +)	Red and green boulder, cobble, and pebble conglomerate; minor red shale and siltstone

Table of Formations—concluded

Era	Period (or Epoch)	Rock Units (Thickness in feet)	Lithology
	No contact (possibly facies equivalent of Musgravetown Group)		
Precambrian (cont'd.)		Hodgewater Group (12,000 +)	
		Snows Pond Formation (4,000 +)	Green to grey, wavy-bedded siltstone and silty slate; minor red bands
		Whiteway Formation (3,500 +)	Red, pinkish white, and grey sandstone and shale, changing (northwards) to red sandstone and conglomerate near Bay de Verde
		Halls Town Formation (4,000 ±)	Massive green to grey sandstone, siltstone, silty slate
	Angular unconformity (below Musgravetown Group)		
		Connecting Point Group (25,000 +)	Green to black greywacke, cherty quartzite, slate; some sandstone and conglomerate; grey to black acidic lavas and pyroclastic rocks; some red cherty quartzites in Random Sound and red siltstones and pyroclastic (?) rocks in Southern Bay
	Angular (?) unconformity (contact not exposed)		
		Love Cove Group (15,000 +)	Thin bedded, acidic to basic lavas and pyroclastic rocks, some interbedded slate, sandstone and conglomerate; now largely regionally metamorphosed to chloritic and sericitic greenschists

DESCRIPTION OF FORMATIONS

Precambrian Rocks

The Precambrian rocks of the two map-areas include three major rock groups and a single additional formation. These are, from oldest to youngest, the Love Cove, Connecting Point, and Musgravetown Groups, and the Random Formation. Some question still exists as to whether the Random Formation is Precambrian or

basal Cambrian (McCartney, in press). Evidence from these two map-areas favours a Precambrian age.

The Love Cove Group is of mixed facies, including clastic sediments, lavas, and pyroclastic rocks, almost all of which are regionally metamorphosed. Individual units are generally less than 50 feet thick. The Connecting Point Group rocks are of eugeosynclinal facies, including much greywacke, black slate or shale, chert, and minor volcanic rocks. These rocks are relatively unmetamorphosed and are commonly in beds many tens of feet thick. The Musgravetown Group rocks are of continental lithofacies, with coarse fanglomerates, volcanic rocks, and cross-bedded sandstones. The Musgravetown Group rocks are in many respects similar to late Precambrian red beds in other parts of Canada. Rocks of the Random Formation have been described as shoreline deposits (McCartney, 1958), hence may be regarded as transitional facies from the continental Musgravetown Group red beds to the marine shelf facies of the Lower Cambrian rocks.

Love Cove Group

Rocks of the Love Cove Group were first recognized as a distinct mapping unit by Kemble Widmer (1949) in 1948 from studies in the region north of Clode Sound, Bonavista Bay. To them he gave the name *Love Cove schists formation,* with the following description:

> "schists formed from conglomerates, sandstones, shales, basic and acid flows and dikes. West of railroad includes non-schistose volcanics".

The name and description appear only on his unpublished map, as no report was written. Love Cove is a small embayment on the south shore of Clode Sound, 3 miles southwest of Charlottetown. A good section of sericite and chlorite schists is exposed there.

The term 'Love Cove Group' was proposed by the writer (Jenness, 1957; 1958b) when it was found that the unit was older than all others in the area, was traceable for many miles to north and south of Clode Sound, and showed indications of being divisible into several formations.

Distribution and Thickness

Love Cove rocks occur in two relatively narrow bands that trend just east of north across the east side of Terra Nova map-area and the northwest corner of Bonavista map-area. Both bands widen southwards to a maximum width of 9 miles. Only the eastern band continues south of the two map-areas, as the western band is cut off by the Ackley batholith. Both bands continue northward into the northern part of Bonavista Bay, the eastern band continuing into the bay, the western band losing most of its identity within the granitic rocks along the north shore of Bonavista Bay. Love Cove, the geographic locality after which the group is named, lies near the centre of the eastern band, where an almost continuous cross-section of chlorite and sericite schists is exposed for a distance of 5 miles along both sides of Clode Sound.

No true indication of thickness is yet possible, as the structure of the group has not been unravelled. A minimum thickness of 15,000 feet is probable.

Lithology

The rocks of the Love Cove Group have three general lithological characteristics: they include a wide variety of sedimentary and volcanic rocks interbedded with each other; they are regionally metamorphosed to rocks typical of the greenschist facies; and individual beds or bands are generally less than 50 feet thick. Thus, many rock types can be observed within a short distance, and in areas of scattered outcrops each outcrop generally differs in lithology from those near it. In this way the Love Cove Group differs from most of the younger groups in the two map-areas, which are generally similar lithologically through considerable thicknesses.

Key horizons have not been recognized in the group. Four generalized lithological subdivisions (map units) have been shown on the accompanying geological maps, but do not possess stratigraphic significance. They are the following:

1. undifferentiated rocks, both sedimentary and volcanic, and including the many chlorite and sericite schists of undetermined origin.

1a. volcanic rocks, including both lavas and pyroclastic rocks, with relatively minor amounts of included schists or metasediments;

1b. metasedimentary rocks, including metamorphosed sandstones, greywackes, conglomerates, and slates, locally also including minor bands of schists and/or volcanic rocks;

1c. granitized and feldspathized equivalents of the above rocks, commonly close to the margins of the Ackley batholith.

From available evidence, the volcanic rocks are most abundant in the southeast corner of Terra Nova map-area, whereas the sedimentary rocks are more common in the northern half of both map-areas. Feldspathized and granitized parts of the group occur along its westernmost exposures, particularly south of Maccles Lake.

Undivided Love Cove Rocks (map-unit 1). In the marsh-covered areas north and a few miles south of Clode Sound, and south of Salmon Pond, rock exposures are too widely scattered for reliable subdivision. The few rocks exposed within these areas are commonly chlorite schists, sericite schists, chlorite-sericite schists, and less commonly epidote-chlorite schists. Many of these rocks probably were originally sediments, but their sedimentary characteristics have been obliterated by metamorphism. Here and there within the undivided parts of the group are small recognizable bands of volcanic rocks, but these do not appear to have much continuity. Areas designated on the two geological maps by the number 1, therefore, consist of mixed sedimentary and volcanic rocks.

Volcanic rocks. Volcanic rocks (map-unit 1a) of the Love Cove Group underlie an extensive area south of Clode Sound, their distribution corresponding closely to an area of high rocky ridges. The eastern half of this area of volcanic rocks consists principally of acidic lavas and pyroclastic rocks, whereas the western half consists mainly of intermediate lavas and pyroclastic rocks, but with some acidic

volcanic rocks and interbedded sediments. Smaller bands of volcanic rocks have been traced for relatively short distances east and west of Salmon Pond, east of Maccles Lake, northward from Charlottetown along the 54°W longitude line to Alexander Bay. Within these relatively narrow bands the volcanic rocks include rhyolites, trachytes (some of which are porphyritic), and andesites. Basalts may be present, but if so have been converted to chlorite schists and are not readily identified. These flow rocks are accompanied by pyroclastic rocks, chiefly tuffs, which have been described as rhyolitic, trachytic, and andesitic according to their colour, composition, and hardness. Very little coarse pyroclastic material has been observed.

Rhyolites range in colour from dark purple to light pink, are uniformly hard and brittle, break with subconchoidal fracture, and locally display excellent columnar jointing. Most of them weather whitish, owing to the high feldspar content, but the weathered rind is rarely more than ⅛ inch thick. Buff or whitish coloured euhedral phenocrysts of feldspar comprise a small part of some of the lavas, and small quartz 'eyes' are generally present. Thick massive rhyolite underlies parts of the high ridge on the south and northeast sides of Tug Pond, and on the crest of the ridge overlooking the Shoal Harbour River valley a few miles farther north. Specimens of rhyolite examined in thin section show that they, like other rocks in the group, have undergone considerable mineral alteration. Clayey aggregates, and chlorite and sericite flakes are commonly developed, and some epidote or zoisite is locally in evidence.

The trachytes are various shades of grey, and contain locally small buff to pale green euhedral phenocrysts of feldspar, and narrow elongate colour streaks that provide a lineation (trachytic structure), which is generally parallel with the local strike trends. These rocks are not plentiful, but have been observed in the Tug Pond, Shoal Harbour Pond, and Salmon Pond regions of Terra Nova map-area. Specimens examined in thin section show that the feldspars are considerably dusted with clay minerals and sericite, and accompanied by small flakes of chlorite, which represent the ferromagnesian component of the rocks. Epidote grains are present in some specimens.

Andesite is almost as plentiful as rhyolitic rocks, and comprises the dominant rock type northwest and southwest of Tug Pond. Thick andesite lavas form parts of the high hills along the west side of Black River Pond. These flow rocks are commonly greyish green, fine grained, rarely porphyritic, and contain scattered veinlets of epidote. They are generally massive, but locally display a minor schistosity. Specimens examined in thin section show that the feldspars are largely altered to zoisite, and that these rocks contain moderate amounts of chlorite. Alteration and schistosity appear to be more extensive than in the rhyolites, probably owing to the absence of quartz and the increased proportion of ferromagnesian minerals.

Basaltic lavas are probably represented within the Love Cove Group, but none has yet been recognized. Some of the dark green chlorite-epidote schists may have originally been basalts.

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Many bands of tuff have been observed within the group. These are commonly composed of sand-sized particles, but in some exposures contain small angular pebble-sized fragments. The types most commonly encountered are buff-purple siliceous varieties interpreted as rhyolitic tuffs, and greyish green varieties interpreted as andesitic tuffs. They generally contain fragments of lava similar to those outcropping nearby. All are considerably altered. Many exposures of tuff occur between Tug and Sleigh Ponds, and immediately southeast of Salmon Pond. Specimens examined in thin section show that sericite and chlorite flakes are abundant, which is in part the reason for the pronounced schistosity of these rocks.

Few coarse pyroclastic rocks have been observed within the group. Andesite agglomerate outcrops 1 mile northwest of Tug Pond. It contains elliptical andesitic bombs up to 8 inches long in a granular tuffaceous matrix. The bombs are flattened in the plane of schistosity. This agglomerate is associated with finer tuffs and lavas, all of which display moderate to strong schistosity.

The recognition of these volcanic rocks as a part of the Love Cove Group is facilitated in many places by the intercalation of either schistose sediments or chlorite and/or sericite schists, for such rocks are not found in younger rock groups in the two map-areas. Such recognition is much hindered, however, by the apparent absence of recognizable schistose units south of Tug Pond, and by the juxtaposition of volcanic rocks belonging to both the Connecting Point and Musgravetown Groups near Traytown and among the islands farther north in Bonavista Bay. These complications may explain why Christie (1950) did not recognize the Love Cove rocks as a separate map-unit.

Metasedimentary rocks. Metamorphosed sedimentary rocks (map unit 1b) are most abundant at the northern ends of the two bands of Love Cove Group rocks, but are locally plentiful around Whitehead Pond, Thorburn Lake, and Clode Sound in the southeastern half of Terra Nova map-area. Sandy facies are dominant, but a few beds of metamorphosed conglomerate and slate have been observed. Practically all are schistose. Thin lava flows are commonly intercalated with these metasediments.

Schistose metamorphosed sandstones and siltstones are extensively exposed north of Glovertown. Some of them, especially those on the ridge on the south side of Glovertown, closely resemble the crossbedded buff-green, lithic sandstones of the nearby Rocky Harbour Formation, which makes it difficult to establish the contact between them. Where these sandstones occur over a considerable area, however, such as north of Glovertown, interbedded schistose units and thin bands of volcanic rocks permit their identification as members of the Love Cove Group. The sandstones are buff-green, greenish grey, dark grey, and rarely purplish. All have a schistose appearance, owing to the alignment of the sericitic and chloritic matrix along the planes of foliation. Specimens examined in thin section show that many of the sandstones are actually feldspathic greywackes[1], with angular to subangular quartz and plagioclase grains in a matrix of chlorite,

[1] As defined by Pettijohn (1957, p. 291).

epidote, or sericite, and finer-grained quartz and feldspar. A few rock fragments are commonly present.

A few outcrops of impure, buff to grey cherty quartzites and black siltstones have been observed within the group. These are thin bedded rocks, and are commonly associated with argillaceous rocks now converted to sericitic and chloritic schists. Specimens from a ridge a mile west of Whitehead Pond, examined in thin section, consist of angular grains of quartz, plagioclase, and opaque mineral in a very fine grained matrix of quartz, feldspar, and chlorite. These rocks are interbedded with more argillaceous rocks on this ridge, and both have been strongly dragfolded.

Argillaceous rocks are probably plentiful within the group, but only a few thin layers have been recognized. One of these is a thin bed of slate sandwiched between two quartzite beds on the southeast shore of Salmon Pond. Its occurrence between two competent beds may account for its preservation as slate in an environment of somewhat higher metamorphic grade. A similar band of slate between bands of quartzite was observed 1½ miles west of Whitehead Pond. Many of the sericite and sericite-chlorite schists within the Love Cove Group are interpreted as metamorphosed argillaceous sediments; their apparent abundance is taken to indicate the originally widespread distribution of fine clastic sediments.

A few thin layers of pebble and granule conglomerate have been observed within the sedimentary sections of the Love Cove Group, examples being at the west end of Shoal Harbour Pond and on the southwest shore of Salmon Pond. In both places the conglomerates are strongly foliated, with the pebbles and granules elongated along the direction of schistosity. The fragments are of metavolcanic and metasedimentary material.

Feldspathized and granitized rocks (map unit 1c). Extensive potash feldspathization of the Love Cove Group has occurred in several parts of the two map-areas, notably west and southwest of Salmon Pond, from Terra Nova Lake north to Maccles Lake, and from Hare Bay northeast across the northwest corner of Bonavista map-area. Almost all the feldspathized and granitized areas are alongside, or close to, large bodies of granite. Two granitized areas around Salmon Pond, however, are 5 to 8 miles from the nearest exposures of the large Ackley granite batholith. Despite apparent remoteness, the granitization there may nonetheless be related to this batholith.

The modification of the Love Cove rocks ranges from incipient feldspathization to extensive and widespread feldspathization. Incipient feldspathization is displayed by chloritic rocks along the railroad tracks 1 mile north of Terra Nova, which contain only a few small flesh-coloured crystals of potash feldspar. More extensive feldspathization occurred in the chloritic schists on the south shore of Maccles Lake and the north shore of Freshwater Bay just west of Hare Bay, where large tabular porphyroblasts of flesh-coloured potash feldspar constitute as much as 50 per cent by volume of the rock. In some localities, such as east and northeast of Black River Pond, and west of Salmon Pond, quartzose rocks contain sufficient pink feldspar to provide a granitic composition and a granite-

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gneiss appearance. In places where incipient feldspathization has occurred the original rock types can be interpreted without difficulty, but where feldspathization has been extensive, the original composition is indiscernible. Some quartz and albite have developed locally along with the potash feldspar.

The feldspathized granitic gneisses or schists generally contain enough chlorite and sericite to display a prominent foliation. Indeed, the presence of patches of these two minerals, either separately or together, and in places accompanied by epidote, has permitted the partial separation of granitized Love Cove rocks from the more homogeneous, presumably intrusive, biotite granites in the Black River Pond, Salmon Pond, and Hare Bay areas.

The feldspars that are developed in the Love Cove rocks are similar to those in nearby granites, being mainly microcline, with a little albite locally in the form of individual grains and as perthitic intergrowths in microcline. Both feldspars generally are moderately altered to secondary clay minerals, and/or secondary mica.

The sedimentary rocks of the Love Cove Group appear to have been the most susceptible to the processes of feldspathization and granitization.

Structure and Metamorphism

One of the most obvious structural features in the rocks of the Love Cove Group is the almost ubiquitous development of a pronounced schistosity. Schistose members of younger groups in the two map-areas are localized either along fault zones or, in the case of the Gander Lake Group, to regional metamorphic zones, but in the Love Cove Group all but the most siliceous rocks are schistose. The schistosity is almost always steeply inclined, with a north to north-northeast orientation. In most outcrops it is the only structural element measurable, for stratification in the volcanic rocks is extremely rare, and that in the sedimentary rocks is generally obscured by the schistosity. Bedding has been recognized, however, in a few exposures such as those 2 miles west of Whitehead Pond, at the east end of Salmon Pond, and on a small peninsula 1 mile north of Traytown. In each of these three places the bedding trends obliquely to the regional trend of the schistosity, and is moderately to steeply inclined. Cleavage-bedding relationships in these localities suggest that at least some of the Love Cove rocks have been strongly folded.

All contacts between the Love Cove and the Musgravetown rocks are shown as faults. Although faults are nowhere exposed, their presence is assumed because of sharp contrasts in attitudes and metamorphism within 100 feet of the contact zone, and the alteration of the two contrasting groups of rocks in narrow bands for so many miles. These faults are probably nearly vertical, because of the straightness of their trends, but a dip of about 45 degrees is indicated where the Salmon Brook fault crosses a ridge just east of Whitehead Pond.

The contact between the Love Cove Group rocks and the metamorphosed rocks of the Gander Lake Group to the west is uncertain, as it is not exposed, and schistosity and metamorphic grades are not appreciably different on each side

of the boundary. This contact may be an angular unconformity, but is more probably a fault or system of faults.

Most of the rocks in the Love Cove Group belong to the greenschist metamorphic facies, characterized by the presence of chlorite, sericite, epidote, and quartz alteration products. Apart from the feldspathized parts of the group near the Ackley batholith, no higher metamorphic grade has been observed within the group; however, a few rocks of apparently lower metamorphic grade have been observed. These include thin beds of slate (mentioned above) and several layers of massive rhyolite that extend north from the Tug Pond area to Shoal Harbour River. Both rhyolites and quartzites have a mineral composition that made them inherently resistant to the low grade metamorphic processes.

Age and Correlation

The regional low-grade metamorphism of the group sets it apart from all succeeding groups within the two map-areas. As pebbles of Love Cove chlorite schist occur in the basal conglomerates of the Musgravetown Group, metamorphism of the Love Cove Group occurred before Musgravetown time. As the Love Cove rocks are more highly folded and metamorphosed than Connecting Point Group rocks, it follows, therefore, that they are the oldest Precambrian rocks in the two map-areas.

They do not resemble the oldest Precambrian rocks (Harbour Main Group) on Avalon Peninsula, with which they have been compared, but their structural trends suggest that they may be related to a volcanic-sedimentary rock sequence at the north end of Burin Peninsula (Bradley, 1962). They are, however, separated from these rocks by part of the Ackley batholith.

Connecting Point Group

The name 'Connecting Point Group' was proposed by Hayes (1948) for a thick sequence of quartzitic rocks exposed at the east end of Clode Sound, in Bonavista Bay. Connecting Point is a prominent peninsula between Clode Sound and Goose Bay. Better exposures of the group occur along the shore of Newman Sound and the shore between Newman Sound and Clode Sound. Much of this shoreline can be walked, permitting detailed study of the rocks.

Hayes originally included the schistose rocks west of Charlottetown in the group, but these rocks have since been incorporated in the Love Cove Group (Jenness, 1957; 1958b).

Distribution and Thickness

Rocks of the Connecting Point Group trend southward from the centre of Bonavista Bay to and beyond the southern limit of Bonavista map-area. The group is flanked by the Musgravetown Group to east and west through much of its extent, but is locally overlain by Cambro-Ordovician rocks in the Random Island area. It underlies about 750 square miles of Bonavista map-area.

Approximately 17,000 feet of Connecting Point sediments are exposed between Newman Sound and Clode Sound, but neither top nor bottom of the group is

present in this section. The total thickness of the group is estimated to be between 25,000 and 30,000 feet.

Lithology

Because of its great thickness without distinctive key beds and formational subdivisions, the lithology of the Connecting Point Group can only be discussed in general terms. Several features are characteristic of the strata in the group. The first is that the rocks are typical of what Pettijohn (1949, p. 443) has called the 'geosynclinal facies', that is, they consist largely of sandy and silty greywackes, black and grey slates, with only minor conglomerates, pyroclastic rocks, lavas, and cherty quartzites, and no carbonate rocks. The second characteristic is that along the coastal exposures these rocks invariably appear whitish on the weathered surface (Hayes, 1948). A third, less diagnostic characteristic, but one nevertheless of considerable mapping value locally, is the widespread occurrence of diabasic dykes within rocks of the group (McCartney, in press). Brief descriptions of the various rock types have been published by Hayes (1948), Rose (1948), Christie (1950), and Jenness (1958b).

Argillaceous rocks are probably the most abundant members of the group, dark grey and black varieties being the most widespread. Grey and greenish grey varieties are exposed in a few places, particularly around Bread Cove in Clode Sound, and around the narrows of Newman Sound. These argillaceous rocks are mainly slates with well developed slaty cleavage, but locally where cleavage is more or less lacking they might be more accurately described as argillites. Many of the black slates enclose thin beds of siltstone and/or crossbedded, fine-grained feldspathic greywacke in a repetitious succession. These sandy beds are generally less than ½ inch thick, but locally they are thicker and are the dominant rock type. Almost all gradations from black slate to feldspathic greywacke have been seen in shoreline exposures. Graded bedding is present in many of these units. Except within the end members of the black slate-greywacke series, few beds of the alternating members are more than 6 feet thick. Thinnest beds occur within the dominantly slaty facies.

Greywackes are probably next in abundance to the slates within the Connecting Point Group. They are various shades of grey to black, and range in grain size from silt to coarse sand. In thin section the greywackes display the following characteristic features: poor sorting; angularity of grain shape; abundance of plagioclase; rock fragments; and chloritic and argillaceous matrix. Carbonate is locally present in amounts exceeding 5 per cent. Facies containing fragments of assorted rock types are locally abundant. The rock fragments are commonly aligned parallel with bedding planes, and consist of sedimentary rocks such as slate and siltstone, and intermediate to basic volcanic rocks. Under the microscope the volcanic rock fragments generally are seen to be only slightly altered mineralogically and, hence, were probably not derived from the Love Cove Group, for the rocks in this group were regionally metamorphosed in pre-Connecting Point time. Composition of the clastic fragments of plagioclase in several thin sections ranged between An_{30} and An_{40}, implying their derivation from an

intermediate-compositioned igneous rock. In eastern Newfoundland the only relatively unaltered volcanic rocks known to be older than the Connecting Point Group are those of the Harbour Main Group on Avalon Peninsula. Rocks of the Harbour Main Group may, therefore, have provided the plagioclase grains and volcanic fragments within the Connecting Point greywackes.

Greenish grey cherty quartzites form another common rock type. They are brittle, hard rocks, with pronounced bedding plane jointing in most exposures. Thin laminae of dark slates or siltstones are locally interbedded with them (Plate III). Individual beds range in thickness from a few inches to 4 feet.

Thin-bedded, red cherty quartzites were observed in the following four localities: (1) just west of Hickmans Harbour on both sides of Random Sound; (2) on the north shore of Smith Sound just west of Clifton; (3) on the southeast side of Cutler Head at the mouth of Southern Bay, Bonavista Bay; (4) on the northwest side of Sweet Bay west of Cutler Head. These are mentioned specifically because they are the only known occurrences of red sediments in thousands of feet of greenish grey to black sediments in the Connecting Point Group. The red quartzites almost all occur within a few hundred yards of rocks of the younger Musgravetown Group, and have in the past been mistaken for them. Such a mistake is easily made on the south shore of Random Sound opposite Hickmans Harbour, where thin bedded cherty quartzites of the Connecting Point Group change colour upward (and eastward) in the section from greenish grey (which is the typical facies in the group) to alternating red and green (in thin beds), and then to red. The red quartzites are overlain abruptly, although not visibly, by reddish pebble conglomerate and basaltic lava. The conglomerate and lava resemble rocks of the Bull Arm Formation near the base of the Musgravetown Group, but the underlying red cherty quartzites do not. Somewhat similar problems of interpretation exist at each of the other three localities where the red sediments are associated with typical Connecting Point sediments. However, structural irregularities that occur at each locality may, on further study, solve the stratigraphic problems.

Conglomerates occur within the Connecting Point Group at only a few localities (Jenness, 1958b). They are generally less than 10 feet thick, of unknown continuity along strike, and are regarded as deposits reflecting brief local conditions at variance with the general environmental and depositional conditions. They may be the product of submarine slides (Kuenen and Sanders, 1956). These conglomerates contain pebbles of quartz and siliceous rocks, and are commonly associated with thin bands of 'washed' sandstone, which approach orthoquartzite in composition.

Volcanic rocks were first recognized within the Connecting Point Group near the Narrows of Newman Sound in 1953 (Jenness, 1958b), and have since been observed by the writer at five other localities around Bonavista Bay. The exact stratigraphic position of these rocks is not yet known, but they appear to lie near the top of the group. The succession of interbedded slates and pyroclastic rocks just west of the Narrows of Newman Sound, which is overlain by andesitic lavas (Jenness, 1958b), provides almost indisputable field evidence that the

volcanic rocks belong to the Connecting Point Group, and in this locality they lie at or near the top of the group. Christie (1950) previously had mapped them in the Musgravetown Group. These volcanic rocks extend northward across the Southeast Arm of Alexander Bay near Traytown, and probably continue across the islands farther north, where lavas outcrop along the west side of Long Reach Island and on Hail Island. Red acidic lavas have also been observed on the northwest shore of Sweet Bay, about a mile north of Wolf Island, and some pink to purplish felsite and acid tuff underlie the basal Musgravetown conglomerate on the east side of Southward Head in Southern Bay. At each of these localities the volcanic rocks lie in the uppermost part of a thick succession of Connecting Point rocks.

North of Alexander Bay it is extremely difficult to distinguish and separate the rocks of the three Precambrian groups from each other, for they all include considerable amounts of acid and intermediate-compositioned volcanic material, and all lie in more or less parallel bands.

Structure and Metamorphism

The base of the Connecting Point Group is not exposed, but rocks of this group are less deformed and less metamorphosed than those of the Love Cove Group, which indicates a period of orogeny prior to deposition of the Connecting Point Group. An angular unconformity between Connecting Point rocks and basal Musgravetown conglomerate on the west side of Southern Bay provides evidence of structural deformation separating these two groups. The few extensive fold directions presently recognized within the Connecting Point Group trend somewhat west of north and hence are at variance with the prominent north-northeast-trending fold axes of the younger Musgravetown rocks. Deformation of the rocks of the Connecting Point Group was not intense, however, for in places they are almost flat-lying. Much of the close folding seen along the shores of Newman Sound occurs within incompetent slate members of the group.

Metamorphism of the Connecting Point Group is limited to the development of quartzites from sandstones, and slates from shales.

Age and Correlation

No fossils have been found in the Connecting Point Group. Structural evidence provides a reliable indication of the stratigraphic position of the group, however, for it lies with angular unconformity beneath the Musgravetown Group, which in turn lies a few hundred feet beneath fossiliferous Lower Cambrian rocks. No absolute age can be given the group, but it is presumably fairly late Precambrian.

Comparison with the Conception Group around Conception Bay has been made by Hayes (1948), Rose (1948, 1952), and McCartney (in press). There is no question that the rocks of the two groups have many aspects in common, both lithologically and structurally. However, the Conception Group underlies the Cabot Group near St. John's, and the Hodgewater Group between Conception and Trinity Bays, whereas the Connecting Point Group underlies the Musgravetown Group. As McCartney (in press) has not been able to correlate directly

the Cabot, Hodgewater, and Musgravetown Groups, it is not possible to make direct correlation of the Connecting Point and Conception Groups.

Musgravetown Group

The name Musgravetown Group was proposed by Hayes (1948) for a thick succession of red and green, coarse clastic sediments and interbedded volcanic rocks that overlie the Connecting Point Group and underlie the Random Formation and/or Lower Cambrian shales in Bonavista and Trinity Bays. Musgravetown is a village in Goose Bay, about 4 miles south of Connecting Point. Better exposures of the Musgravetown Group are found in other parts of Bonavista map-area than around Musgravetown, but no complete section occurs in any one locality.

Detailed mapping of the Musgravetown Group south of Random Sound has resulted in the establishment of several formations within the group in the Sunnyside and Dildo regions (McCartney, in press). Two of these, the Bull Arm and Crown Hill Formations, outcrop in the present map-areas. Formational names are proposed in this report for two other map-units, which have not been recognized south of Random Sound. A fifth division of the Musgravetown Group is recognized, comprising the rocks between the upper two formations and the lower two, but it is too little known for formational definition. It forms part of the areas shown as 'undivided Musgravetown rocks' on the two geological maps accompanying this report.

Distribution and Thickness

Rocks of the Musgravetown Group occur in three roughly parallel bands that trend north-northeast across the two map-areas. Best exposures are in Bonavista map-area, where much of Bonavista Peninsula is underlain by the group. All three bands extend southwestward from Bonavista Bay to beyond the southern boundaries of the two map-areas.

The thickness of the group is roughly estimated to be 10,000 feet.

Lithology

The rocks of the Musgravetown Group differ markedly from those of the underlying Connecting Point Group in colour, texture, mineral composition, and origin. The Musgravetown Group rocks are chiefly red and green, coarse-grained conglomerates, subgreywackes[1], arkoses[1], and acidic to basic lavas, of relatively shallow-water, continental or epicontinental origin. They are thus markedly different from the Connecting Point Group rocks, which are generally monotonously repetitious, grey to black, fine-grained greywackes and slates, of relatively deep-water, marine origin.

The areal distribution of the several formations is best known in the Random Island area; elsewhere formational boundaries are either assumed or are not yet established.

[1]Classification of Pettijohn (1957, p. 291)

Cannings Cove Formation. The name Cannings Cove Formation is proposed here for the lowest formation in the Musgravetown Group. It is a coarse conglomerate with minor shale and siltstone, and is highly variable in thickness. The formation is named after the village of Cannings Cove on the west shore of Goose Bay in Clode Sound where it is well exposed.

The only complete section of the formation yet known is on the east side of Southward Head, 13½ miles east-northeast of Cannings Cove. The formation there is only 100 feet thick, although it is much thicker in incomplete sections exposed elsewhere. At Southward Head, moderately dipping, red conglomerate overlies with angular unconformity steeply dipping rocks of the Connecting Point Group (*see* Plate IV). Most of the fragments are cobble size, ranging from 6 to 10 inches in diameter, but a few boulders up to 16 inches diameter occur just above the erosional contact. The boulders and cobbles are mostly angular to subrounded fragments of red lavas and sandstones, and comprise about 30 per cent of the conglomerate. The other 70 per cent consists of poorly sorted pebbles and various-sized sand grains of the same rock types. The red colour of the conglomerate is caused by the red colour of the fragments. A few greenish grey pebbles are also present. The conglomerate is overlain by several hundred feet of andesitic and basaltic rocks of the Bull Arm Formation on the east side of Southward Head. On the west side of the Head, however, the conglomerate is missing, and Bull Arm basalt is faulted against steeply dipping Connecting Point beds.

The formation is not present at Cutler Head (3 miles northwest of Southward Head), where volcanic rocks and interbedded pinkish grey sandstones of the Bull Arm Formation are faulted against Connecting Point rocks. It is present, however, on the west side of Sweet Bay, 3 miles southwest of Cutler Head, where it has been faulted against steeply dipping Connecting Point volcanic and clastic rocks. In this locality, a green conglomerate underlies the red conglomerate. Although neither the base nor the top of the formation is present, the conglomerate there is just over 200 feet thick. It is thus at least twice as thick there as it is in the complete section at Southward Head, 3½ miles to the east. The cobbles in both red and green conglomerates are subangular to subrounded, and average between 4 and 5 inches in diameter, with some up to 8 inches. A few boulders are present as well. Both boulders and cobbles are poorly sorted, and occur within a poorly sorted sandy and pebbly matrix. Bedding is almost indiscernible. The green conglomerate consists of buff to grey and greenish grey fragments of Connecting-Point-type cherty quartzites. A few fragments of reddish felsite, porphyritic felsite, and sandstone occur in the green conglomerate and become increasingly abundant upwards in the section. They are the dominant rock types in the upper 100 feet. Their relative abundance therefore governs the colour of the conglomerate at this locality, green in the lower half, red in the upper half. Fragments in the upper half are typical of Musgravetown sediments and volcanic rocks found elsewhere. The reddish conglomerate that comprises the upper part of the formation there resembles the reddish conglomerate at Southward Head, 3½ miles to the east. The underlying green conglomerate thus appears to be an additional member at the base of the formation and the group.

The thickest known section of the formation occurs along the west shore of Goose Bay around the village of Musgravetown, where the formation consists of a thick sequence of greenish conglomerate overlain by reddish conglomerate, the general succession being similar to that at Sweet Bay, 11 miles to the northeast. Thicknesses near Musgravetown however, are far greater, for the green conglomerate is at least 1,700 feet thick and the overlying red conglomerate at least 700 feet thick. The base of the formation is not exposed, although it probably lies within a few tens of feet of the lowest exposure at Cannings Cove. From Cannings Cove to Man Point, a mile to the south, the conglomerates are green, consisting chiefly of fragments of Connecting-Point-type rocks. From Man Point south around much of the rest of Goose Bay, the conglomerates are red. A fairly thin band of conglomerate transitional between red and green lies between the two members. Some sandy units are interbedded with the red conglomerates. The top of the formation is not exposed in this section. Hayes (1948) named the Musgravetown Group on the basis of the rocks exposed along the shore of Goose Bay near Musgravetown; these rocks are now known to comprise only the bottom part of the group.

A 340-foot section of the formation is exposed 3 miles to the northwest, on the south shore of Clode Sound. The bottom members are not fully represented. This section consists of the following units:

Unit	Lithology	Thickness (feet)	
		Unit	Above base
12	Grey basalt porphyry (base of Bull Arm Fm. ?)	20	
	Conformable contact		
11	Red pebble conglomerate, coarsening upward to rounded cobbles, 6–8 inches diameter	30	339+
10	Red shale (or argillite) with pebble beds	15	309+
9	Red pebble conglomerate	4	294+
8	Red argillite and siltstone, very fissile	10	290+
7	Red, rounded pebble conglomerate, friable	10	280+
6	Red shale (or argillite), much fractured	40	270+
5	(not exposed)	75+	230+
4	Red conglomerate, poorly cemented	20	155+
3	Greyish green conglomerate, with red fragments; very coarse sized pebbles and cobbles	40	135+
2	Greyish green pebble conglomerate, cobble beds, very poorly cemented	20	95+
1	Green silty pebble sandstone and conglomerate, sandstone at base	75+	75+
	Fault contact		

The lowest visible member of the formation is faulted against Connecting Point siltstones, so that the basal members of the formation may have been omitted. Nevertheless, enough of the formation is present to indicate that it is much thinner in this section than near Musgravetown.

On the north shore of Clode Sound near Bread Cove, the Cannings Cove Formation consists of about 100 feet of red conglomerate, with neither top nor bottom exposed. Some green conglomerate could lie concealed beneath overburden, however, along the east side of the red conglomerate. The material in the red conglomerate is angular to rounded, poorly sorted, and vaguely bedded. Fragments range from sand-sized particles to 6-inch cobbles, and rare boulders. The rock types comprising the cobbles in the red conglomerate there include sandstones, conglomerates, and lavas similar to some of the members of the Musgravetown Group elsewhere, as well as cherty quartzite of the Connecting Point Group, and schists of the Love Cove Group. A pebble of pink granite of unknown origin was seen in the conglomerate at this locality. The red conglomerate is overlain by an almost complete section of the Bull Arm Formation.

The formation appears to have been cut off by a fault 3 miles northwest of Bread Cove, and has not been recognized farther north. Nor has it been recognized with certainty more than a mile or two south of Goose Bay. The formation thus appears to be a wedge-shaped unit at the base of the Musgravetown Group, of local distribution, thickest around Goose Bay and thinning in all directions from this centre. It has not yet been recognized more than 15 miles from Goose Bay. Hayes (1948) interpreted the deposits as originally alluvial fans adjoining uplifted fault blocks; this interpretation still fits the available evidence. As the upper part of the formation contains fragments that resemble lavas and sediments of the Bull Arm Formation, and as the Bull Arm Formation is the basal member of the Musgravetown Group to the south, and perhaps also north, of Goose Bay, the Cannings Cove Formation is apparently restricted in distribution and probably contemporaneous with parts of the Bull Arm Formation in adjoining regions.

Bull Arm Formation. Hayes (1948) recognized the presence of a thick volcanic unit above the basal conglomerate of the Musgravetown Group to which he gave the name 'Bull Arm Felsite Member' for its occurrence along Bull Arm, Trinity Bay. The Bull Arm 'member' does not appear around Musgravetown village on his geological map, although volcanic rocks are widespread in that area. The unit was elevated to formational status by McCartney (1958). In the present report, the base of the formation is arbitrarily selected at the lowest volcanic member. The top of the formation is likewise placed at the top of the uppermost volcanic member (W. D. McCartney, oral communication), although it has not yet been located in the present area. It is realized that these boundary limits may not necessarily be at the same stratigraphic and time horizon in all areas, for the nature of the formation makes it probable that marginal limits will be gradational and/or interfingering.

The formation has been recognized in several parts of the two map-areas (*see* accompanying geological maps), and volcanic rocks, which probably belong to the formation, have been observed in the following additional places (not indicated on the geological maps):

1. At the head of Little Content Cove in Pitt Sound Reach

2. On the south shore of Rocky Bay (north of Glovertown), within half a mile of the eastern contact of the Musgravetown Group
3. On the ridge on the northwest side of Glovertown
4. Two miles west of Glovertown
5. On the Terra Nova River 5½ miles above its mouth
6. On the railroad tracks a few hundred feet northwest of Thorburn Lake
7. On Southward Head above the basal Musgravetown conglomerate
8. On the north shore of Smith Sound opposite Britannia
9. On the south shore of Random Sound opposite Hickman's Harbour
10. On the brook northwest of Whitehead Pond.

Volcanic rocks in localities 1, 2, and 5 above may belong to formations stratigraphically above the Bull Arm Formation, for they seem to lie near the top of the group, within the Rocky Harbour Formation. The volcanic rocks at localities 8 and 9 above are stratigraphically out of place relative to adjoining Musgravetown rocks, and have probably been faulted into their present position.

The formation lies immediately above the red basal Cannings Cove conglomerate at Southward Head, and just west of Bread Cove. At Southward Head, somewhat over 250 feet of basaltic lavas (representing only a part of the formation) are exposed. Nearby at Cutler Head the formation consists of approximately 1,600 feet of mixed volcanic and sedimentary rocks, but it has been faulted against the Connecting Point Group and the Cannings Cove Formation is absent. Several bands of sandstone and tuff are interbedded with the basic lavas at this locality.

The entire Bull Arm Formation is present on the north shore of Clode Sound just west of Bread Cove, but is incompletely exposed. Its thickness there has been estimated at somewhat over 2,500 feet (Jenness, 1958b). In this section the lower half of the formation consists of basaltic lavas with interbedded red conglomerates and sandstones, which conformably overlie the red conglomerate of the basal Cannings Cove Formation. The upper half of the formation consists largely of red, grey, and purplish felsitic lavas. A similar sequence of basic volcanic rocks, overlain by more acidic varieties, has been noted in the formation south of Bonavista map-area (McCartney, in press). Thicknesses of the formation in other parts of the present map-areas are not known.

Basaltic lavas are well exposed on the north shore of Clode Sound west of Bread Cove. They are commonly dark grey to black, fine grained, and massive or amygdaloidal. As seen under the microscope, they are relatively unaltered rocks, with calcic plagioclase, pyroxene, and iron oxide as the principal minerals, and an ophitic to diabasic texture. Oxidized amygdaloidal tops are recognizable in some of these lavas. Patches of serpentine in a basalt exposed in Milners Cove on the south side of Clode Sound suggest that it was originally an olivine basalt. Basaltic rocks have been seen in other places where the formation is recognized, but their stratigraphic position within the formation in these places cannot generally be established. McCartney (1958) has drawn attention to the similar mineralogy of the basaltic lavas in the Bull Arm Formation and that of the many basic dykes

within the Connecting Point Group, and has suggested a common origin for the two.

Andesitic lavas are well exposed west of Bread Cove in association with the basalts, trachytes, and rhyolites. They have a lighter colour (generally greenish grey) than the basalts, and contain a higher proportion of plagioclase to pyroxene. Alteration is extensive in some of the andesitic specimens examined under the microscope, and plagioclase compositions could not be determined.

Acidic lavas near the top of the formation in Clode Sound include brittle dusky red purple trachytes, grey rhyolites, and blood-red rhyolites that commonly contain small quartz phenocrysts. Red felsitic rocks form the ridge behind Clarenville and occur for about ½ mile along the west shore of the Southwest Arm of Random Sound. Acidic lavas are also fairly abundant on the islands east of Bloody Reach, north of Glovertown. Viewed under the microscope most of these acidic lavas are moderately altered to chlorite, carbonate, and clay minerals.

Pyroclastic rocks have been recognized in association with the lavas and sedimentary rocks in a few localities, notably (1) at Cutler Head, (2) south of Plate Cove, (3) on and near the Terra Nova River 8 miles south of Glovertown, (4) 2 miles west of Glovertown, and (5) on the south shore of Cottel Island. These are chiefly acidic tuffs. Some contain lapilli. A band of light grey weathering tuff on the west side of Cutler Head is more than 40 feet thick. A few bands of agglomerate and volcanic breccia have been observed.

Thin beds of red shale, sandstone, and conglomerate occur within the Bull Arm Formation along Clode Sound, at Cutler Head, and southwest of Clarenville. Their areal continuity is not known. Faintly crossbedded pinkish grey subgreywackes and grey sandstones that are interbedded with lavas along the brook northwest of Whitehead Pond may be a part of the Bull Arm Formation.

Undifferentiated middle formation(s). A complex of clastic sediments lies between the volcanic rocks of the Bull Arm Formation and the top two formations in the Musgravetown Group. These rocks have not as yet been subdivided, but from the variety of included rocks, they will probably be divided into at least two formations. These rocks occur mainly east of the easternmost Cambrian basin on Bonavista Peninsula. Because of their gently folded structure in this region, individual members undoubtedly underlie broad areas. Well over 500 feet of strata are included within this unit.

The many rock types observed within this part of the Musgravetown Group include reddish grey, grey, and greenish grey, lithic sandstones and siltstones, which are locally well crossbedded, pebble conglomerates ranging from grey to brown, and a few thin bands of red sediments. The grey lithic sandstones and siltstones have been observed only in the eastern half of Bonavista Peninsula and resemble parts of the Snows Pond Formation on the Carbonear Peninsula. Mixed reddish grey and greyish, fine sandy sediments along the south shore of the Southwest Arm of Random Sound east of Hodges Cove have no known counterparts elsewhere in Bonavista map-area, although they do continue southward into Sunnyside map-area (McCartney, 1958). Red sandstones and shales are exposed above the Bull Arm Formation west of Bread Cove in Clode Sound, and at Port

Blandford. Exposures in these areas, however, are too widely scattered to permit establishment of a stratigraphic succession, or even to indicate the dominant facies. These red sandstones contain considerable amounts of sand-sized rock fragments and plagioclase grains, and are more accurately described as arkoses or subgreywackes[1], depending upon the proportion of these two components. Both types have been identified.

Rocky Harbour Formation. The name Rocky Harbour Formation is here proposed for a succession of crossbedded, yellowish green, lithic sandstones that underlie the Crown Hill red beds at the top of the Musgravetown Group at Rocky Harbour, near the east end of Random Sound. The formation is estimated to be about 1,000 feet thick, although the base of the formation is not exposed there. A 500-foot section is exposed in a cliff just east of Rocky Harbour, at least another 50 feet can be seen in the clear water beneath the cliff, and an additional 300 to 400 feet overlie the strata at the top of the cliff. The formation has been recognized from St. Jones Within, northward across Random Island and for several miles north of Smith Sound. Similar strata occur at Kings Cove in Bonavista Bay, west of Terra Nova River a few miles above its mouth, and north of the Northwest Arm of Alexander Bay. Representative specimens examined in thin section reveal that the Rocky Harbour sandstones consist largely of angular to subangular grains of feldspar and quartz, and fragments of schists and volcanic rocks, in a matrix of clayey material, epidote, chlorite, and iron oxide. The sandy particles are poorly sorted, and have evidently been transported only a short distance from their source. Most of the sandstones are more accurately classified as subgreywackes (Pettijohn, 1957, p. 291); a few, however, contain more feldspar than rock fragments and are classified as arkoses. From their composition, it appears that they have been derived from schists of the Love Cove Group, as no other rocks presently exposed in eastern Newfoundland contain so much altered material (e.g. chlorite, epidote, and clay materials) relative to quartz.

Crossbedding attitudes around Alexander Bay suggest that the sediments came from the southwest, whereas crossbedding attitudes in the type locality at Rocky Harbour suggest that the sediments there came from the northwest. Directions thus appear to converge on an area west of Clode Sound where rocks of the Love Cove Group even now yield sand-sized fragments of chlorite, epidote, and sericite-rich schists, owing to the dominance of greenschist facies over other rock types in this region. A different composition of sediment would have resulted from the erosion of the acidic volcanic rocks that occur in the Love Cove Group farther south, which may explain why the Rocky Harbour Formation is not recognizable south of Bonavista map-area.

Crown Hill Formation. The name Crown Hill is given by McCartney (1958) to the formation below the Random Formation around Crown Hill, 6 miles south of the Southwest Arm of Random Sound. In its type locality the formation is chiefly a red pebble conglomerate. This type of rock is found immediately below the Random Formation on both sides of the Northwest Arm of Random Sound

[1] On the basis of the classification of sandstones in Pettijohn (1957, p. 291).

near Hickman's Harbour, and for a short distance north of Random Island. The formation also underlies the Random Formation at Keels in Bonavista Bay. In each of these regions (except in the type locality) it overlies the greenish, crossbedded sandstones of the Rocky Harbour Formation. A similar red pebble conglomerate overlies crossbedded green sandstone (Rocky Harbour Formation?) at the mouth of Content Reach near the northwest corner of Bonavista map-area, and appears also on Deer Island. The formation has not been recognized in Terra Nova map-area.

East of Hickman's Harbour the formation is fully exposed on both sides of Random Sound, and is estimated to be 2,500 feet thick. Interbedded with the rounded pebble conglomerate that forms much of the formation are red sandstones and minor amounts of red siltstones and grey to greenish grey sandstones. The colour of the Crown Hill Formation is attributed mainly to the red colour of the volcanic material that composes the pebbles and sand-sized particles in the conglomerates. A thin red oxide coating occurs on the sand-sized or smaller particles.

In the Kings Cove-Keels region the formation is thicker and contains less conglomerate and more sandstone than on Random Island. An excellent section is exposed along the coast north from Kings Cove Head, where an estimated 3,000 feet of the formation overlies green sandstones of the Rocky Harbour (?) Formation. The upper part of the formation lies beneath the sea just east of the village of Broad Cove (also known as Dunterra), but about 1,500 feet of the formation underlies the Random Formation at Keels nearby. There may be some overlapping of strata in the two sections, as they have not yet been matched to ascertain the complete, though composite, section. The section north from Kings Cove Head is described below, as measured by H. W. Dodge, Jr., the writer's assistant in 1957. A metallic tape was used to measure the strata. Allowing for some repetition of beds because of faulting at Broad Cove (Dunterra), the total thickness of the Crown Hill conglomerate in the two sections between Kings Cove Head and Keels is between 3,000 and 4,000 feet.

Unit No.	Lithology	Thickness (in feet)	
		Unit	Above base of formation
	Upper contact concealed below sea-level		
20+	Red feldspathic[1] sandstone, undivided	1,600+(estim.)	3,009+
19	Pink to red feldspathic sandstone, minor yellowish bands	300	1,409
18	Maroon arkose and argillite with a few thin (3-4 inches) buff bands throughout. One 3-foot blue-green, fine-grained quartzitic sandstone bed about middle of unit	200	1,109
17	Thick-bedded maroon feldspathic sandstone and argillite, with narrow buff bands	220	909

[1] As used here feldspathic sandstone is a field term indicating the recognition of feldspar in outcrop. These rocks are more accurately designated as arkoses or subgreywackes (Pettijohn, 1957) depending on the relative proportions of rock fragments to feldspar they contain.

16	Similar to unit 1	15	689
15	Alternating red feldspathic sandstone and quartzitic sandstone with beds of buff, and green and buff sandstone, the latter comprising about 50%; thin bedded	120	674
14	Red, fine-grained quartzite or quartzitic sandstone	6	554
13	Alternating beds of maroon and buff sandstone, buff streaks in the maroon beds; minor green to blue-green beds	45	548
12	Alternating maroon and buff sandstones	50	503
11	Red sandstone with buff beds	40	453
10	Red sandstone with buff beds. Minor erosional disconformity 6 feet above base	30	413
9	Red sandstone with prominent buff streaks, well jointed	85	383
8	Thick bedded red feldspathic sandstone with buff laminations; minor granule and small-pebble conglomerate	75	298
7	Alternating red granule conglomerate and lithic sandstone; minor buff beds; lowest 3 feet green to buff conglomerate with green and red silt laminations	33	223
6	Red granule and small-pebble conglomerate	18	190
5	Mixed red feldspathic sandstone and granule conglomerate composed as follows: red feldspathic conglomerate, minor fine-grained red feldspathic sandstone ..... 10 ft. grading down into red feldspathic sandstone with minor conglomerate and buff sandstone ..... 9 ft. red feldspathic sandstone with minor conglomerate ..... 5 ft. — — — — disconformity — — — — massive green-yellow fine-grained sandstone ..... 5 ft.	29	172
4	Greenish buff and red feldspathic sandstone, the former dominant	20	143
3	Similar to unit 1, but lower 3 feet mainly white to buff	16	123
2	Similar to unit 1	7	107
1	Red and buff banded feldspathic sandstone, red argillite, several granule conglomerate layers spaced at 2-4 foot intervals, lensing; considerable contemporaneous sedimentary fold structures	100	100

Conformable contact; top of green sandstone (Rocky Harbour? Formation)

Christie (1949 field notes) reported the presence of red sandstones and conglomerates at the mouth of Content Reach. On the basis of outcrop distribution, the section there is approximately 2,800 feet thick. These red clastic rocks overlie a thick sequence of green and buff crossbedded subgreywackes, which probably belong to the Rocky Harbour Formation. The red beds lie within a north-northeast plunging syncline and their upper members are beneath the sea. Christie also noted red sandstone and conglomerate on Deer Island, on what might be the east limb of the same syncline.

Structure and Metamorphism

The base of the Musgravetown Group lies with pronounced angular unconformity upon rocks of the Connecting Point Group on Southward Head (*see* Plate IV), and the top of the group is conformably beneath the Random Formation in Random Sound (*see* Plate V A). Within the group the Bull Arm Formation lies apparently conformably upon the basal Cannings Cove Formation, as seen at Southward Bay and in Clode Sound. The top of the Bull Arm and the base of the Rocky Harbour Formations have not been seen in either of the two map-areas. The Rocky Harbour Formation lies conformably below the

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Crown Hill Formation. Minor erosional unconformities occur locally within the group.

Folds within the group are generally broad and gentle, with north-northeast trending fold axes throughout Bonavista map-area and in parts of Terra Nova map-area. Broad open anticlinal domes, which apparently change along strike to equally open synclinal basins, are particularly well exposed near the east end of Bonavista Peninsula; this type of structure is representative of the type of folding throughout the group, the rocks appearing less folded than the Connecting Point rocks. Evidence within the present map-areas indicates that the group was folded together with the Cambro-Ordovician rocks above it in the Random Sound area, although the latter, less competent beds were locally more severely folded.

Many faults occur within the Musgravetown Group, chief amongst which are the N15°E boundary faults, which produced the sandwich-like alternation of Musgravetown Group strata with older rocks. These faults are discussed in the following chapter.

Rocks of the Musgravetown Group are essentially unmetamorphosed, but a few shales and sandy units, which are believed to lie above the Bull Arm Formation, have been thermally metamorphosed by granite at the east end of Pitts Pond near Terra Nova. These sediments were originally red, but have been converted to bluish grey (specular hematite) as much as a mile from the granite contact. Within a few hundred feet of the contact they have been converted to cordierite and garnet-mica hornfels.

Age and Correlation

As the upper part of the Musgravetown Group lies conformably below the relatively thin Random Formation, which in turn almost conformably underlies the oldest known Lower Cambrian strata in eastern Newfoundland, the group is interpreted as being late Precambrian.

The Musgravetown Group continues south of the present map-areas where McCartney (in press) has traced it through facies changes into part of the Hodgewater Group. Part of the latter group closely resembles part of the Cabot Group near St. John's, but direct correlations between the Musgravetown and Cabot Groups are not possible.

Hodgewater Group

The name Hodgewater Group was proposed by Hutchinson (1953) for a sequence of four sedimentary formations exposed along the road between Brigus and Whitebourne on Avalon Peninsula. The four formations were subsequently traced northward along Carbonear Peninsula, and southward and southeastward by McCartney (1954; 1956; in press).

Distribution and Thickness

Three of the four formations of the Hodgewater Group occur at the northern end of Carbonear Peninsula, in the southeast corner of Bonavista map-area. The

basal formation of the group, the Carbonear Formation, is not present. The Halls Town Formation occurs only south of Caplin Cove in Conception Bay, in a small infaulted (?) block north of Old Perlican, and along the north shore of Carbonear Peninsula at Grates Cove. The Whiteway Formation underlies all of the northern part of the peninsula and Baccalieu Island, and the Snows Pond Formation underlies the southwest part of the peninsula, as contained within Bonavista map-area. The boundaries for these three units were indicated by Christie (1950), but their separation into the Halls Town, Whiteway, and Snows Pond Formations resulted from a joint examination of critical areas by the writer and W. D. McCartney in 1957.

The approximate thicknesses of these formations in Bonavista map-area are: Halls Town Formation—4,000 feet; Whiteway Formation—over 3,500 feet; Snows Pond Formation—over 4,000 feet. The total stratigraphic thickness of the Hodgewater Group in Bonavista map-area may thus be as much as 12,000 feet.

Lithology

As the lithological composition of the formations of the Hodgewater Group has been described in detail by Hutchinson (1953) and McCartney (in press), only brief résumés of the upper three formations are included in this memoir. McCartney has found that the various facies continue unchanged along strike for many miles to the south, and only in the Whiteway Formation in the present area does there appear to be an important facies change.

Halls Town Formation. The Halls Town Formation consists of buff-weathering, massive green to grey feldspathic sandstones, siltstones, and silty slates. Wave ripple-marks that are exposed along the road just south of Caplin Cove are apparently common structures in many parts of the formation. The base of the formation is not present in Bonavista map-area, but the formation there is lithologically similar to the formation in the map-area to the south (McCartney, in press).

Whiteway Formation. The Whiteway Formation consists of red, pinkish white, and grey feldspathic sandstones and shales in the southern half of their exposure in Bonavista map-area. Northward these rocks grade into red sandstones and conglomerates, with the latter dominant on Baccalieu Island. This type of facies change was not observed farther south along Carbonear Peninsula, but is similar in many respects to the facies change in the upper part of the Signal Hill Formation near St. John's about 35 miles to the south (McCartney, in press). Cross-bedding is locally present within the sandstone.

Snows Pond Formation. The Snows Pond Formation consists of green to grey, wavy-bedded siltstones and silty slates, commonly weathering a light buff colour. A few thin red bands occur in the upper part of the formation on the shore just west of New Chelsea. The filmy-thin wavy beds are present at many horizons, and are a characteristic feature of the formation throughout much of its continuation in map-areas farther south.

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Structure

The three formations are in conformable succession in Bonavista map-area; the lowest and uppermost contacts of the group are not exposed. All three have been gently folded into broad synclines and anticlines trending northeast. A major strike fault, not observed in outcrops, is suggested by structural irregularities west and southwest of Caplin Cove. A shorter strike fault appears to bring to the surface a wedge of the Halls Town Formation 2 miles north of Old Perlican, but it also has not been observed in outcrops. No other faults are known in the area.

Age and Correlation

As the Hodgewater Group underlies the Random Formation, which in turn underlies Lower Cambrian strata in Trinity Bay, its age is considered as late Precambrian.

Partial lithological correlations with units of the Musgravetown Group to the west and the Cabot Group to the east have been made (McCartney, in press), but it is impossible to correlate directly owing to the geographic distribution of the three groups.

Random Formation

The name 'Random terrane' was introduced by Walcott (1900a) for arenaceous and quartzitic beds lying between Signal Hill conglomerate (Crown Hill Formation of this report) and overlying Cambrian beds in eastern Newfoundland. Walcott's paper included a measured section of these beds just east of Hickmans Harbour on Random Island. Hayes (1948) used the term 'Random formation' but included units within it that are now interpreted as part of the Musgravetown Group. Christie (1950) redefined the formation and established its type section as the exposures originally described in Walcott (1900a). This section is on the west side of the tight syncline that is exposed on the south shore of Random Island, immediately east of Hickmans Harbour (*see* Plate IV B)

Distribution and Thickness

The formation occurs along the flanks of the four northeast-trending Palæozoic basins in the southern half of Bonavista map-area, and may also underlie Lockers Flat Island in the northwestern corner of the same map-area. It is not present in Terra Nova map-area.

In its type locality on the west limb of a syncline just east of Hickmans Harbour, the Random Formation was originally reported as 415 feet thick (Walcott, 1900a). This thickness, however, included a basal unit 31 feet thick that is now regarded as part of the underlying Musgravetown Group. The thickness was subsequently reduced to 360 feet in a re-measurement by A. M. Christie (1950, field notes). Christie's subdivisions differ appreciably from Walcott's (*see* Figure 7). Christie also noted that the thickness of the formation on the *east* side of the syncline at the type locality was only 266 feet. Neither section is completely exposed, and both contain at least one closed fold. A probable fault further complicates the type section making reliable measurement more difficult.

Christie measured the following thicknesses in complete or nearly complete sections of the Random Formation:

Milton..... 271 feet
Keels ..... 265 feet, on the west limb of the syncline
Keels ..... 339 feet, on the east limb of the syncline

Two almost complete sections of the formation are exposed at Burn Point in Smith Sound, and a third occurs on the north shore of the Southwest Arm of Random Sound, between Hatchet Cove and St. Jones Within. These sections have not been measured, but from figures given by Hayes (1948) the Random Formation on the east limb of the syncline at Burn Point is about 370 feet thick. The two sections at Burn Point would provide reliable thicknesses, for the rocks stand almost vertically and do not appear to be otherwise folded or faulted, whereas the rocks in the section near Hatchet Cove are folded and locally shattered.

An estimated 1,300 feet of strata exposed on Lockers Flat Island, including one thick white quartzite band, bear a strong resemblance to parts of the Random Formation, and have been shown as Random on the Bonavista geological map. If they are actually Random strata they indicate a marked thickening of the formation northward. The formation apparently thins southeastward across Trinity Bay (McCartney, in press).

Lithology

The Random Formation in Bonavista map-area is made up of a mixture of sandy sediments ranging from white quartzite, its most characteristic member, to greenish grey or grey shaly sandstones, to pink crossbedded quartz sandstones or quartzites. Details of the stratigraphic succession are given in Appendix B and shown in Figure 7. Noteworthy are the apparent lithological differences on opposite limbs of the synclines east of Hickmans Harbour and at Keels. These may mark lateral variations in facies as a result of widespread variations in conditions of original deposition.

Thin sections of sandstone members of the formation reveal the angularity of the quartz grains, and the relatively high proportion of plagioclase (up to 25 per cent) in these rocks. The sediments are much 'cleaner', however, than the sandstones in the underlying Musgravetown Group, as rock particles comprise only a minor proportion. The red colour of some of the Random sediments is caused by a combination of red oxide coating and a reddish argillaceous matrix.

In general the lithology of the formation is transitional between the dominantly continental facies of the underlying Musgravetown Group and the marine facies of the overlying Lower Cambrian strata. McCartney (in press) observed that some beds within the Random Formation on Avalon Peninsula resemble sediments within the underlying Precambrian rocks, whereas others resemble overlying Lower Cambrian strata. From this he concluded that the formation represents a shoreline facies formed by a transgressing sea in late Precambrian or very early Cambrian time.

The angularity of the grains and the relatively high plagioclase content in some members indicate that the sediments were not subjected to lengthy trans-

portation prior to deposition. Nor were they reworked to any extent following deposition, as might be expected if they were shoreline deposits. The white quartzite that typifies the formation appears to be a winnowed or 'cleaned' form of the enclosing sediments, and may represent local off-shore bar-like accumulations. From Figure 7 it is apparent that these quartzitic members do not occur at regular stratigraphic horizons throughout the formation.

Structure

The Random Formation conformably overlies rocks of the Musgravetown Group (*see* Plate VA and B). In most contact areas the base of the formation is very difficult to recognize, and has been drawn somewhat arbitrarily. The top of the formation, however, is generally capped by an 8 to 18-inch bed of quartz-granule sandstone with a calcareous cement, which lies at the base of the Lower Cambrian shales (*see* Plate VI). Locally an erosional unconformity occurs at this formational boundary, a description of which is given in the section on the Bonavista Formation.

The Random Formation has been folded together with the overlying Cambrian rocks and the underlying Musgravetown rocks. However McCartney (in press) has recognized around the head of Trinity Bay, 30 miles south of Bonavista map-area, slightly different orientations of the fold axes of the Random and underlying late Precambrian strata, and has suggested that some folding of the Musgravetown Group rocks occurred immediately prior to the deposition of the Random Formation in that area.

Palæontology

Walcott (1900a) reported the presence of annelid trails in the Random Formation at its type locality, but no fossils have yet been identified from the formation anywhere in eastern Newfoundland.

Age and Correlation

As the Random Formation lies at the Precambrian-Cambrian time boundary its true age has been a controversial subject for many years. Overlying fossil-bearing shales are unquestionably Lower Cambrian; and underlying Musgravetown sandstones and conglomerates are assuredly Precambrian. No distinct structural breaks occur between these three stratigraphic units, however, so that the determination of the Random's age is largely influenced by the field investigators' fundamental geological beliefs. Small wonder that no agreement has been reached in 50 years!

Within Bonavista map-area the Random sediments resemble the underlying Musgravetown sediments much more than they do the overlying Cambrian calcareous shales. The Random sediments also grade down into the Musgravetown sediments at all exposures in the map-area. Furthermore, there is a fairly sharp lithological change at the top of the Random, from feldspathic sandstones to calcareous shales, which near Smith Point appears to be an erosional unconformity. These three factors favour inclusion of the Random Formation with the

underlying rocks as Precambrian, a view shared also by Hutchinson (1962). Nevertheless, McCartney's (in press) evidence of divergence of fold axes at the head of Trinity Bay, as mentioned above, must be reckoned with. Perhaps it is an indication of local crustal disturbance. Both McCartney and the writer agree, however, that the Random Formation may in fact, straddle the Precambrian-Cambrian time boundary.

The Random Formation in Bonavista map-area can be correlated stratigraphically with the Random Formation around Avalon Peninsula and on Burin Peninsula. It may be lithologically similar to quartzitic rocks at the base of Cambrian strata on Cape Breton Island and in New Brunswick, but direct stratigraphic correlation is not possible.

Palæozoic Rocks

Palæozoic sedimentary rocks in the two map-areas include a complete succession of Lower, Middle, and Upper Cambrian strata together with some Lower Ordovician strata, all of marine shelf facies and occurring almost entirely in the southern half of Bonavista map-area. They also include the extensive and thick Middle Ordovician Gander Lake Group, a eugeosynclinal facies, which lies almost entirely west of Bonavista map-area. The Cambro-Ordovician shelf sediments occur in several small downfaulted basins, and are similar both lithologically and structurally to the various small basinal remnants of Cambro-Ordovician miogeosynclinal sediments on Avalon and Burin Peninsulas. Extensive palæontological studies have been made on them, but little palæontological work has been done on the Middle Ordovician strata in Terra Nova map-area.

Hutchinson (1962) recently outlined the palæogeographic conditions in eastern Newfoundland during Cambrian times. He stated that the sediments are mostly of near shore, fairly shallow water facies, deposited in north-to-northeasterly trending arms of the sea between two low-lying land bodies, one east of what is now Conception Bay, the other somewhere about central Newfoundland. No similar study of the Ordovician rocks has yet been attempted.

The Problem of Mapping the Cambro-Ordovician Rocks

The Cambro-Ordovician sedimentary rocks in the region around Random Island have been the subject of frequent and intensive studies ever since Matthew (1899) drew attention to the excellent stratigraphic and palæontological succession of Cambrian and Lower Ordovician rocks along the northwest shore of Smith Sound. Matthew's studies were followed by those of Walcott (1900b), Van Ingen (1914), Howell (1926), Hayes (1948), Christie (1950), and Hutchinson (1962). The succession of Cambrian trilobites in these rocks has made them a classic section in eastern North America, and has provided type localities and sections for three of the six Cambro-Ordovician stratigraphic units in eastern Newfoundland. It is understandable, therefore, that the stratigraphic succession should have become subdivided largely on the basis of faunal content. The subdivisions so established by the early workers are thus biostratigraphic units rather than lithostratigraphic (i.e. rock) units. Furthermore, within the present map-

areas the early workers concentrated their studies upon two localities—the northwest shore of Smith Sound near Smith Point, and the west shore of Random Island —partly because the rocks there are so well exposed and easily accessible, partly because equivalent rocks farther east in Smith Sound and on Random Island are more strongly contorted and metamorphosed, so that the collecting of fossils is less satisfactory.

Both Christie and the writer found considerable difficulty in using the established biostratigraphic units for regional reconnaissance mapping, particularly when the only distinctive unit within the entire Cambro-Ordovician succession is a relatively thin (24- to 30-foot thick) pink limestone bed known as the Smith Point Limestone. To complicate matters further this is not the only limestone in the sequence, for thinner beds of pink limestone occur intermittently in both the underlying and overlying formations. These thin beds of pink limestone have caused confusion and misinterpretation in mapping on more than one occasion. The problem of mapping is still further complicated by the apparent lithological homogeneity of the upper part of the Cambro-Ordovician succession in this area, although the contained fauna indicate an age range from Middle Cambrian through Early Ordovician for the strata.

In order to resolve the difficulties resulting from the use of the original biostratigraphic units as mapping units, the writer proposes the division of the entire Cambro-Ordovician miogeosynclinal succession in the Bonavista map-area into two groups, based chiefly upon lithological factors. The name *Adeyton Group* is given to the lower part of the succession, the name *Harcourt Group* to the upper part. The Adeyton Group consists chiefly of red and green shales (locally slates) with thin bands of interbedded pink, green, or grey limestone, whereas the Harcourt Group consists chiefly of dark grey to black shales (locally slates) with thin interbeds of argillaceous sandstone. No red or green sediments have been observed in the Harcourt Group anywhere within the present map-areas, nor do they appear to be present within equivalent rocks elsewhere on Avalon and Burin Peninsulas (Hutchinson, 1962). Some grey sediments do occur in the Adeyton Group, but only in the uppermost parts. The Adeyton Group is divisible into four formations, the Harcourt Group into two.

Richly fossiliferous rocks of the type involved here require two geological maps to demonstrate properly their distribution, one showing the distribution of the mappable rock units (*formations*, as defined by the American Commission on Stratigraphic Nomenclature, 1961), the other showing the areal distribution of the rocks according to their age (*time-rock units*, such as Lower Cambrian Series, Middle Cambrian Series, etc.)[1]. These two types of maps are nearly similar, differing only in details, as can be seen by comparing Figure 5 with Figure 6.

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[1] If more palæontological information were available, a third type of map might also be constructed, showing the geographic distribution of the faunal zones contained by the rocks. Hutchinson (1962) has shown the Cambro-Ordovician rocks in eastern Newfoundland can be divided into 13 faunal zones—3 in the Lower Cambrian, 4 in each of the Middle and Upper Cambrian, and 2 in the presently known Lower Ordovician. These zones are only recognized in a few excellent shore exposures, however, and have not been traced inland.

Hutchinson (1962) recently divided the Cambrian strata into five formations and an additional group. His divisions are in part lithostratigraphic, in part, biostratigraphic, and he has not attempted to trace his units inland from the excellent shore exposures. It is because some of his units are not mappable in Bonavista map-area on the reconnaissance scale used in the present investigation that the new units are proposed. They differ only slightly from those of Hutchinson, but are believed to be much more applicable for regional mapping. A comparison of the two types of units is shown below.

Epochs	Hutchinson's Units	Jenness' Units
Early Ordovician	Clarenville Group	Harcourt Group
Late Cambrian	Elliott Cove Group	Elliott Cove and Clarenville Formations
Middle Cambrian	Manuels River Formation	Manuels River Formation
	Chamberlain's Brook Formation	Adeyton Group Chamberlain's Brook Formation
Early Cambrian	Brigus Formation Smith Point Limestone Bonavista Formation	Brigus Formation Smith Point Limestone Bonavista Formation

The top of the writer's Adeyton Group is arbitrarily placed at the same stratigraphic position as the top of the Chamberlain's Brook Formation, as described by Hutchinson (1962). The Elliott Cove and Clarenville Groups, as described by Hutchinson, are merged into one map-unit by the writer, for they are lithologically indivisible in Bonavista map-area.

Adeyton Group

The name Adeyton Group is here proposed for a sequence of red, green, and grey shales and slates, with thinly interbedded pink, green, and grey limestone, lying disconformably above the Random Formation and seemingly conformably below the Harcourt Group (as defined herein) in the region around Random Island. The group is named after the village of Adeyton on the Northwest Arm of Random Sound. The group consists of four previously named formations: the Bonavista, Smith Point, and Brigus Formations of Early Cambrian age, and the Chamberlain's Brook Formation of Middle Cambrian age. The thin Smith Point Limestone could perhaps be considered as a member only, within the overlying and underlying lithologically similar (but faunally different) Brigus and Bonavista Formations (which would then be a single formation), but the limestone's unusual colour, its tendency to stand out above the surrounding shales on shore as well as inland, and its apparent widespread distribution throughout Bonavista map-area and adjoining areas on Avalon and Burin Peninsulas, give it a prominence as a mapping unit worthy of formational rank.

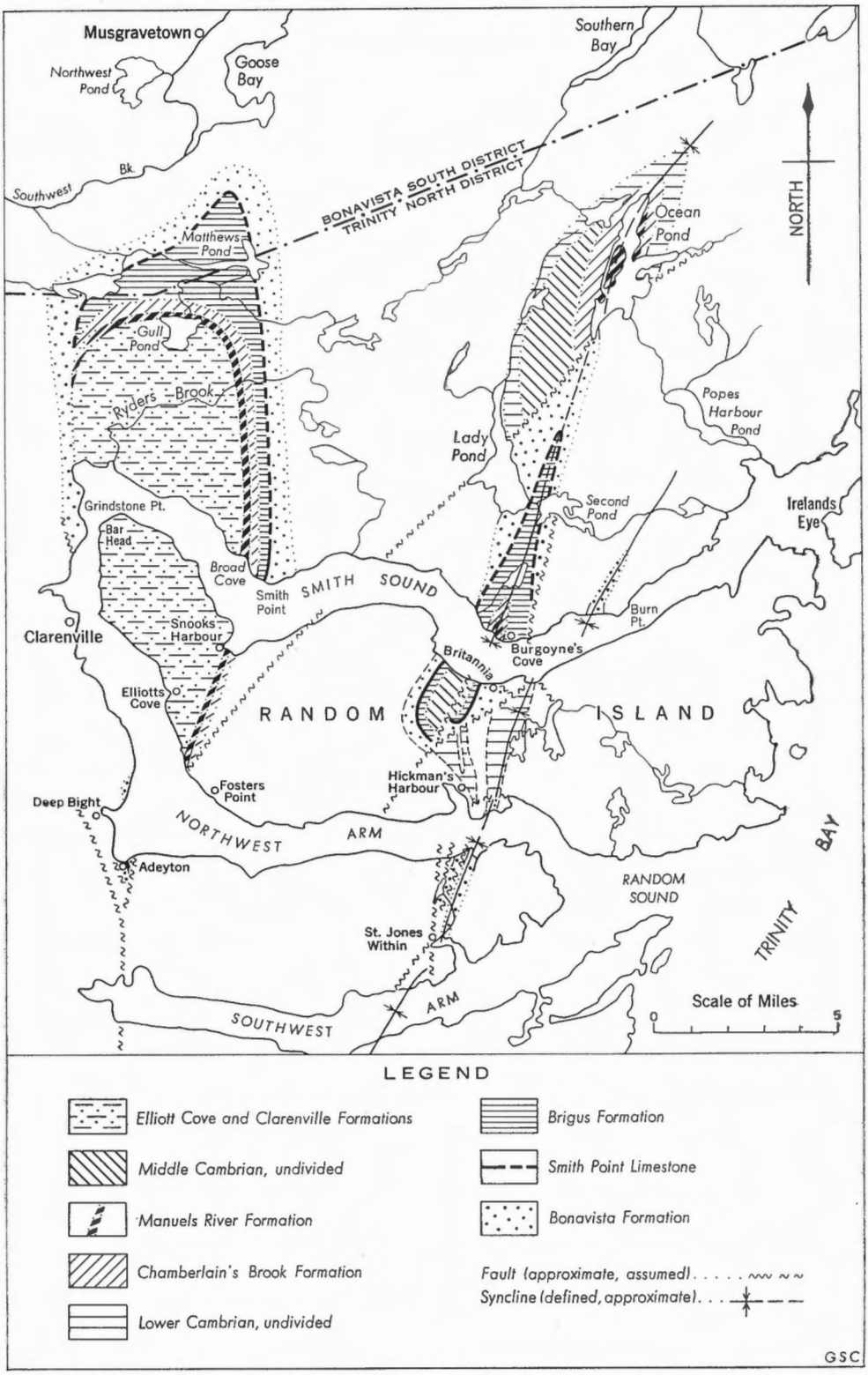

Figure 5. ***Random Island area showing the approximate distribution of the Cambro-Ordovician lithostratigraphic units in the eastern and western basins.***

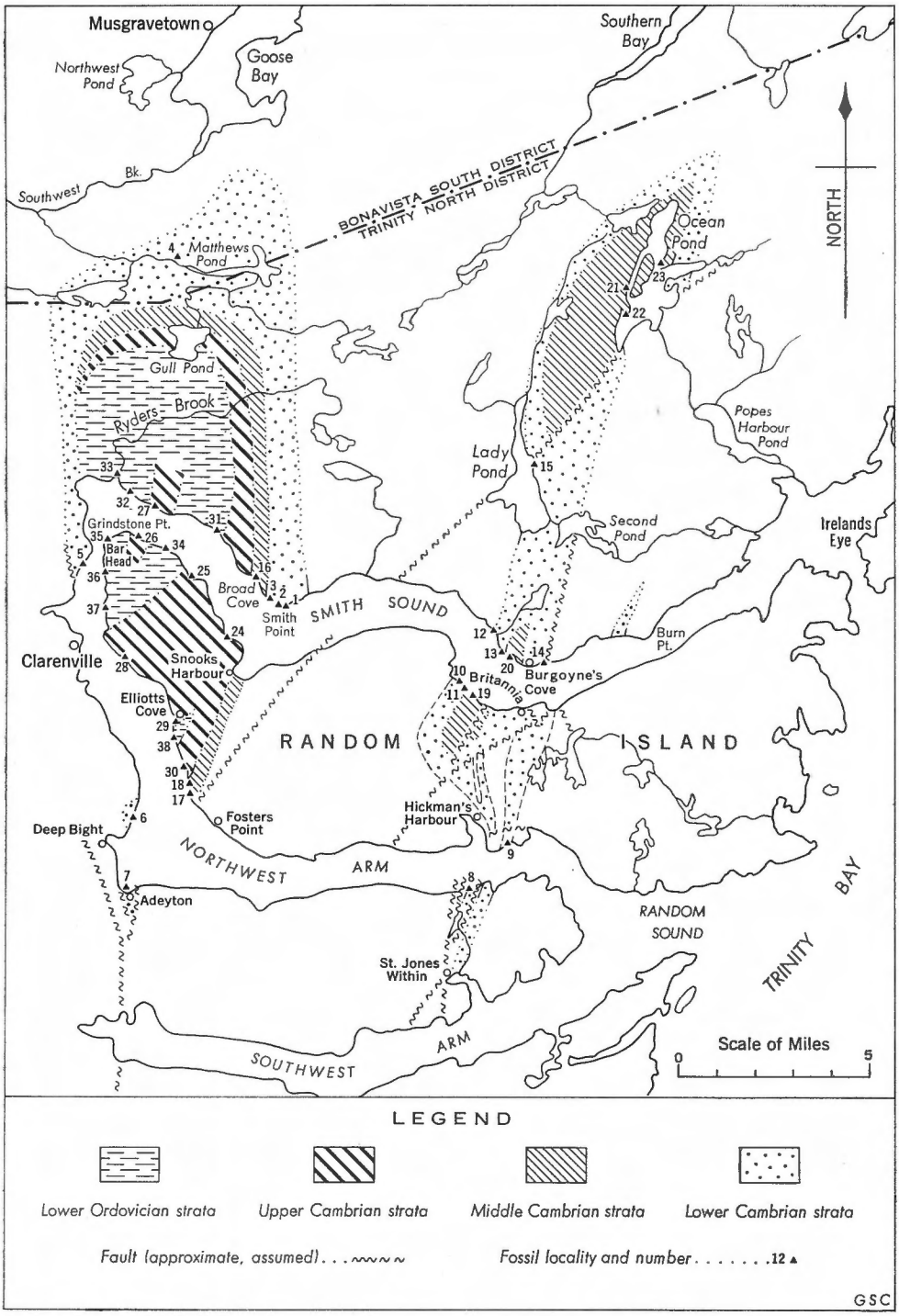

Figure 6. *Random Island area showing the approximate distribution of the Cambro-Ordovician biostratigraphic units in the eastern and western basins. Thirty-eight of the fifty-seven known fossil localities are also indicated; the additional nineteen are shown on Figure 7. Fauna are listed in Appendix D.*

The group is exposed in Bonavista map-area in four widely separated localities, three of which are visibly infolded with late Precambrian sediments (*see* Figure 5). In two of these localities the group lies within structural basins 5 or more miles apart that cross Random Island and continue for several miles north of Smith Sound. Part of the group is exposed in a smaller basin at Keels in Bonavista Bay, and possibly also on two small islands at the west end of Lockers Flat Island in the northwest corner of the Bonavista map-area.

The group is just under 1,200 feet thick along the shore of Smith Sound but is nowhere completely exposed.

Bonavista Formation

The name Bonavista was proposed by Van Ingen (1914) for the lowest formation of the Cambrian rocks in the area about Conception and Trinity Bays. No type section was designated. The excellent exposures along the northwest shore of Smith Sound in Bonavista map-area have since been selected as the type section for the formation (Hutchinson, 1962).

Distribution and Thickness

The distribution of the Bonavista Formation is shown on Figure 5, but the inland boundaries are generalized, owing to the scarcity of exposures away from the coast. The formation is also present at Keels, but the uppermost part is missing. Small fragmentary blocks of the Bonavista Formation have been observed on the shore at Adeyton, and along shore ½ mile northwest of Deep Bight (near Adeyton). Nodular greenish grey shales on two tiny islands at the west end of Lockers Flat Island in the northwestern part of Bonavista map-area are also considered as possible members of the Bonavista Formation.

The thickness of the formation in the type section in Smith Sound is reportedly 444 feet (Hutchinson, 1962). This consists of 441 feet that Walcott (1900b) had placed below the Smith Point Limestone, plus a 1-foot band of limestone and a 2-foot band of shale that Walcott had included with the Smith Point Limestone. The writer found that the base of the formation lies 100 to 200 feet beneath the lowest unit included in Hutchinson's section, and is separated from it by a stretch of shoreline without outcrops. An additional 51 feet of strata exposed there are regarded as basal members of the formation, for they have at their base a calcareous quartz granule conglomerate (or sandstone), 12 to 18 inches thick, which rests upon white quartzite of the Random Formation. The actual thickness of the formation in the type section may thus be as much as 650 feet.

At Keels, Christie (unpublished field notes, 1950) measured 465 feet of beds on the east side of a syncline, and 405 feet on the west side where there are two gaps in the section for which he did not record thicknesses. He evidently believed that a 2-foot thick bed of grey limestone containing hyolithid forms, which occurs about half-way up in the western section at Keels, was the Smith Point Limestone; however, on the basis of Hutchinson's isopach map (Hutchinson, 1962) the Smith Point Limestone at that locality should be at least ten times as thick. Furthermore, such thin limestone beds occur at several horizons within

the Bonavista Formation in other parts of the map-area. These sections at Keels thus do not appear to include all of the Bonavista Formation.

Christie has also measured the formation alongshore near Milton, where about 150 feet of it are exposed, and in shore exposures just east of Hickmans Harbour (above Walcott's type section of the Random Formation) where 416 feet of the formation are present.

The only section containing both upper and lower limits of the formation is at Smith Point; unfortunately even this is an incomplete section, for part is concealed. From available exposures, however, it is suggested that the Bonavista Formation within Bonavista map-area has a maximum thickness between 450-650 feet. Hutchinson (1962) has shown that the formation attains its maximum thickness in the Random Island-Keels regions, thinning to zero thickness to the southeast in Conception and St. Mary's Bays, and to the southwest in Fortune Bay.

Lithology

The Bonavista Formation consists chiefly of red and green shales and slates, with some thin beds of grey, green, and pink limestone. Limy nodules occur along the bedding planes of many of the shaly units. Details of the lithology, as observed at Smith Point, Milton, Hickmans Harbour, and Keels, are provided in the stratigraphic sections (*see* Appendix C), and in the columnar sections on Figure 7.

Throughout the Random Island region the base of the formation is marked by a very thin conglomeratic unit consisting of pea-sized rounded quartz granules in a white calcareous sandstone. In the type section of the formation this unit is 12 to 18 inches thick, is overlain by a greenish sandy shale, and underlain by white Random quartzite (*see* Plate VI). A similar granule sandstone ('conglomerate') with carbonate cement occurs at the base of the formation just east of Hickmans Harbour above the type section of the Random Formation. There it is only 7 inches thick and is closely crumpled. The sediments immediately beneath this sandstone are thinly-bedded sandy units of the Random Formation rather than white quartzite. Opposite Hickmans Harbour, on the south side of the Northwest Arm of Random Sound, the granule sandstone is 8 inches thick and rests with a slightly undulant surface on Random white quartzite, as at Smith Point. This granule sandstone at the base of the formation is a relatively insignificant unit in the localities cited above, but it evidently assumes greater importance to the southeast on Avalon Peninsula, where it appears as a coarse conglomerate as much as 16 feet thick at the base of the Bonavista Formation (Hutchinson, 1962).

The granule sandstone is believed to be the basal member of the Bonavista Formation rather than the upper member of the underlying Random Formation, for the following reasons:

(1) A similar calcareous granule sandstone, ranging from 2 to 8 inches thick, occurs at the base of the lowermost Cambrian silty shales on both sides of the Northwest Arm of Random Sound just east of Hickmans

Harbour, and on the east side of the small Cambrian basin near the east end of Smith Sound;

(2) A slightly undulant surface occurs between the thin calcareous granule sandstone and the underlying Random white quartzite in two of the three localities mentioned above (drag-folding obscures the relationship in the third locality, on Random Island);

(3) The strata above the granule sandstone in these localities are conformable;

(4) The lithological character of the beds beneath the granule sandstone differs in various localities, white quartzite in Smith Sound and on the south side of the Northwest Arm of Random Sound, but shaly grey sandstone (a few inches thick) on the south shore of Random Island;

(5) Calcareous pebble conglomerate rests with a slightly irregular surface on Random white quartzite in exposures elsewhere in Trinity Bay south of Bonavista map-area (McCartney, 1958, p. 17), and coarser conglomerates occur elsewhere around Avalon Peninsula at the base of the Cambrian immediately overlying Random quartzites (McCartney, in press);

(6) Lime scattered throughout the Lower Cambrian rocks as calcareous cement or limestone bands, beds, and concretions, does not appear anywhere within the Random Formation; its appearance as a cement in the granule sandstone on top of the Random Formation marks the first appearance of limy material in significant quantity in the stratigraphic column of eastern Newfoundland, and is further evidence that the granule sandstone belongs within the Bonavista Formation and is of Cambrian age.

Structure and Metamorphism

The base of the Bonavista Formation has been observed in three localities, as described above, evidence from which indicates that an erosional unconformity marks the contact with the underlying Random Formation. The Bonavista Formation is overlain conformably by the Smith Point Limestone. It has been folded together with the Random Formation and overlying formations, and locally faulted, particularly in the central basin between St. Jones Within, Hickmans Harbour, and Burgoyne's Cove. These structures are post-Early Ordovician in age. Cleavage is prominently developed in all but the limestone beds within the formation.

Rocks of the formation within the tightly folded eastern basin that crosses Random Island at Hickmans Harbour display a slightly higher grade of metamorphism than those in the type section near Smith Point. It is in this eastern basin that the formation has been quarried for slate. Elsewhere the argillaceous rocks that comprise most of the formation are chiefly shales.

Palæontology

Few fossils have been found within rocks of the Bonavista Formation in Bonavista map-area, those known being within thin limestone members that occur

at various horizons throughout the formation. Four such members containing specimens of the primitive gastropod *Coleoloides* have been recorded just east of Hickmans Harbour by Walcott (1900b). Walcott also mentioned *Coleoloides typicalis, Hyolithes rugosus* Matt.?, *Urotheca pervetus* Matt., and unidentified crustaceans collected from two fossiliferous beds in the Smith Point section (*see* Appendix D). The writer has observed specimens of *Hyolithes* in three other localities: on the south shore of Random Sound opposite Hickmans Harbour; just north of Deep Bight; and just east of Keels on the shore of Bonavista Bay.

Age and Correlation

The stratigraphic position of the Bonavista Formation places it immediately below the oldest tribolite-bearing Cambrian rocks in eastern Newfoundland. The formation is therefore interpreted as the basal Cambrian formation (Hutchinson, 1962).

The Bonavista Formation within Bonavista map-area can be correlated with stratigraphic sequences below the Smith Point Limestone elsewhere in eastern Newfoundland, on the basis of both stratigraphic position and identical fauna. Correlations with strata elsewhere in Canada and Europe are less certain, however, although Hutchinson (1962) has suggested tentative correlations with basal Cambrian beds in northwestern Newfoundland, Cape Breton Island, New Brunswick, and Shropshire, England, on the basis of similar stratigraphic position beneath *Callavia*-bearing beds.

Smith Point Limestone

The name Smith Point Limestone was first used by Walcott (1900a) for a prominent bed of pinkish red massive limestone near the middle of the Lower Cambrian succession on the northwestern shore of Smith Sound. The unit provides an excellent key bed wherever exposed, despite a thickness of less than 30 feet in Bonavista map-area.

Distribution and Thickness

The distribution of the Smith Point Limestone is limited to the southern half of Bonavista map-area. There the formation has been observed in the following five localities (*see* Figure 5): (1) at Smith Point in Smith Sound, the type locality; (2) on Random Island just west of Britannia; (3) on the shore at Adeyton; (4) on the highway 9½ miles north-northwest of Smith Point; and (5) at the east end of Lady Pond. Other beds of pink limestone up to 6 feet thick occur at several horizons within the Bonavista and Brigus Formations, and have occasionally been mistaken for the Smith Point Limestone. Hutchinson (1962) has shown, however, that the Smith Point Limestone has a relatively constant thickness over extensive areas in eastern Newfoundland, and that, in the Random Island region, its thickness is between 24 and 35 feet. This criterion permits ready distinction of the Smith Point Limestone from the thinner limestone beds elsewhere in the Lower Cambrian formations.

The Smith Point Limestone is 24 feet thick at the type section near Smith Point, and approximately the same thickness at Adeyton. The thicknesses of the formation at the other three localities in Bonavista map-area have not been determined. The formation probably increases in thickness eastward from 24 feet at the type section to 30 to 35 feet in the central basin near Hickmans Harbour (Hutchinson, 1962).

Lithology

The Smith Point Formation is typically a dull, pinkish red, thin to fairly thick-bedded limestone. In places it includes thin layers of interbedded red shale with pink limestone nodules. Texturally the rock is very fine grained, with abundant veinlets of white calcite and small widely distributed shell fragments. In exposures at Adeyton and at Smith Point, concentric-layered, cabbage-sized algal structures are a prominent feature. The limestone has a rough weathered surface, and tends to stand up as massive, spine-like ridges amidst the more easily eroded adjoining shales. This characteristic, coupled with its unusual colour and readily recognized appearance have made this formation the best marker bed in the two map-areas.

Structure

The limestone is a massive resistant unit, contrasting sharply with the thinly cleaved shales or slates above and below it. It has been extensively fractured, but most of the fractures are filled in with calcite. Large blocky slabs several feet in each dimension are found at most exposure sites. The formation lies conformably above the Bonavista Formation and conformably below the Brigus Formation.

Palæontology

Almost all the fauna known from exposures of the Smith Point Limestone within Bonavista map-area were collected and identified by Walcott (1900b) (*see* Figure 7). These are listed below according to their place of origin (for details see Appendix D).

F-2 (Figure 6) Type locality, Smith Point, near northeast end of Smith Sound:

Callavia bröggeri[1] } upper 6 inches of formation
Solenopleura ? sp. }

Hyolithes princeps
Iphidea labradorica (*Kutorgina granulata* M.)
Fordilla troyensis
Scenella reticulata ?
Randomia aurorae
Helenia bella
Coleoloides typicalis
Hyolithellus micans ?
Orthotheca pugeo
} $3\frac{1}{2}$ feet below top of formation

[1] Called *Olenellus* (H) *bröggeri* by Walcott.

F-10 (Figure 6) North shore of Random Island, just west of Britannia:

Hyolithes princeps and other unidentified forms

Fossils have been observed in the Smith Point Limestone at Adeyton, but have not been collected for identification.

Age and Correlation

Lying roughly midway between the base and the top of the Lower Cambrian strata, the Smith Point Limestone is stratigraphically about middle Lower Cambrian. Palæontologically, it is "clearly early Lower Cambrian in age" (Hutchinson, 1962).

The Smith Point Limestone is correlated with Lower Cambrian *Callavia*-bearing strata of the Boston area, Massachusetts, and at Comley, Shropshire, England (Hutchinson, 1962).

Brigus Formation

The name Brigus was originally proposed by Van Ingen (1914) for fossiliferous Lower Cambrian strata that were above the Bonavista Formation, but which were believed to be below the Smith Point Limestone in southeastern Newfoundland. Hutchinson (1962) has now redefined the formation, showing that it lies *above* the Smith Point Limestone, and has assigned it a type locality just south of Brigus, on the west shore of Conception Bay.

Distribution and Thickness

The Brigus Formation occurs on the shores of Smith Sound near Smith Point, near Burgoyne's Cove, and just west of Britannia. It is present also at Adeyton, and probably occurs between Smith Sound and Ocean Pond.

The thickness of the formation, where it overlies the Smith Point Limestone in Smith Sound, was reported by Walcott (1900b, p. 311) to be 369 feet, although the thickness of the strata he lists on pp. 306-309 adds up to only 343 feet.[1] The formation there is completely exposed. Another completely, or almost completely, exposed section of the formation occurs just west of Burgoyne's Cove opposite Britannia, but this has not been measured. Walcott (1900b, p. 309) also reported the presence of 360 feet in another section, only partly exposed, on the north shore of Random Island near Britannia. About 60 feet of the formation is exposed above the Smith Point Limestone at Adeyton. The formation has not been measured elsewhere within Bonavista map-area. It is probably thicker in the Britannia region than in other parts of Bonavista map-area (Hutchinson, 1962).

[1] This thickness has been obtained from Walcott's measured section by including the lowest 11 inches of his unit *1e* with the Brigus Formation, and all strata below that to the top of the Smith Point Limestone. This is in accordance with the usage of Hutchinson (1962), who placed the Smith Point Limestone at the base of the Brigus, the manganese zone (which is the top 25 inches of Walcott's unit *1e*) at the top of the formation. The section totals 343 feet. Walcott stated on p. 311 of the same paper that there are 369 feet of Lower Cambrian strata above the Smith Point Limestone. Dale (1914, p. 432) measured 368 feet in the same section.

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Lithology

The Brigus Formation is lithologically rather similar to the Bonavista Formation, with which it has commonly been confused. It thus consists chiefly of red and green shales and slates, with thin beds of red and green limestone. Limestone nodules occur in some of the shale beds, particularly in the lower half of the formation. Green shales are less plentiful than red shales in the lower half, but are more plentiful in the upper half of the formation. Details of the lithology are shown on Figure 7.

Structure

The Brigus Formation has been folded and faulted in association with the other Cambro-Ordovician strata in the southwest part of Bonavista map-area, and cleavage, generally parallel with bedding, is prominently developed within most of its beds. The formation conformably overlies the Smith Point Limestone near Smith Point, and appears to be conformably (possibly disconformably) overlain by Middle Cambrian strata near both Smith Point and Burgoyne's Cove.

Palæontology

Trilobites appear in the Brigus Formation, particularly in the lower half where thin, fossil-bearing limestone beds are present (*see* Figure 7 and Appendix D).

Walcott (1900b) listed the following forms found within the bottom 40 feet of the formation in the Smith Sound section (locality F-3, Figure 6):

Obolella atlantica
Microdiscus bellimarginatus S. and F.
Microdiscus N. sp.
Olenellus (Holmia) *bröggeri*
Zacanthoides sp. undet.
Agraulos sp.
Micmacca walcotti

Walcott also listed the following fauna 40 to 50 feet higher in the same section:

Obolella atlantica
Hyolithes sp.
Orthotheca sp.
Microdiscus sp. undet.
Olenellus (H.) *bröggeri*
Solenopleura? *bombifrons*?

Walcott further recorded the occurrence of *Olenellus* (Holmia) *bröggeri* (now *Callavia bröggeri*) from a horizon 140 feet below the top of the formation on the south side of Smith Sound near Britannia (locality F-11, Figure 6).

Several thin beds of pink limestone with fossil fragments occur a few feet below a black manganiferous zone between Clifton and Burgoyne's Cove on the north shore of Smith Sound. These presumably are fossil zones near the top of the Brigus Formation, but fossil collections and identifications have not been made.

Hutchinson (1962) has shown that the Brigus Formation contains two faunal zones, a lower *Callavia* zone, well represented by that genus and other forms, and an upper *Protolenus* zone, containing sparse fragmentary specimens. The *Callavia* zone actually extends several feet below the formation into the underlying Smith Point Limestone.

Age and Correlation

The age of the Brigus Formation, on the basis of its faunal content, is medial to late Early Cambrian. It is stratigraphically the uppermost Lower Cambrian formation in eastern Newfoundland.

The formation can be correlated palæontologically with *Callavia*- and *Protolenus*-bearing beds in New Brunswick and Shropshire, England (Hutchinson 1962).

Chamberlain's Brook Formation

The name Chamberlain's Brook Formation was proposed by Howell (1925) for the oldest Middle Cambrian rocks exposed on the east shore of Conception Bay. The formation has been slightly redefined by Hutchinson (1962) to include the manganiferous zone at its base, in which Hutchinson found Middle Cambrian trilobites.

Distribution and Thickness

The Chamberlain's Brook Formation occurs west of Smith Point on the northwest shore of Smith Sound, north of Fosters Point on the west side of Random Sound, and on the west shore of Ocean Pond north of Smith Sound. Its recognition in each of these localities is based on the discovery of *Paradoxides bennetti,* the index fossil for this formation in eastern Newfoundland. The formation is probably present as well on both sides of Smith Sound near Britannia, because fossils belonging to the overlying Manuels River Formation have been identified there. The formation is unknown north of Smith Sound except for the one locality where *Paradoxides bennetti* has been identified (locality F-21, Figure 6), but it is fairly widely distributed elsewhere in eastern Newfoundland (Hutchinson, 1962).

West of Smith Point the formation is reported to have a thickness of 332 feet (Hutchinson, 1962), but part of the uppermost unit may belong to the overlying Manuels Brook Formation. Just north of Fosters Point on Random Island it is only 276 feet thick, but there the basal members, including the manganese zone, are not present. The formation is thicker in Trinity and St. Mary's Bays to the south of Bonavista map-area (Hutchinson, 1962).

Lithology

Within Bonavista map-area the Chamberlain's Brook Formation consists largely of greenish shales (or slates) with several tens of feet of interbedded red shales (or slates) and minor thin layers of pink and grey limestone. Thicker beds of red shale (or slate) evidently occur in this region than in Trinity and Conception Bays, where the formation is better known and is mainly a greenish shale (or slate). A thin manganiferous zone is only slightly developed at the base

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of the formation in the Smith Point section. It is better developed, in the form of two closely spaced black bands, on the west side of Burgoyne's Cove. This manganese zone is a thin but prominent basal unit in the formation in Conception and Trinity Bays to the southeast. Details of the lithology of the formation can be seen on the columnar section (Figure 7).

Structure

The shale and slate beds within the formation are well cleaved, and in the region just east of Burgoyne's Cove they are also closely folded. The formation appears to rest conformably upon the Lower Cambrian Brigus Formation, but a pronounced faunal change, without a corresponding lithological change, suggests that a considerable time hiatus is represented by the boundary between the two formations. For this reason this boundary is regarded as a disconformity.

Palæontology

The Chamberlain's Brook Formation contains the index fossil *Paradoxides bennetti* Salter, the oldest of a succession of widely known Middle Cambrian paradoxid trilobites found in the Atlantic faunal realm on both sides of the Atlantic Ocean. *P. bennetti* is a large species, up to 12 inches long. Well preserved specimens occur most commonly in thin calcareous beds intercalated in thick shale (*see* Figure 7 and Appendix D). Fossils within shaly units are generally fragmented and distorted by cleavage.

Two zones of *P. bennetti* occur within the upper half of the formation west of Smith Point. *P. eteminicus* has also been found there (Hutchinson, 1962). One *P. bennetti* zone has been observed by A. M. Christie on the west side of Ocean Pond, and fragmentary but unidentified fossils have been reported within the lower part of the formation just north of Fosters Point, on the west side of Random Island (Hutchinson, 1962).

Age and Correlation

The presence of *P. bennetti* dates the Chamberlain's Brook Formation as early Middle Cambrian. Hutchinson (1962) has correlated it palæontologically with early Middle Cambrian strata on Cape Breton Island, in New Brunswick, near Boston in Massachusetts, and in Wales and Scandinavia.

Harcourt Group

The name Harcourt Group is here proposed for a succession of alternating dark grey and black shales, silty shales, siltstones, and minor grey limestones that are apparently conformable with the underlying Middle Cambrian Chamberlain's Brook Formation in the Random Island region. The group is named after the village of Harcourt in Smith Sound. The group includes a basal formation named the Manuels River Formation by Hutchinson (1962), and two younger biostratigraphic units, which Hutchinson called the Elliott Cove Group and the Clarenville Group, but which the writer regards as one lithostratigraphic unit.

The group is exposed in Bonavista map-area in three separate regions, the largest of which is at the west end of Random Island and for 5 miles north of it. The group underlies an area of about 25 square miles, more than half of the

western Cambro-Ordovician basin. It is also present in a tightly folded synclinal basin at Burgoyne's Cove in Smith Sound, and in a similar basin on Ocean Pond, 9 miles to the north; neither of these two basinal areas covers more than 5 square miles. In each of the three basins the group is enclosed by rocks of the underlying Adeyton Group.

The total thickness of the group is nowhere exposed, but is estimated to be somewhat less than 3,000 feet.

The Harcourt Group differs regionally from the underlying Adeyton Group by its lack of red or green shales (or slates) with which the latter group abounds, and by its thin beds of siltstone or sandstone in contrast to the thin limestone beds in the Adeyton Group. The striking colour change between these two groups, which represents a transition in conditions of sedimentation from near-shore oxidizing conditions to deep-water stagnating conditions, is apparently more pronounced in the Random Island region than farther southeast on Avalon Peninsula.

Manuels River Formation

The name Manuels River Formation was proposed by Hutchinson (1962) for a succession of grey and black shales or slates with thin interbedded grey to black limestone, which lies immediately above the Chamberlain's Brook Formation in southeastern Newfoundland and contains Middle Cambrian fauna. The rocks included in this formation had previously been subdivided by Howell (1925), but Hutchinson found Howell's subdivisions inapplicable away from the type locality at Manuels River, Conception Bay.

Distribution and Thickness

The Manuels River Formation is exposed at the following four places in Bonavista map-area: (1) on the west end of Random Island just north of Fosters Point; (2) at Broad Cove, on the north shore of Smith Sound just west of Smith Point; (3) in Burgoyne's Cove, on the north side of Smith Sound; (4) on the east and west shores of Ocean Pond, northeast of Burgoyne's Cove (*see* Figure 5). The formation has presumably been eliminated by erosion or structural displacement from other parts of the Palæozoic basins in Bonavista map-area. The formation is fairly easily recognized by means of the characteristic faunal zones it contains.

The thickness of the Manuels River Formation in a complete section just north of Fosters Point, at the west end of Random Island, is only 95 feet (Hutchinson, 1962). Thicknesses at Burgoyne's Cove and Ocean Pond have not been measured, but are probably of the same order of magnitude. The formation in its type section at Manuels River, Conception Bay, is only 65 feet thick.

Lithology

The Manuels River Formation consists mainly of grey to black shales (locally slates), with a few thin bands of grey to black limestone. Some of the limestone beds are fossiliferous. The formation in the central Palæozoic basin at Burgoyne's Cove is slightly more metamorphosed than it is north of Fosters Point and at

Broad Cove. The composition of the rocks is not appreciably different from that of the underlying Chamberlain's Brook Formation, but the colour change from reds and greens of the Chamberlain's Brook strata to dark greys and blacks is one of the most marked lithological changes within the entire Cambrian succession in Bonavista map-area. Although it is a sharp change in Bonavista map-area, to the southeast some grey coloured shales (or slates) do appear below the base of the Manuels River Formation within the Chamberlain's Brook Formation. Details of the lithology are shown in the columnar sections in Figure 7.

Structure

The Manuels River Formation has been folded with the underlying and overlying Cambrian strata, and like them is somewhat more deformed within the central Palæozoic basin than in the western basin near Smith Point. No structural discordance appears at its base where it is in contact with the underlying Chamberlain's Brook Formation, but the pronounced colour change of the sediments at this contact, together with a distinct faunal change, may mark a slight disconformity. Hutchinson (1962), however, has questioned the existence of such a stratigraphic break. Most of the beds within the formation display good cleavage, but the thin limestone beds tend to be massive and resistant to weathering.

Palæontology

Fossils are fairly plentiful within the formation, both in shaly members and in thin limestone beds (*see* Figure 7 and Appendix D). Two faunal zones have been established, a lower *Paradoxides hicksi* zone, and an upper *Paradoxides davidis* zone. These index trilobites are plentiful within certain beds of the formation, and have been recovered and identified,[1] together with certain other forms, from four localities within Bonavista map-area (fossil localities F-18, 20, 22, and 23, on Figure 6; *see* also Appendix D).

Age and Correlation

The two *Paradoxides* fauna indicate that the Manuels River Formation ranges in age from medial to late Middle Cambrian. Stratigraphically the formation comprises the upper quarter of the Middle Cambrian succession in the map-area.

The formation has been correlated palæontologically with the *P. hicksi* and *P. davidis* beds in Cape Breton Island and New Brunswick, as well as in England and Wales (Hutchinson, 1962).

Elliott Cove and Clarenville Formations

The names Elliott Cove Formation and Clarenville Series were introduced by Van Ingen (1914) for two stratigraphic units of Late Cambrian and Early Ordovician age respectively that occur on the northwest shore of Smith Sound. Hayes (1948) referred to them both as "formations", and Hutchinson (1962) called them both "groups". Separation of the two units was based upon their fossil con-

[1] Unless otherwise noted, specimens were collected by A. M. Christie and identified by R. D. Hutchinson of the Geological Survey of Canada.

tent, so they are in fact biostratigraphic units. The writer, in conducting reconnaissance mapping, found the two units to be one indivisible lithostratigraphic unit, and mapped them together (*see* Figure 5). For this reason, also, they are described together in this report.

Distribution and Thickness

The occurrence of the Elliott Cove and Clarenville Formations within Bonavista map-area is apparently restricted to the Cambro-Ordovician basin at the west end of Random Island and immediately north of it, where they underlie about 24 square miles of terrain.

The total thickness of the two formations is not known, for exposures are poor in the map-areas, and no complete or nearly complete stratigraphic section is present. Hutchinson (1962) has measured 393 feet of Upper Cambrian strata north of Fosters Point on the west end of Random Island, and A. M. Christie (unpublished manuscript, Geological Survey of Canada) has suggested that the Upper Cambrian rocks may be as much as 1,000 feet thick, the Lower Ordovician strata perhaps 2,000 feet thick. Although these may be somewhat exaggerated estimates, the thickness of the two formations may well be of the order of 2,000 feet.

Lithology

The Elliott Cove and Clarenville Formations are composed mainly of medium to dark grey and black shales that commonly weather dull brown. Accompanying the shales are numerous thin beds of grey siltstone, locally crossbedded, and beds of black limestone nodules and concretions. Some of the latter exhibit excellent cone-in-cone structure (*see* Plate VII). There is a general increase upward in the formations in the abundance of coarser facies, with a proportional decrease in the abundance of shaly facies.

The beds of micaceous or argillaceous siltstone range from 1 inch to 12 inches in thickness. In thin section these are seen to be recrystallized rocks with the micaceous minerals well oriented and the quartz grains recrystallized and in part elongated parallel with the micas. Grains of plagioclase and small granules of opaque oxide are also present.

Disk-shaped limestone concretions ranging between 1 foot and 3 feet in diameter, and from 4 inches to 12 inches in thickness, occur at many horizons within the two formations (*see* Plate VII). Many fossil horizons have been located, but these appear to be widely separated stratigraphically. Most of the fossils are preserved within thin black shale beds.

A small basalt dyke occurs within this formation about a mile south of Elliotts Cove and nearby is a concordant body of the same rock type, 3 to 10 feet thick. If this concordant body is a flow rock, as suggested by A. M. Christie (unpublished field notes, Geological Survey of Canada), it would indicate minor volcanism in Upper Cambrian or Lower Ordovician times. No other volcanic rocks have been observed in eastern Newfoundland in rocks of these ages. This rock is more probably a sill related to the post-Cambrian basic dyke system in the area.

Structure

The lower part of the Elliott Cove and Clarenville Formations on Random Island has been gently folded; higher up in the formations toward the centre of the basin, the rocks are considerably crumpled and closely folded. Some of the beds may be overturned. Axes of folds trend slightly east of north, as in the other nearby Palæozoic basins, but may be somewhat warped. The contact between the lower of the two formations and the underlying Manuels River Formation appears conformable both structurally and lithologically, although Hutchinson (1962) reported some lithological change accompanying a faunal change at this contact. This contact may thus be disconformable and mark a period of non-deposition. The formation is overlain unconformably by Pleistocene glacial deposits.

Palæontology

Van Ingen (1914) set up three faunal zones within the Upper Cambrian rocks and an additional five in the Lower Ordovician. More recently Hutchinson (1962) has outlined four faunal zones within the Upper Cambrian, which from oldest to youngest are as follows: *Agnostus pisiformis* zone, *Olenus* zone, *Parabolina* zone, and *Peltura* zone.

Fossil zones assigned by Van Ingen (1914) to the Lower Ordovician include the following index fossils: *Bryograptus, Shumardia, Parabolina harrieta, Niobe howelli,* and *Bellerophon randomi.*

Fossils are fairly plentiful at certain horizons within the formation, although seemingly absent from considerable thicknesses separating the various zones. A. M. Christie recorded fifteen fossil localities in his field notes (localities F-24 to F-38 on Figure 6; *see* also Appendix D).

A specimen of *Parabolina* was observed by R. D. Hutchinson (personal communication) in June 1958, in strata on the west shore of Random Island approximately 1 mile south of Elliotts Cove. It is not yet known whether this marks another band of Lower Ordovician strata, or whether it is just part of the Upper Cambrian.

Age and Correlation

The faunal content of the Elliott Cove and Clarenville Formations indicates that they range in age from Late Cambrian to Early Ordovician (Tremadocian). Stratigraphically they lie above the Middle Cambrian beds, but below the uppermost Lower Ordovician beds, as exposed at Wabana in Conception Bay.

Fossil zones in the Upper Cambrian strata exposed south of Elliotts Cove on the west side of Random Island contain, from the base upwards, *Agnostus, Olenus, Parabolina,* and *Peltura* species and are palæontologically correlated with similar faunal zones in New Brunswick and various parts of Europe (Hutchinson, 1962). The Ordovician fauna are likewise comparable with Tremadocian fauna in the Maritimes and Europe.

Gander Lake Group

The term *Gander Lake Group* was proposed by the writer (Jenness, 1958a) for a great thickness of shales, slates, and greywackes, and some interbedded

volcanic rocks, that cross Gander Lake in a northeasterly direction. These rocks had earlier been called *Gander Lake Series* by Twenhofel (1947) and assigned to a Silurian age. The attributed Silurian age has since been disproved.[1] The group is exposed in cross-section for almost the entire length of Gander Lake, i.e. nearly 30 miles. No other equally good exposures of the group are known.

Distribution and Thickness

The Gander Lake Group underlies approximately 1,100 square miles (or one third) of Terra Nova map-area, and is known to continue northeastward almost to the coast. It may also continue southwestward to the south coast to merge with the Baie d'Espoir Group (Jewell, 1939). The group includes mica schists at the east end of Gander Lake, formerly believed to underlie it (Twenhofel, 1947), and also about 25 square miles of granitized clastic sediments in the northwest corner of Bonavista map-area.

The thickness of the group cannot be closely estimated as yet because its upper and lower limits have not been determined. The lower part of the group is metamorphosed and granitized along its eastern limits, and the upper part apparently lies west of Terra Nova map-area[1]. Extensive folding in some sections and the scarcity of outcrops adds to the difficulty of thickness determinations. However, on the basis of the exposures along Gander Lake, the writer suggests that the group is at least 25,000 feet thick.

Lithology

The Gander Lake Group consists mainly of a thick succession of argillaceous and arenaceous rocks of fairly typical eugeosynclinal facies. It contains three broad lithological units, a lower one composed chiefly of arenaceous rocks, a middle one of mixed sedimentary and volcanic rocks, and an upper one chiefly of argillaceous rocks. Formal names for these units are not yet justified, for there is still insufficient data on their stratigraphic boundaries, thicknesses, and structures. Parts of all three units have locally been contact metamorphosed, and the 'lower unit' displays a general increase, from west to east, in grade of metamorphism, through the chlorite zone to the biotite zone of metamorphism.

The Lower unit. The rocks comprising the 'lower unit' of the Gander Lake Group consist chiefly of light to dark grey, fine- to medium-grained greywackes and argillaceous sandstones. These rocks appear to be at least 10,000 feet thick, but the base of the unit has not been found. The unit is best exposed for 16 miles along the north shore of Gander Lake east of the ultrabasic rocks. Only the upper part of the unit is exposed within this 16 miles; the lower part of the unit extends another 14 to 15 miles farther southeast. The 'lower unit' thus underlies an area nearly 30 miles wide that trends north-northeasterly across Terra Nova map-area.

The rocks of the 'lower unit' are only moderately well sorted as to size, and rounded grains are uncommon. In fact, the only rock seen in the entire

[1] See footnote to Table of Formations, page 29.

'lower unit' that has extensive rounding of particles is a relatively thin pebble conglomerate exposed on the north shore of Home Pond. Many of the greywackes contain thin laminations of shaly material. These laminations are particularly noticeable in the lighter coloured sediments where they give the rocks a wafered appearance. Shaly beds commonly provide the loci of joint planes in these rocks. In some exposures the laminations are less than $\frac{1}{4}$ inch apart and $\frac{1}{16}$ inch or less thick. In others they are more widely separated and the rocks become more homogeneous and massive, with fewer joint planes.

Most members of the 'lower unit' consist of angular quartz and plagioclase in a clayey or secondary mica matrix. The proportion of these few constituents varies considerably, thereby controlling the present composition and appearance of the rocks. Compositionally, the rocks in this unit range from greywackes to quartzites to silty slates to slates.

Specimens of the arenaceous rocks in the 'lower unit' that were examined under the microscope contained from 50 to 90 per cent angular to subangular quartz, together with from 0 to 30 per cent plagioclase, and from 0 to 30 per cent muscovite, biotite, chlorite, or sericite (i.e. secondary mica) and small amounts of granular opaque oxide. Fragments of tourmaline occur in some of the specimens that were collected from the upper half of the 'lower unit' within the chlorite zone of metamorphism. Carbonate, sphene, apatite, and pyrite have been observed as accessory minerals in other specimens. The quartz grains commonly show strain structure, and the plagioclase grains are generally dusty as a result of alteration to clay minerals.

Other sedimentary rock types within the 'lower unit' (excluding the regionally metamorphosed equivalents of the greywackes and argillaceous sandstones) include a quartz pebble conglomerate on Home Pond, a wide band of black pyritiferous slate between Kepenkeck Lake and Deer Pond, and narrow bands of grey slate locally interbedded with the greywackes and sandstones in several localities.

A single small exposure of a metavolcanic rock in this otherwise wholly sedimentary unit has been seen on the shore of Terra Nova River about a mile west of Mollyguajeck Lake. The rock is a dark green andesite consisting of a fine-grained matte of altered plagioclase and secondary hornblende with scattered grains of iron oxide and sphene, and veinlets of epidote. Its present mineral composition is fairly compatible with the regional grade of metamorphism indicated by the enclosing metasediments,—i.e. within the biotite zone, but close to the biotite isograd.

The 'lower unit' lies wholly within the chlorite and biotite zones of regional metamorphism, the nature of which is discussed later in this chapter. The mineralogically simple rocks in the unit have responded to metamorphism by converting to schists and paragneisses of relatively simple composition. This factor permits these metamorphic rocks to be fairly easily recognized and differentiated from nearby rocks of the Love Cove Group, even in places where both have been considerably feldspathized or granitized.

Individual beds within the 'lower unit' probably have great continuity along strike. The unit, however, is almost lacking in distinctive marker beds and/or

fossiliferous beds that would permit reliable interpretations of the stratigraphy and continuity of its many members. The only useful marker beds known to the writer are the pyritiferous black slates in a band almost 1 mile wide that has been traced intermittently from Kepenkeck Lake northward for 18 miles to the west side of Deer Pond. These slates are concealed beneath dense vegetation north of Deer Pond.

The Middle unit. The 'middle unit' of the Gander Lake Group comprises more than 2,500 feet of intercalated volcanic and sedimentary rocks. Nearly half of it consists of fine- to medium-grained pyroclastic rocks. Neither the base nor the top of the unit has been seen, but the position of both can be established within a few tens of feet on the north shore of Gander Lake, where the actual contacts are obscured by small bodies of ultrabasic rock. The unit is best exposed on this part of Gander Lake, even though outcrops are discontinuous. Exposures on the south side of the lake are not as good, for the rocks have been contact metamorphosed by nearby granite and are more difficult to recognize. The 'middle unit' has been traced for 40 miles to the north of Gander Lake (Jenness, 1958a) and for 25 miles to the south. Throughout this length it is recognized by the presence of volcanic members and associated sedimentary members that differ markedly from those in either the 'lower' or 'upper units'. The unit has a maximum surface width of about 2 miles.

The volcanic rocks include both lavas and pyroclastic rocks. Both have been recognized on the north shore of Gander Lake and in many exposures farther north. Only the pyroclastic rocks have been recognized south of Gander Lake, and these have been contact metamorphosed almost beyond identification. The pyroclastic rocks are more plentiful than the lavas, but are nowhere more than a few hundred feet thick. They include agglomerates, lapilli tuffs, and tuffs. The lowest volcanic member of the 'middle unit' on the north shore of Gander Lake is an *agglomerate,* with stretched and aligned fragments of lava of intermediate composition. Most of the fragments are less than 6 inches long; a few are more than 1 foot long. This particular exposure weathers dark green, but the agglomerates along strike farther north more commonly weather dull brown. One exposure of *lapilli* and *fine tuff* has been observed on the north shore of Gander Lake a few yards west of the agglomerate just described. Better exposures occur between the lake and the highway 1¾ mile distant, and north of the highway (Jenness, 1958a). Tuffs exposed on the Hunt's Pond road, 5 miles south of Gander Lake, have been contact metamorphosed to schists containing abundant small biotite flakes and garnet crystals in a groundmass of microscopic-sized iron oxide granules and quartz. A narrow band of schist with actinolite needles instead of garnet also occurs at this locality.

Tuffaceous rocks are more abundant than lavas north of Gander Lake, and are thickest and coarsest just east of Second Pond on Gander River (15 miles north of Gander Lake). The tuffaceous rocks become finer grained and thinner bedded to the north and south of Second Pond. Although exposures are scarce inland from Gander Lake the pyroclastic rocks appear to be lensoid, probably intertonguing with sedimentary members of the 'middle unit'.

A fine- to medium-grained *basalt* outcrops on the north shore of Gander Lake, about ⅔ mile west of the agglomerate. It is overlain by a coarse-grained greywacke, and is flanked on its lower (i.e. east) side by a body of altered diorite (epidiorite?). It is the only lava exposed on Gander Lake, and is relatively structureless, but pillowed basalt and andesitic lavas have been observed within the 'middle unit' farther north (Jenness, 1958a).

Sedimentary rocks within the 'middle unit' include types found nowhere else within the Gander Lake Group. They are best exposed on the north shore of Gander Lake, where they comprise much of the upper half of the unit. They include pebbly greywacke, grey and black slates, and fossiliferous calcareous argillites and siltstones. Farther north the 'middle unit' contains crossbedded sandstones, granule to pebble conglomerates, and clastic limestones (Jenness, 1958a), facies not observed within Terra Nova map-area. Each of these sedimentary facies is generally less than 50 feet thick.

Coarse-grained pebbly greywacke is the most commonly exposed sedimentary member of the 'middle unit' along the north shore of Gander Lake. It is medium grey, and contains up to 30 per cent fragments, which consist chiefly of pebbles of quartz and angular fragments of slate up to 1 inch in diameter. Similar clastic rocks exposed on the south shore of Gander Lake have been contact metamorphosed to micaceous schists, and only the quartz fragments remain seemingly unchanged. The greywackes on the north shore of Gander Lake are underlain by black and grey slates and calcareous members containing two fossil zones. One of these fossil zones lies in a medium grey, carbonate-bearing argillite a few feet stratigraphically beneath the greywacke that is exposed near the western (upper) side of the 'middle unit'. The fossils occur within a zone 25 feet thick. Most of the fossils in this zone are distorted brachiopod moulds, but a lone unidentified trilobite pygidium was recovered by the writer from this zone in 1952. The second fossil zone lies ⅔ mile to the east. It is a light grey calcareous siltstone about 3 feet thick.

The 'middle unit' lies just west of the chlorite isograd, but some members have been locally contact metamorphosed south of Gander Lake.

The Upper unit. The sediments in the 'upper unit' of the Gander Lake Group consist dominantly of slates—grey, green, red, and black varieties being represented in decreasing order of abundance. These rocks occur in monotonous succession, hundreds of feet thick. The base of the unit is faulted against serpentinite on the north shore of Gander Lake, the only place where it has been seen, and the top lies west of Terra Nova map-area.[1] From the excellent exposures on Gander Lake, however, the unit appears to be more than 10,000 feet thick. Exposures along the north shore of Gander Lake are almost continuous from the ultrabasic belt west to Gander River, 6 miles distant, and along most of this distance, the strata dip moderately to steeply to the west. Grey slates are the dominant lithofacies, but in the upper part of this unit, towards Gander River, these slates become interbedded with greywackes and graptolitic black slates (or argillites). The black slates (or argillites) are abundant on the highway on the east side of the Gander River bridge

[1] See footnote to Table of Formations, page 29.

and in a railroad quarry 1½ miles south of the bridge. Three bands of interbedded red and green slate are exposed on the north shore of Gander Lake, each several hundred feet thick. Only one such band has been recognized to date on the south shore. Colour variations in some of the grey slates aid in the recognition of bedding.

Individual beds within the 'upper unit' may have considerable continuity along strike. The red slates on Gander Lake and the black graptolitic slates in a quarry south of Glenwood may prove to be useful marker beds. No other easily recognized members have been seen in the 'upper unit' of the group.

The 'upper unit' is dominantly an argillaceous facies with some thin beds of fine- to medium-grained greywacke in the upper part. Thin sections of the greywackes display poorly size-sorted, angular, quartz grains, with up to 15 per cent plagioclase grains in an argillaceous matrix. The high proportion of clay to sandy components in the 'upper unit' places its members almost at the clayey end of a claystone-sandstone textural series; the rocks in the 'lower unit', on the oher hand, are largely quartz and plagioclase and are near the sandy end of such a series.

The 'upper unit' lies west of the two regional metamorphic zones, but has been contact metamorphosed by granitic rocks in a few places south of Gander Lake.

Metamorphism

Rocks of the Gander Lake Group have been subjected to three kinds of metamorphism, which are, in order of decreasing area of influence; (1) regional metamorphism, which has converted much of the 'lower unit' of the group into schists and gneisses; (2) contact metamorphism, which has produced metamorphic aureoles in the Gander Lake sediments along the western margin of the Ackley granitic batholith, the effects of which cannot be recognized east of the biotite isograd; and (3) granitization, which has produced granite-like bodies in the regionally metamorphosed Gander Lake sediments along the east side of the Ackley batholith.

Regional Metamorphism. The 'lower unit' of the Gander Lake Group has been regionally metamorphosed, with the resultant development of chlorite and biotite schists and mica-quartz paragneisses in Terra Nova map-area. The relatively homogeneous composition of the 'lower unit' lends itself nicely to subdivision into metamorphic zones. Few facies are present within these zones.

Use of the Barrow-Tilley metamorphic zone concept together with the Eskola facies concept is justified on the grounds that they collectively provide a simplified means of interpreting the lithological and textural variations encountered. Readily understandable, for example, is the interbedding of biotite schists and biotite-plagioclase-quartz gneisses, for these were originally interbedded argillaceous and impure arenaceous sediments. If the original mineral compositions of these rocks within the 'lower unit' of the group had been more variable, the resultant facies would have been much more complicated and the metamorphic zone concept

probably inapplicable. The chlorite isograd has been placed where chlorite appears in the argillaceous sediments as a result of recrystallization, and the biotite isograd where recrystallized biotite first appears.

The *chlorite isograd* is drawn approximately at the east side of the Gander River ultrabasic belt on Gander Lake, for the argillaceous rocks there have a chloritic sheen and locally justify the name phyllite. The position of this isograd south of Gander Lake is questionable, owing to the presence along its probable position of rocks locally contact metamorphosed to the amphibolite facies near two bodies of granite, and also to the scarcity of outcrops in this region. The isograd probably lies 1 mile to 2 miles east of Southwest Gander River and approximately parallel with it. The chlorite zone extends across a width of about 18 miles, all of which is contained within Terra Nova map-area.

The *biotite isograd* has been located fairly accurately at three places: on the south side of Lake St. John; at a point near the west end of Gambo Pond; and along the railway tracks just east of Gander Lake. To the northeast of this last locality the position of the biotite isograd is less accurately known, but it does cross Gull Pond and continues along the east side of Wing Pond. Its position across much of the terrain between Lake St. John and the railway tracks near Gander Lake is obscured by granitic rocks. The grade of metamorphism increases eastward from this isograd, with the gradual elimination of chlorite by conversion to biotite. Chlorite and muscovite have survived in several of the stratigraphic bands as much as 6 miles east of the biotite isograd. Presumably their conversion to biotite has been impeded by the dominantly quartzose nature of the surrounding rocks. Chlorite is rare in the metamorphosed members of the Gander Lake Group east of Lake St. John. The biotite zone has a maximum width of 12 miles; its eastern side abuts sharply against greenschists of the Precambrian-aged Love Cove Group, probably along a fault zone.

As a result of the regional metamorphism, the members of the 'lower unit' of the Gander Lake Group west of Terra Nova are well-defined, intercalated mica-quartz paragneisses and mica schists, the schists occurring chiefly as thin layers between thicker layers of paragneiss. The argillaceous sandstones or greywackes in the 'lower unit' have been converted to biotite-plagioclase-quartz paragneisses, the more argillaceous sediments to muscovite and biotite schists. One outcrop of amphibolite occurs alongside the private road near the west end of Terra Nova Lake, where it is interbedded with biotite-quartz paragneiss. This rock could originally have been a calcareous shale, and does not necessarily denote a higher degree of metamorphism.

A small area of rocks of anomolously lower degree of metamorphism is partly exposed along the highway on the ridge just west of Gambo, where it lies between the two masses of granite. The rocks there are dominantly finely laminated greyish quartzitic facies, with thin argillaceous seams, roughly $\frac{1}{8}$ to $\frac{1}{4}$ inch apart, now consisting chiefly of fine-grained muscovite and chlorite. Why these rocks have not attained the biotite grade of metamorphism is not known; possibly the local dominance of arenaceous material has successfully prevented the recrystallization of the argillaceous seams to biotite.

Contact metamorphism. Contact metamorphic effects have been superimposed upon regional metamorphic effects in the rocks of the Gander Lake Group along the western margin of the Ackley granite batholith and around the leucogranite near Dead Wolf Pond. Such effects have not been recognized east of the biotite isograd. As a result rocks of the group are locally converted to micaceous schists, in places prominently spotted, and to cordierite hornfels. Andalusite porphyroblasts are partly developed in the metasediments at the granite contact on the highway a mile north of the bridge at the east end of Gander Lake. These metasediments lie within the 'lower unit' of the group, several hundred feet below its top. Cordierite is present only within a few hundred feet of the granitic rocks. Coarsely spotted micaceous schists extend an equal or greater distance beyond the zone of cordierite development, gradually showing a decrease in recognizable metamorphic features (i.e., spotting and mica development). Different metamorphic facies are present where the granitic rocks have contact metamorphosed sediments other than the usual quartz-feldspar-clay (or mica) rocks. Thus the calcareous and tuffaceous members of the 'middle unit' of the Gander Lake Group have become rocks containing actinolite, hornblende, and locally zoisite and/or epidote. Such rocks have been seen along the south shore of Gander Lake east of Hunts Cove, on the road just north of Hunts Pond, and on the ridge immediately south of the mouth of Dead Wolf Brook. Garnets developed in the tuffaceous rocks on the road near Hunts Pond, and amphibolitic rocks exposed between the south shore of Gander Lake and Caribou Lake indicate the highest grade of contact metamorphism produced within the two map areas.

Granitization. The original quartz-plagioclase-clay composition of most of the 'lower unit' of the Gander Lake Group evidently made it highly susceptible to granitization, for large areas of the unit are now slightly, moderately, or extensively granitized. The widespread development of flesh-coloured potash feldspar porphyroblasts, and injections of granitic material along the foliation planes of the schists (*see* Plate VIII A) are evidences of such granitization. North of Esker Pond (N. Lat. 48°14′, W. Long. 54°31′), and also north of Lockers Bay, sediments of the Gander Lake Group are so extensively granitized that it is difficult to distinguish them from the intrusive granite. In some places they can be recognized by the presence of patches of oriented biotite flakes, local pockets of unassimilated paragneiss still retaining the regional foliation (*see* Plate VIII B), and areas of migmatitic or hybrid rocks. Almost all gradations between paragneiss and homogeneous granite have been observed in outcrops. A close relationship between regional metamorphism and the granitization of the 'lower unit' of the Gander Lake Group, similar to the pattern outlined by Read (1957), seems probable.

Structural Features

Structural features of the Gander Lake Group include small scale primary and secondary structures not discussed in the following chapter, and contact relations. The former include graded bedding, crossbedding, slaty cleavage, drag folds, slip folds, crenulations (or crinkles), and distortion of fossils. The latter include contacts with the Love Cove Group, the ultrabasic rocks, and the granites.

Graded bedding is well developed in alternating greywackes and silty argillites exposed along the north shore of Gander Lake, just east of the outlet of the lake. It is rare elsewhere in the group. *Crossbedding* has been observed in only one exposure, a greyish green, fine-grained sandstone that outcrops ¾ mile south of the highway at Twin Ponds (7 miles west of Gander). *Slaty cleavage* is developed in all argillaceous members of the group, and where best revealed, as on the shores of Gander Lake, is parallel with the axial planes of the major regional folds. Dips on the cleavage range from vertical to gently west, but are generally steeper than 50 degrees. *Drag folds* occur in clusters along the shores of Gander Lake within the 'upper unit' of the group. They commonly have amplitudes that measure only a few tens of feet. Small isoclinal drag folds overturned to the east appear along the south shore of Gander Lake just east of Hunts Cove (*see* Plate IX A), and even tighter folds have been observed in the metasediments near the Ackley batholith (*see* Plate IX B). Small *slip-folds* have been observed on the limbs of some of the drag folds referred to above, the dimensions of which are only fractions of inches to several inches (*see* Figure 8). Crenulation (or crinkling) of slates has been observed on the east shore of Hunts Cove (Plate X). The crenulations are more or less parallel with the regional strike, and may have been superimposed upon the slaty cleavage during the intrusion of the nearby granite. *Distortion of fossils* is readily apparent in the fossil locality on Gander Lake near the top of the 'middle unit', where distortion in the plane of the rock cleavage of the moulds of *Horderleyella*-like brachiopods has resulted in lengthening of the moulds in one direction (the "b" or fold axis of Bruno Sander), shortening in the other. The moulds are also distorted (flattened) in the direction normal to the planes of bedding and cleavage. Distortion of these fossils is about 25 per cent (Jenness, 1954).

The Gander Lake and Love Cove Groups are presumably separated by a fault or fault zone. The contact between them has not been observed, but is interpreted as a fault (or fault zone) because of the abruptness in the change of metamorphic grade from biotite grade on the west side of the contact to chlorite (sericite-epidote) grade on the east side, and because the contact is parallel with the general strike of several better defined fault zones farther east. Were the contact an unconformity, the metamorphism that developed rocks of the biotite grade in the Gander Lake Group would not have had its area of influence stopped abruptly at the contact between the two groups. Recognition that the change from biotite to chlorite in the rocks marked a major stratigraphic boundary rather than a metamorphic gradient permitted the author to trace the contact between the two rock groups with considerable confidence across many miles of outcrop wherein the rocks have been granitized. The contact fault must have developed after the regional metamorphism of the Gander Lake Group, but before the intrusion of the Ackley batholith.

Only two contacts between members of the Gander Lake Group and an ultrabasic rock have been observed in the two map-areas. On the north shore of Gander Lake, grey slate that lies at or near the base of the 'upper unit' is in visible contact with a small body of highly shattered serpentinite. The slate has been con-

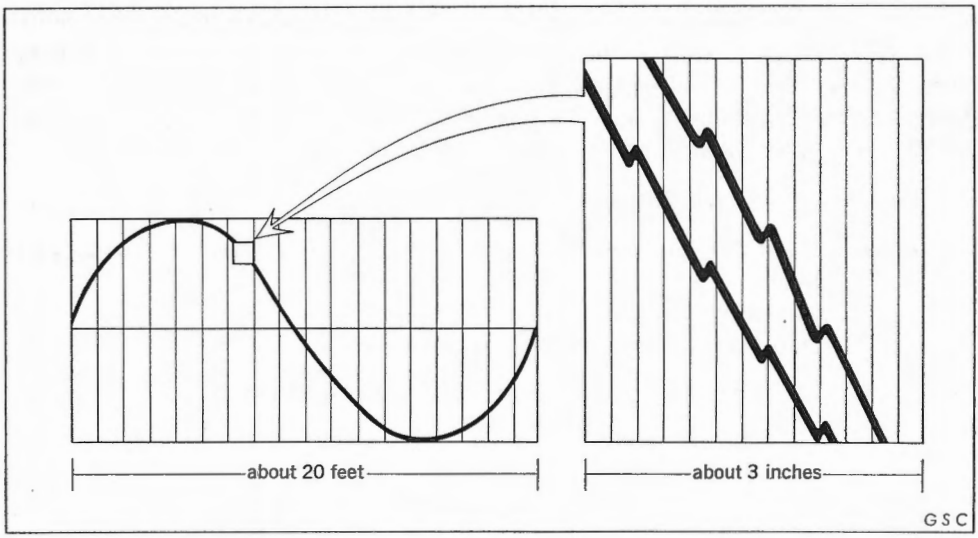

Figure 8. *Diagram showing slip folding in grey slates with thin siltstone bands, and its position on the limbs of larger drag-folds. North shore of Gander Lake, 2 1/2 miles west of ultrabasic rocks. Vertical lines represent axial-plane cleavage.*

verted to a blackened brittle hornfelsic rock with numerous pyrite and quartz veins within 20 feet of the serpentinite, and the beds are slightly bowed upward. On the south shore of Trinity Bay (in Bonavista Bay), 1½ miles west of Drake Island, a 60-foot dyke of serpentinite with minor talc and carbonate cuts across granitized biotite-quartz paragneiss. Neither paragneiss nor serpentinite show any contact effects.

Although few contacts between Gander Lake Group sediments and the Ackley granite batholith have been seen, cross-cutting relations and contact metamorphic aureoles along the west flank of the batholith, where the grade of regional metamorphism of the Gander Lake sediments is within the chlorite zone, indicate intrusive relationships. Gander Lake Group-Ackley batholith contact relations farther east, within the biotite zone of regional metamorphism, are transitional, however, and show many indications of feldspathization and granitization (*see* Plate VIII A and B). The contact metamorphic aureole around the leucogranite near Dead Wolf Pond is interpreted as indicating its intrusive relationship to the Gander Lake Group.

Palæontology

Fossils have been recovered from rocks of the Gander Lake Group at four localities within Terra Nova map-area.[1] These include two localities within the 'middle unit' where it is exposed on the north shore of Gander Lake, a third on the highway just north of these two, and a fourth locality on the east side of Gander River just south of Glenwood.

[1] Three new graptolite localities were found by members of a Geological Survey of Canada field party in 1962. They are all west of Gander River, at the following localities: Lat. 48°54.5′, Long. 54°58.6′; Lat. 48°55.3′, Long. 54°58.7′; and in Salmon Pond Brook at Lat. 48°59.8′, Long. 54°53.1′. (*See also* footnote to Table of Formations.)

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Only five additional fossil localities are known elsewhere within the entire group. Of these, only two have yielded fossils sufficiently well preserved for generic identification. Their faunal lists are published for the first time in this report. The three remaining localities occur on or near Weirs Pond (N. Lat. 49°13′, W. Long. 54°23′) and have yielded no identifiable specimens (Jenness, 1958a).

Fossil localities and identifications[1] are as follows:

Locality 1. (GSC loc. 36010) North shore of Gander Lake, 6¼ miles east of outlet.
Chaetetes Fischer in Eichwald 1829
Brachiopod fragments, possibly *Hesperorthis* sp.

Locality 2. (GSC loc. 36009) North shore of Gander Lake, 5½ miles east of outlet.
Valcourea sp. Raymond 1911
Horderleyella sp. (?)
Unidentified trilobite pygidium

Locality 3. Trans-Canada Highway, 1 mile north of locality 1.
Brachiopod fragments, possibly *Hesperorthis* sp.

Locality 4. (GSC loc. 36007) South end of quarry on east shore of Gander Lake, 1 mile south of Glenwood.
Climacograptus cf. *rectangularis* (McCoy)

Locality 5. (Fossil locality originally discovered by D. M. Baird in 1951) West shore of Gander River, 1¾ miles north-northeast of railway bridge at Glenwood (N. Lat. 49°01′, W. Long. 54°51.3′).
Climacograptus sp.
Dicranograptus sp.
Diplograptus sp. (?)
Nemagraptus sp. (?)

Locality 6. (GSC Palæontological Rept. 06/51) Southwest shore of Middle Ridge Pond (N. Lat. 48°16′, W. Long. 55°07′). (Collected by H. S. Scott in 1951.)
Climacograptus cf. *scharenbergi* Lapworth
Climacograptus bicornis Hall

Localities 1, 2, and 3 lie within the upper part of the 'middle unit' of the Gander Lake Group; localities 4 and 5 lie towards the upper part of the 'upper unit'; and locality 6 appears to lie near the top of the 'lower unit'. The rock at locality 3 may be a large glacial boulder rather than outcrop. The fossils it contains resemble those in locality 1.

[1] Specimens from localities 3 and 5, and genera *Horderleyella* (?) in locality 2 and *Hesperorthis* (?) in locality 1 were identified in 1953 by Professor C. O. Dunbar of Yale University. Specimens from locality 6 were identified in 1951 by Dr. A. E. Wilson of the Geological Survey of Canada. Other specimens listed were identified in 1959 by Dr. L. M. Cumming of the Geological Survey of Canada.

Age and Correlation

All fossils recovered to date from the Gander Lake Group indicate or favour a Middle Ordovician age for the enclosing rocks.

Biostratigraphic correlation of parts of the Gander Lake Group with parts of the Exploits Group in the Bay of Exploits (Heyl, 1936) that contain similar genera of graptolites seems feasible, but has not yet been attempted. Lithostratigraphic correlation of the Gander Lake Group with all or part of the Exploits Group, which contains various slates, greywackes, and thick lava and pyroclastic sections, also is possible. Lithostratigraphic correlation of the Gander Lake Group with the Bay d'Espoir Group south of the present map-areas appears probable, judging from the apparent structural continuity of the two groups. The Bay d'Espoir Group has yielded only one fossil to date[1], a probable Ordovician gastropod, from near the middle of the group, so that biostratigraphic correlation is not possible. Weeks (1957) has suggested a lithostratigraphic correlation of the Bay d'Espoir Group and the Meguma Group in Nova Scotia, both of which, like the Gander Lake Group, consist of essentially two parts, a lower dominantly arenaceous part and an upper dominantly argillaceous part. However, the upper argillaceous unit (Halifax Formation) in the Meguma Group is now known to contain graptolites of Early Ordovician age (Stevenson, 1959, p. 10; Crosby, 1962), so that the lithological similarities of the two groups are apparently coincidental.

Plutonic Rocks

Plutonic rocks in Terra Nova and Bonavista map-areas include small bodies of altered diorite, gabbro, and ultrabasic rocks of Ordovician or earlier age, large bodies of Devonian granitic rocks, and many small dykes of Precambrian to Devonian or younger age. The basic and ultrabasic rocks have been metamorphosed (metasomatically) by the granitic rocks.

Basic and Ultrabasic Rocks

Diorite and Gabbro

Distribution

Small bodies of diorite have been observed on the north side of Whitehead Pond, the west side of Gull Pond, on the Hare Bay road 2 miles west of Traverse Brook, on several islands from the Inner Gooseberry Islands south to Great Black Island, and on Willis and Tumbler Islands. The diorite that comprises the several small islands of the Inner Gooseberry Islands region is probably a single intrusive plug. Gabbro (epidiorite?) occurs with the ultrabasic rocks on the north side of Gander Lake, and from there northward almost to the coast (Jenness, 1958a).

[1] This was discovered on June 17, 1953, by C. G. Johnson of the Newfoundland Labrador Corporation, on the southwest corner of the peninsula immediately east of Riches Island in Bay d'Espoir (N. Lat. 47°46.7′, W. Long. 55°49.1′). The fossil was examined by Dr. A. E. Wilson, who reported (Sept. 22, 1953):

> "Gastropoda—might be an *Eotomaria* sp.
> "The specimen is very poor for a definite identification, but it appears to be of Ordovician age."

The specimen was destroyed during study and no further collections have been made.

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Lithology

The diorite is a fine- to medium-grained, equigranular, medium to dark green rock. It consists of intermediate plagioclase (50-60 per cent) and hornblende or pyroxene (30-40 per cent), with minor amounts of quartz and magnetite. The quartz is generally distinguishable megascopically with close scrutiny, but comprises less than 10 per cent of the diorite. Both pyroxene and hornblende are present in the Inner Gooseberry Islands body, but the pyroxene is dominant. Alteration differs in each body, being least extensive in the Gull Pond body and most extensive in the Inner Gooseberry Islands body. In the Gull Pond body the plagioclase contains only small amounts of clayey and micaceous alteration products and the hornblende and biotite are fresh, but potash feldspar is locally present and the rock appears recrystallized. The introduction of the potash feldspar, development of biotite, and recrystallization may have been effected by the nearby intrusive granitic rocks (part of the Ackley batholith). In the Inner Gooseberry Islands body, the plagioclase is almost completely altered to clay minerals, but the pyroxene and hornblende are only slightly altered to chlorite. Titaniferous magnetite in this body (as shown by relict Widmannstätten texture) has been largely replaced. In the diorite at Whitehead Pond the plagioclase is partly altered to clay minerals, whereas the hornblende is almost completely altered to chlorite.

The gabbro associated with the ultrabasic rocks north of Gander Lake is almost entirely altered to zoisite, clay minerals, chlorite, and/or secondary hornblende. Variations in composition and texture are common. The ferromagnesian mineral was originally pyroxene, relicts of which are recognizable in some specimens. This rock may be what some geologists call epidiorite.

Structural Relations and Age

Contacts between the Whitehead Pond and Gull Pond bodies and the enclosing rocks are not exposed. The former is surrounded by rocks of the Precambrian Love Cove Group and is presumed to be younger than them. It may be Precambrian in age. The Gull Pond diorite body is surrounded by metasediments of the Ordovician Gander Lake Group, and in one outcrop appears to have penetrated the metasediments. As it seems to have been feldspathized by the nearby Devonian granites, it is regarded as post-Middle Ordovician but pre-Middle Devonian. The Inner Gooseberry Island pluton has intruded members of the Connecting Point Group, and is therefore no older than late Precambrian. Closer dating of this pluton is not possible.

The gabbroic rocks cut across and engulf slate and tuff members of the Gander Lake Group north of Gander Lake, but are, in turn, apparently cut by pyroxenite dykes (Jenness, 1958a). The gabbro is therefore tentatively regarded as of late Ordovician age, intruded shortly before the ultrabasic rocks.

Ultrabasic Rocks

Distribution

Ultrabasic rocks occur in isolated lenses along a narrow belt across the northwestern corner of Terra Nova map-area. This belt—the Gander River ultra-

basic belt (Jenness, 1958a)—continues north of the map-area almost to the coast. It also continues to the southwest for about 40 miles. The lenses of ultrabasic rocks are generally elongated more or less parallel with the structures of the Gander Lake Group rocks. They have been rounded off by glacial action, and now occur as low hummocky knolls. The entire ultrabasic belt from near the headwaters of Northwest Gander River to the north coast has been called the 'Eastern Serpentine Belt' (Snelgrove, 1934), but because of the small proportion of serpentine to other minerals this term is no longer regarded as appropriate.

Fifteen lenses have been delineated in that part of the ultrabasic belt within the confines of Terra Nova map-area. Most of them are on the north side of Gander Lake. In addition, a lens of serpentinite occurs a mile southwest of Lake St. Johns, approximately 18 miles southeast of the main belt, and a dyke of serpentinite cuts paragneiss on the south shore of Trinity Bay in the northwest corner of Bonavista map-area, approximately 35 miles east of the ultrabasic belt.

Lithology

The ultrabasic rocks consist of pyroxenite, serpentinite, and carbonate schist; the serpentinite presumably formed by the complete alteration of dunite, the carbonate schist by the complete alteration of both pyroxenite and serpentinite. Pyroxenite is the most abundant rock type, carbonate schist next in abundance.

Pyroxenite. The pyroxenite is medium to coarse grained, greyish green to dark green, with a megascopically monomineralic appearance. However, microscopic examination shows that it consists of two pyroxenes (bronzite and diopside), together with small amounts of phlogopite mica and magnetite.

The composition of eight orthopyroxenes and five clinopyroxenes from specimens collected between Gander Lake and the northern boundary of Terra Nova map-area are given below. The compositions of the orthopyroxenes were determined by measuring the "Z" index of refraction in powdered grains in immersion oils and monochromatic light, and those of the clinopyroxenes by measuring the 2V (on the universal stage) and the "Y" index of refraction in powdered grains in immersion oils and monochromatic light. These measurements were then compared with Hess' graphs for orthopyroxene (Hess and Phillips, 1940, p. 280) and clinopyroxene (Hess, 1949, p. 634) to obtain the approximate chemical composition of the two minerals. Values for the clinopyroxenes are probably less accurate than those for the orthopyroxenes because of imperfections in both the mechanics of measuring 2V's and indices and in Hess' compositional graph.

The compositional ranges shown by 34 orthopyroxenes and 17 clinopyroxenes[1] in specimens collected throughout the entire ultrabasic belt north of Gander Lake were $En_{74.5-82}$[2], and $Ca_{39-49}Mg_{45-60}Fe_{1-6}$, respectively (Jenness, 1954).

[1] Values could not be determined on the additional 17 clinopyroxene specimens because of local alteration, brecciation, or unsatisfactory orientation of the clinopyroxene grains accompanying the orthopyroxene.

[2] Corresponding to indices of refraction 1.699 to 1.6885 respectively; only one orthopyroxene was below En_{77}.

Locality	Orthopyroxene	Clinopyroxene
1. North shore, Gander Lake	En_{80}	$Ca_{40}Mg_{58.5}Fe_{1.5}$
2. North shore, Gander Lake	$En_{80.5}$	$Ca_{41}Mg_{57}Fe_{2}$
3. North shore, Gander Lake	En_{81}	$Ca_{41}Mg_{56}Fe_{3}$
4. North shore, Gander Lake	En_{82}	$Ca_{49}Mg_{45}Fe_{6}$
5. Along railroad, east of Twin Ponds	$En_{80.5}$	$Ca_{45}Mg_{51.5}Fe_{3.5}$
6. North shore, Gander Lake	En_{82}	———
7. North shore, Gander Lake	En_{81}	———
8. Lake, 2 miles north of Twin Ponds	En_{79}	———

These figures indicate that (1) both the bronzite and the diopside are low in iron—i.e. they are magnesian-rich varieties, and (2) neither mineral shows an appreciable or systematic variation in composition throughout the entire ultrabasic belt.

The presence of the two pyroxenes establishes the pyroxenite as *websterite* (Johannsen, 1938, p. 460). Clinopyroxene is probably more abundant than orthopyroxene, but this is difficult to establish because of their similar appearance, both in outcrops and under the microscope.

Most of the pyroxenite is relatively unaltered, but some breccia zones occur marginally, along which serpentine is developed. The pyroxenite near the intrusive leucogranite near Dead Wolf Brook, south of Gander Lake, is altered to a calcite-actinolite rock.

Serpentinite. Serpentinite occurs in Terra Nova map-area as three small isolated bodies and several dykes marginal to pyroxenite bodies. It is apple-green to dark greenish black, fine grained, and locally has a splintered structure. It consists almost entirely of secondary serpentine minerals, but also includes scattered grains of chromite, secondary magnetite, and ferromagnesian carbonate. No relicts of olivine have been found, but the occurrence of disseminated chromite and the local preservation of an equigranular texture (as seen in thin section) are regarded as evidence that the original rock was a dunite.

Two small bodies of serpentinite outcrop east of the ultrabasic belt. One is a small lens in a bog just southwest of Lake St. John, about 18 miles east of the main ultrabasic belt. It contains scattered carbonate grains and talc stringers. The other is a 60-foot thick dyke that cuts across feldspathized paragneiss on the south shore of Trinity Bay in Bonavista Bay, about 35 miles southeast of the main ultrabasic belt. This rock contains small scattered rhombs of carbonate and flakes of talc, indicating incipient alteration to talc-carbonate schist.

Serpentinites are more plentiful and occur in larger lenses north of Terra Nova map-area (Jenness, 1958a).

Metamorphism

The pyroxenite and serpentinite have locally been altered to carbonate schists. These schists are of two principal types—calcite-actinolite schists, and talc-

and/or quartz carbonate schists (Jenness, 1958a). The former were developed by the metamorphism of pyroxenite, probably along or near fault zones; the latter were developed by the metamorphism of serpentinites, first by the formation of carbonate, then by the formation of quartz and/or talc. The carbonate in the talc-quartz-carbonate schists is generally an Fe-bearing magnesite (breunnerite). Calcite-actinolite rocks in several stages of development from pyroxenite occur near the mouth of Dead Wolf Brook, south of Gander Lake. Quartz-carbonate schist, which formed from serpentinite, has been observed on the east side of the ultrabasic belt half a mile north of the Trans-Canada Highway, and in many outcrops farther north (Jenness, 1958a). Carbonate rhombs occur in the small serpentinite body southwest of Lake St. John, and in some serpentinite exposures on the north side of Gander Lake. Younger granitic rocks are fairly near in each case.

Structural Relations

The trend of the individual lenses of ultrabasic rocks conforms with the general strike of the enclosing sediments of the Gander Lake Group, although in detail they may cut discordantly across the sedimentary bedding. North of Gander Lake, where the bedding of the Gander Lake sediments is nearly vertical, many of the ultrabasic rocks are more sill-like. The almost exclusive localization of the ultrabasic rocks to the volcanic members of the lower half of the 'middle unit' of the Gander Lake Group is puzzling. Whether this part of the group provided a more suitable locus for emplacement because of its different chemical composition or because of a different structural reaction by the tuffs during regional stresses is not known. The latter explanation seems the more reasonable of the two.

Mode of Origin

The mode of origin of the ultrabasic rocks in the map-area is not certain. The low grade of metamorphism shown by the surrounding rocks rules out the formation of the pyroxenites by metamorphism in situ. The ultrabasic rocks may have been emplaced as lubricated crystal aggregates (crystalline mushes) at relatively low temperatures while the enclosing members of the Gander Lake Group were being folded (Jenness, 1958a). The serpentinite probably developed from the parent olivine material by hydration during emplacement. Some later movement by the serpentinite is possible, locally yielding so-called 'cold intrusions'. Both pyroxenite and serpentinite were subsequently altered, probably by fluids introduced during the intrusion of the nearby granitic rocks.

Age and Correlation

As the ultrabasic rocks apparently intruded sediments that are interbedded with fossiliferous Middle Ordovician strata, they are no older than Middle Ordovician in age. They are in turn altered by the nearby Devonian granites. They were therefore emplaced at some time between Middle Ordovician and Devonian times. The writer favours a late-Middle to Late Ordovician age, related to the folding of the Gander Lake Group.

It is not yet possible to relate the ultrabasic rocks in the Gander River belt to those elsewhere in Newfoundland, specifically those on the Burlington Peninsula

or in the Bay of Islands region on the west coast of Newfoundland. The ultrabasic rocks on the Burlington Peninsula in Notre Dame Bay are similar in structure and alteration, but the Bay of Islands ultrabasic rocks are dissimilar both structurally and compositionally.

Granite and Granitic Rocks

Granite and granitic rocks occur over large areas of Terra Nova map-area and in a few small bodies near the western margin of Bonavista map-area. Most of them comprise part of the Ackley batholith, which extends from Fortune Bay and Bay d'Espoir on the south coast of Newfoundland northeasterly across Terra Nova map-area to the northeast coast north of Bonavista Bay. In general these rocks are light red, coarse-grained to coarsely porphyritic biotite granites, but they display many local variations in colour, texture, and composition. Most of them appear to have been derived from the same source, with mineralogical variations attributable in most cases to the chemical influence of the incorporated rocks. A small body of granite in the Louil Hills near Traytown possesses petrographic features suggesting a different history or parentage.

Ackley Batholith

The name Ackley batholith was first used by White (1940) for granitic rocks in the Rencontre area on the north side of Fortune Bay. Bradley (1962) subsequently extended the boundaries of the batholith to the southern border of Terra Nova map-area.

Distribution

The Ackley batholith has been traced from Fortune Bay northeastward across Terra Nova map-area to the north side of Bonavista Bay; it may continue around the northeast coast as far as Fogo Island. Except for a narrow gap south of Lake St. John it is continuous for more than 130 miles, with a minimum width of about 3 miles near Gambo, and a maximum width of about 40 miles near Fortune Bay. The batholith underlies more than 1,000 square miles of Terra Nova map-area. Large apophyses of the batholith occur around Gander Lake, Terra Nova village, and Northern Bight railway station; smaller ones occur near Clarenville, and southwest of Terra Nova Lake. A large elongate body of leucogranite lies along the east side of the ultrabasic belt, in the northwest corner of Terra Nova map-area; it is probably related to the Ackley batholith.

The Ackley batholith lies almost wholly along the eastern half of the Gander Lake Group, and is a distinctly elongate body oriented approximately N30°E parallel with the structural trend of the sediments in that group. Much of the terrain underlain by it is low-lying, with little relief, and is dotted with many small lakes.

Lithology

The Ackley batholith consists mainly of an orange-pink to light red, coarse-grained porphyritic biotite granite. Finer-grained more equigranular phases are

found in some parts of the batholith, and compositional variations are common along the east side of the batholith where schistose country rocks have been partly assimilated. Orange-pink potash feldspar is generally the dominant mineral in the granite, but buff-coloured sodic plagioclase is commonly present in amounts exceeding 15 per cent, and in a few exposures is the dominant feldspar. Potash feldspar crystals in the porphyritic granite are not uncommonly as much as 2 inches long and 1 inch wide. Quartz constitutes from 15 to 25 per cent of the rock, and biotite ranges between 10 and 15 per cent. Indications of contamination of the granite along its eastern side consist of inclusions of unassimilated or partly assimilated mica-quartz paragneiss (from the Gander Lake Group) and chloritic schist (from the Love Cove Group), as well as patches or clusters of oriented biotite flakes or of chlorite and/or epidote.

Recognizable in thin sections of the Ackley granite are perthitic potash feldspar, quartz, biotite, and minor accessory magnetite, apatite, zircon, muscovite, garnet, hornblende, and sphene. Both twinned and untwinned potash feldspar are present in many of the thin sections examined. Many of the grains display microcline (plaid) twinning in only part of their surface, and all gradations from completely twinned microcline to untwinned potash feldspar (orthoclase?)[1] have been observed although not in the same thin section. Almost all the potash feldspar, whether twinned or not, is perthitic and displays oriented films, or partly oriented veins, of plagioclase. The plagioclase in the wider veins shows polysynthetic twinning. The perthite is a replacement type. The large crystals of potash feldspar are commonly poikilitic as well as perthitic. Many of them enclose quartz, plagioclase crystals, and biotite flakes. These large crystals (between 1 inch and 2 inches long) thus appear to have formed later than all other minerals in the granite, and may be porphyroblasts. Large crystals of exactly the same type, the *dents de cheval* of some geologists, occur in the surrounding paragneisses and paraschists along the eastern flank of the Ackley batholith. The potash feldspar is generally only slightly altered to secondary clay minerals.

Plagioclase constitutes between 15 and 50 per cent of the granite. It occurs as subhedral to euhedral crystals, generally well twinned, and contains varying amounts of argillic and sericitic alteration. It is commonly albite, rarely oligoclase. High proportions of plagioclase were observed in outcrops along the eastern border of the batholith, where contamination phenomena are plentiful (*see* Plate VIII B).

Quartz occurs both as coarse grains or grain aggregates, and as fine interstitial particles visible only under the microscope. It is invariably fractured and displays wavy extinction, indicative of strain.

Biotite shows various stages of alteration to chlorite. Unaltered specimens have a pleochroism ranging from straw-yellow to olive-brown; chloritized flakes are invariably greener. Many of the biotite flakes contain small crystals of zircon that are surrounded by pleochroic haloes.

[1] Several grains of the untwinned potash feldspar have been identified by X-ray powder diffraction determinations as a triclinic mineral, hence are considered to be microcline. Other grains yielded indefinite patterns, and may be orthoclase, untwinned microcline, or a structural mixture of the two.

Accessory minerals constitute less than 10 per cent of the granite. Magnetite grains are widely scattered throughout each specimen examined, but apatite and sphene have been seen in only a few specimens. Muscovite occurs locally as well developed flakes, and is more plentiful than biotite in pegmatitic and aplitic phases. A few grains of hornblende were observed in a specimen of biotite granite from Fair Island in the northwest part of Bonavista map-area, but nowhere else. The presence of small inclusions of chloritic schist (Love Cove Group) in the same outcrop from which this specimen was collected suggests local contamination. Tiny red 'pinhead' garnets have been observed in several small granite dykes cutting paragneiss (Gander Lake Group) about a mile north of Terra Nova Lake. Their presence is not readily explained. Myrmekite has been observed in several specimens from the eastern side of the granite body north of Lake St. John and is interpreted as the product of a late magmatic or deuteric reaction between the sodic and potassic feldspars and quartz. It is not plentiful in any of these specimens, but is a common feature in the nearby feldspathized paragneisses and schists.

Northern Bight granite. Granite and granitic rocks, named the Northern Bight granite by Rose (1948), extend from near Northern Bight railway station (at the southeastern border of Terra Nova map-area) southwest into Placentia Bay. They lie a few miles east of the main Ackley batholith. A narrow prong of coarse-grained, seemingly uncontaminated biotite granite trends north from Northern Bight station for 6½ miles into terrain underlain by Love Cove schists. West of the railway tracks the Northern Bight granite is largely a mixture of granitized volcanic and sedimentary rocks and contaminated granite. These granitized rocks continue south of the two map-areas to Placentia Bay.

Uncontaminated biotite granite near Northern Bight station has a granitoid to porphyritic texture and two megascopically visible feldspars. The pinkish feldspar is microcline perthite, with replacement vein-type albite. The buff-coloured feldspar is albite. Both feldspars are partly altered to clay minerals and secondary mica. Biotite is the ferromagnesian mineral. It is partly altered to chlorite, and locally encloses small zircon crystals. This granite is texturally and compositionally similar to the granite of the Ackley batholith and is probably an offshoot from it.

The granitic rocks between the railroad tracks and Black River Pond are flooded with pink feldspar and quartz, and are not easily distinguished from the Northern Bight granite. These rocks are generally schistose, owing to the alignment of various amounts of chlorite and sericite in their matrices. As seen under the microscope, all contain much perthite, albite, and strained and fractured quartz. The ferromagnesian minerals, however, differ from those in the uncontaminated granite, being chlorite and epidote instead of biotite. Sericite is also plentiful. The enclosing rocks display numerous textural and compositional changes perpendicular to their schistosity, which probably reflect original stratification inasmuch as the Love Cove Group rocks nearby are dipping steeply and show many compositional variations across strike. The presence of irregular-shaped patches of greenschist is further evidence that the granitic rocks in this region are granitized metavolcanic and metasedimentary rocks of the Love Cove Group. Conversion of the

many types of Love Cove rocks into granitic rocks has not everywhere proceeded to completion, however, as shown by the partly granitized volcanic rocks north of Black River Pond. Because of the variations displayed by these granitic rocks, the contact between them and the uncontaminated granite is necessarily somewhat generalized on the geological maps accompanying this report. Further subdivision of the granitic rocks between the railroad tracks and Black River Pond is not practical owing to the complexity of structure and lithology of the Love Cove Group. The abundance of microcline perthite, albite, and quartz in these hybrid rocks indicates widespread 'soaking' of the region around Black River Pond by potash-, soda-, and silica-rich material.

Red granite. Three small bodies of orange-red, medium-grained granite occur near Clarenville, associated with Musgravetown and Connecting Point rocks. The largest of the three is exposed for 2 miles along the west shore of Random Sound, 1 mile south of Clarenville. It extends inland for about half a mile, so has a surface area of about 1 square mile. The second body occurs in a few small badly shattered shore outcrops on the point by the Imperial Oil storage tanks at Clarenville. Its areal distribution is so small that it has been exaggerated on the Bonavista geological map. The third body lies on the north side of the mouth of the Shoal Harbour River, 1 mile north of Clarenville. It covers an area of about ¼ square mile.

The granite in these three bodies is characterized by an orange-red colour, a fine- to medium-grained, non-porphyritic texture, and a smaller than normal percentage of ferromagnesian mineral. It contains two feldspars—microcline perthite, and albite. The microcline is peppered with red hematite dust (which accounts for the colour of the rock in the outcrops), and stringers and veinlets of sodic plagioclase. A specimen from the small body near Shoal Harbour contained sodic oligoclase instead of albite, but it also contained much disseminated carbonate, which may account for its more calcic composition. The ferromagnesian mineral, which comprises only about 5 per cent of the granite, may have originally been biotite. It is flaky and has a dark green colour in transmitted light, but is too speckled with opaque particles to be identifiable under the microscope. Apparently the iron content of this mineral, like that of the potash feldspar, has separated out through oxidation. Grains of quartz are abundant in all specimens. Many are slightly fractured, but show less strain shadows than the quartz grains in the Northern Bight granite. In the small bodies at Clarenville and Shoal Harbour, quartz has partly replaced both feldspars producing cuneiform-shaped intergrowths (micrographic texture). It has replaced almost 40 per cent of the feldspar in a small outcrop ¾ mile above the mouth of Lower Shoal Harbour River, southwest of Clarenville.

Aplite and pegmatite dykes. Small aplite and pegmatite dykes cut across the Ackley batholith and associated metasediments in many outcrops. They all contain quartz, perthite, and muscovite, but a single pegmatitic dyke on the north shore of Freshwater Bay 6 miles northeast of Gambo also contains small pockets of black tourmaline. The aplite and pegmatite dykes are most plentiful in the granitized

rocks along the eastern flank of the Ackley batholith, and are interpreted as late magmatic products from the same source as the granite.

Contact Relations

Within the present map-areas the Ackley granite batholith is in contact with members of the Gander Lake, Love Cove, and Musgravetown Groups. Only three contact exposures have been seen. Two of the three are very small, and indicate only that the contact with Gander Lake metasediments is sharp and undulant; one of these is a mile northwest of Deer Pond, the other is on the firetower hill on the south side of Lake St. John. In the third exposed contact, on the Trans-Canada highway just north of the east end of Gander Lake, the granite cuts irregularly across the bedding of thin-bedded micaceous quartzite (Gander Lake Group) and exhibits a chilled marginal facies. Andalusite has developed near the contact on the highway (as described previously), and there can be little doubt that the granite there was intruded in a molten state. The thermal metamorphic aureole around the west side of the batholith leads to the same interpretation. The metamorphism of the slaty rocks around Kepenkeck Lake and Deer Pond is very similar to that produced in shaly members of the Musgravetown Group along the granite contact just east of Terra Nova village (Jenness, 1958b), and indicates development under conditions of moderate temperature and low to medium pressure.

Nowhere along the western margins of the Ackley batholith in Terra Nova map-area are there indications of appreciable additions to the country rock from the granite. These contacts are primarily baked, metamorphic contacts. The contacts along the east flank of the batholith, on the other hand, provide ample evidence of the introduction of large quantities of potash, soda, and silica into the country rocks. The 'soaking' of the schists and paragneisses over many square miles along the east side of the granite makes the drawing of contacts on the geological map difficult. Consequently some intrusive granite is undoubtedly present in areas indicated as granitized rocks on the map, and conversely some granitized rocks are present within areas shown as Ackley granite. Descriptions of the feldspathized and granitized schists of the Love Cove Group and paragneisses of the Gander Lake Group have been given on previous pages of this report.

Exposures along the northeast margin of the granite at the east end of Gander Lake display many small irregular-shaped, sharply bounded xenoliths of metasedimentary rocks, many of which still maintain an orientation similar to that of the accompanying feldspar porphyroblasts (*see* Plate VIII B) and of the nearby metasediments. Tongues of granite penetrate along and across foliation planes in the micaceous metasediments in nearby outcrops. The granite in several exposures along the southeast shore of Gander Lake is white rather than pink, and the plagioclase is oligoclase rather than albite. Some marginal assimilation of country rock by the granite is suspected in this region.

The Northern Bight granite intruded only the Precambrian Love Cove Group in the two map-areas, but it intruded early Cambrian rocks near North Harbour a few miles to the south (Rose, 1948). The granite in turn has been cut by numerous gabbroic dykes, especially in the region just north of Northern Bight station.

No contacts of the red granite near Clarenville have been observed. Nearby rocks are dominantly quartzose sediments, so that little thermal metamorphism at the contacts could be expected, and none was seen. Shattering along the granite-Musgravetown contact south of Clarenville and the granite-Random contact north of Clarenville suggest that these contacts were faulted. Such faults, if existent, would represent post-emplacement structural adjustments.

A stock of porphyritic Ackley granite has intruded contact metamorphosed shales and siltstones of the Musgravetown Group at the east end of Pitts Pond, near Terra Nova village, producing a cordierite hornfels (Jenness, 1958b). The metamorphic aureole is almost a mile wide.

Origin

The western contacts of the Ackley granite batholith are sharp and cross-cutting, with metamorphic aureoles and aplitic and pegmatitic dykes in the adjacent country rock, whereas the eastern contacts are chiefly gradational, with much evidence of potassium metasomatism in the surrounding country rocks, and some lit-par-lit granitic injections (*see* Plate VIII A). As the former phenomena are commonly accepted as criteria for the intrusion of a molten mass, the latter for replacement (i.e. metasomatism), it is probable that the Ackley batholith is a complex body with the characteristics of both types of origin.

Age and Correlation

The Ackley batholith in the present map-areas has contact metamorphosed sedimentary members of the Gander Lake Group, at least a part of which is Middle Ordovician in age. It thus is post-Middle Ordovician. It also appears to be post-tectonic, as it conforms to the regional strike of the metasediments, and encloses xenoliths that display the same regional strike.

The following potassium-argon data[1] have been obtained from specimens of the Ackley batholith and closely related granitized or metamorphosed rocks (Lowdon, 1960; Lowdon, 1961):

Spec. No.	Mineral	Rock	Locality	% K	Chlorite Content	K/Ar Age
GSC 59–94	Biotite	Granite	48°51′N, 54°21.6′W	4.58	30%	244 m.y.
GSC 59–95	Muscovite		(same specimen)	8.14	0	350
GSC 59–96	Biotite	Granitized schist	48°37.2′N, 54°13.5′W	6.78	4	317
GSC 60–150	Biotite	Granite	48°17.7′N, 54°55.4′W	7.32	4	368
GSC 60–151	Biotite	Paragneiss	48°40′N, 54°08.5′W	7.74	0	365
GSC 60–152	Muscovite		(same specimen)	8.31	3	352

Because of analytical irregularities the 244 and 317 m.y. ages are considered unreliable. The above data are interpreted to mean that the intrusion of the Ackley batholith and metamorphism of the accompanying sediments occurred about

[1] Analyses and age determinations were made in the laboratories of the Geological Survey of Canada.

365 ± 15 million years ago. The age of the batholith can therefore be regarded as Devonian, probably late Devonian.

The Northern Bight granite intruded Cambrian rocks in Placentia Bay, but cannot be dated more closely. The red granite near Clarenville is in intrusive or faulted contact with late Precambrian rocks but defies closer dating.

The Ackley granite, Northern Bight granite, and red granite near Clarenville all appear to have been derived from the same source. They may possibly be correlated with granitic rocks on the Burlington Peninsula of northern Newfoundland, which have been dated at 355 million years (Neale, 1960). They also resemble the granites of southwestern Nova Scotia, which have yielded several potassium-argon ages between 350 and 370 million years (Fairbairn, *et al.*, 1960).

Leucogranite

Distribution

A narrow elongate band of leucogranite extends southwest from Gander Lake to the west margin of Terra Nova map-area, a distance of 32 miles, and is known to continue at least 35 miles farther southwest. It may possibly merge with granitic rocks in the Bay d'Espoir region on the south coast of Newfoundland. A gap of 4 miles occurs in the surface exposures of this granite body just south of Hunts Pond, where it is covered by metamorphosed members of the Gander Lake Group.

Lithology

The leucogranite is a white-weathering, medium- to coarse-grained, locally pegmatitic, two-mica (binary) granite. It is composed of microcline, albite, quartz, muscovite, small amounts of biotite, and widely scattered, rounded grains of garnet. The microcline generally displays narrow films of exsolved sodic plagioclase, but the perthitic texture so produced is not nearly so pronounced as that in the Ackley granite. Some of the microcline displays a myrmekitic texture. The plagioclase is albite, commonly slightly dusted with clay alteration minerals, and is more abundant in the pegmatitic facies than microcline. Large grains of an untwinned potash feldspar (orthoclase or untwinned microcline), which contain films and veinlets of plagioclase, were observed in several thin sections of the leucogranite. Muscovite constitutes 10 to 15 per cent of the rock and is almost twice as abundant as biotite. Some of the biotite is chloritized, but fresh flakes show the same straw-yellow to brownish pleochroism found in biotite from the Ackley granite. Books of muscovite in the coarse pegmatitic facies of the leucogranite are commonly 1 inch or more in width, and wormy intergrowths of quartz (graphic granite) are visible megascopically in some of the large crystals of white potash feldspar. Quartz grains are fractured and display wavy extinction indicative of strain. Tiny (1-2 mm) dark red garnets form 5 to 10 per cent of the leucogranite and are its most distinctive and unusual feature.

Contact Relations

Contacts between the leucogranite and the enclosing Gander Lake sediments have not been observed. However, a thermal metamorphic aureole ¼ to ½ mile

wide surrounds the leucogranite, and indicates that it was intruded in a heated, probably fluid condition. Amphibolite and garnetiferous rocks are included within this aureole where it has been superimposed upon the calcareous and tuffaceous members of the 'middle unit' of the Gander Lake Group. The elongate form of the leucogranite, roughly parallel with the regional strike of the surrounding sediments, suggests that it was intruded after the initial folding of these strata.

Age and Correlation

Field evidence shows that the leucogranite was intruded during or after folding of the Middle Ordovician Gander Lake Group. Potassium-argon data have been determined in the Geological Survey laboratories from a specimen of the leucogranite collected just east of Dead Wolf Pond, as follows:

Spec. No.	Mineral	Locality	% K	Chlorite Content	K/Ar Age
GSC 59-97	Biotite	48°39′N, 54°45′ ± W	5.54	40%	374 m.y.
GSC 59-98	Muscovite	(same specimen)	8.10	0	330

Allowing for the 5 to 10 per cent analytical error common to most potassium argon dates, these data are reasonably close to those listed on a previous page for the Ackley batholith (i.e., 365 ± 15 m.y.). They indicate a Devonian (probably late Devonian) age for the leucogranite.

The leucogranite is unique in composition and appearance in eastern Newfoundland, so that correlation with nearby granite bodies is difficult. However, its soda-enriched composition and its pegmatitic texture suggest that it is a late magmatic differentiate of a normal granitic body. It is, therefore, tentatively related to the Ackley batholith. Its potassium-argon age supports this relationship.

Riebeckite Granite

Distribution

Riebeckite granite forms a small group of relatively high (600 feet), rounded hills (the Louil Hills) just east of the village of Traytown in Bonavista map-area. These rocks were earlier called the 'Louil Hills granite' (Jenness, 1958b). They outcrop over an area of about 1½ square miles, most of which is on the south side of an arm of Alexander Bay. A 250-foot hill of the granite lies on the north side of the bay.

Lithology

The riebeckite granite is a light pink, medium-grained, equigranular rock containing 60-70 per cent light pink to orange-pink feldspar, 15-25 per cent glassy quartz, and 5-15 per cent black, lustrous riebeckite. On the north side of the bay the granite is white on the weathered surface and riebeckite is more plentiful and in larger crystals than on the south side of the bay. Numerous joints occur within the granite which, in places, are filled with thin milky quartz veins.

In thin section, specimens of the riebeckite granite display a granular texture and consist of strained quartz, microcline perthite, and partial crystals and needles of riebeckite. Microcline perthite in granite on the north side of the bay contains more veins and stringers of albite than that in granite on the south side. Small patches of magnetite, chlorite, and carbonate were seen in one thin section, but the granite is almost unaltered.

Thin aplitic dykes penetrate the volcanic rocks of the Connecting Point Group within half a mile of the main Louil Hills granite bodies and are presumably offshoots from them. These dykes contain perthite, albite, and quartz, but no mafic minerals.

Origin

The composition and texture of the riebeckite granite agrees closely with the hypersolvus class of granite of Tuttle and Bowen (1958). They regarded this type of granite as of high temperature magmatic origin, crystallizing under water-deficient conditions, whereby the soda feldspar is prevented from separating completely from the potash feldspar. They also stated that rocks of this type commonly occur as small intrusive bodies.

Age and Correlation

Field evidence for the age of the riebeckite granite consists only of the facts that small granitic dykes cut nearby andesitic volcanic rocks of the Connecting Point Group, and one outcrop of country rock on the west side of the Southwest Tickle is granitized. The riebeckite granite thus is probably of post-Connecting Point age, but whether it is late Precambrian, or Palæozoic, is not known.

This granite is unique in this region because of the presence of riebeckite and the extent of perthite development. Although it outcrops within 11 miles of the Ackley batholith, its composition suggests that it is an intrusion of separate origin. It cannot yet be correlated with any known granite in eastern Newfoundland.

Other Granitic Rocks

Several separate masses of feldspathized or granitized rock have been mapped along the eastern flanks of the Ackley batholith and the northern part of the Northern Bight granite. As these involve rocks of either the Gander Lake or Love Cove Group, they have been discussed in the sections dealing with those groups.

Boulders of hornblende granite occur along the shore of Gander River between Glenwood and Gander Lake. This granite consists of two megascopically visible feldspars (orange-pink potash feldspar and buff-coloured plagioclase), quartz, and hornblende. It weathers orange, is medium grained, and has an equigranular texture. This type of granite occurs on and around Mount Peyton (N. Lat. 48°57′, W. Long. 55°00′) but has not yet been observed in outcrop within Terra Nova map-area. However, its eastern contact may lie beneath dense vegetation in the northwest corner of the map-area.[1]

[1] See footnote to Table of Formations, page 29.

Dyke Rocks

Dykes of andesitic and basaltic composition occur in many parts of the two map-areas, but appear to fall into four fairly distinct age categories, on the basis of the rocks in which they occur. Andesitic dykes occur in both the Love Cove and Musgravetown Groups, but those in the older group are more altered and deformed, and are, therefore, assumed to be older. Gabbroic dykes, commonly diabasic but locally porphyritic are plentiful in rocks of the Connecting Point Group, and probably originated from the same source as the late Connecting Point or early Musgravetown basic volcanic rocks. A few gabbroic dykes cut Palæozoic granites and Middle Cambrian limestone south of Clarenville.

Dykes of granite, aplite, and pegmatite are fairly plentiful in areas close to the granitic rocks to which they are unquestionably related. They are discussed in the section on granite and granitic rocks.

Dykes in the Love Cove Group

Distribution

Small andesitic dykes have been observed in exposures of Love Cove rocks west and northwest of Clarenville, on the fire-tower ridge (locally known as Mount Blandford) 5½ miles southeast of Port Blandford, on both shores of Clode Sound, and on the northeast and southwest ends of Pitt Sound Island. All are narrow, generally less than 20 feet wide, and pinch out within short distances along strike. Only about a dozen have been seen.

Lithology

The dykes that cut rocks of the Love Cove Group are generally medium greenish grey, fine grained, and locally porphyritic. Hornblende phenocrysts occur in a dyke east of Shoal Harbour Pond, and another south of Tug Pond; feldspar and quartz phenocrysts are visible in a few others. Epidote and quartz stringers are commonly present. As seen in thin sections, they contain much chlorite, epidote, and clay minerals, a typical low-grade metamorphic assemblage. A few of the dykes contain secondary albite, hornblende, or quartz. Biotite occurs in a dyke on an island in Terra Nova Lake near the Ackley batholith, to which its development can probably be attributed.

The dykes have the same metamorphic history, structurally and mineralogically, as the enclosing Love Cove rocks, and belong to the greenschist facies.

Structural Relations and Age

The dykes in the Love Cove rocks have undergone a similar amount of structural deformation as the enclosing rocks, as is shown in an exposure 1¾ miles west of Clarenville (*see* Plate XI). In contrast, dykes in younger strata in the area are undeformed.

The dykes cutting members of the Love Cove Group are pre-Connecting Point (Precambrian) in age.

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Dykes in the Connecting Point Group

Distribution

Basic dykes are plentiful in rocks of the Connecting Point Group throughout Bonavista map-area. They are especially abundant along both shores of Newman Sound, the southeast shore of the Northwest Arm of Sweet Bay, and along both shores of Smith Sound between the two Palæozoic basins. All are gabbroic; many are diabasic, others porphyritic. Thicknesses of the dykes commonly range from 1 foot to 60 feet; however, one dyke in Sweet Bay is 300 feet thick.

Lithology

The gabbroic dykes in the Connecting Point rocks weather light to medium brown, and range in texture from aphanitic to diabasic to porphyritic. The porphyritic varieties contain plagioclase phenocrysts, generally less than 10 mm long, but in places as much as 25 mm long. Compositionally, the dykes consist of 55 per cent or more calcic plagioclase with pyroxene, magnetite, and locally pyrite. The presence of pyrite is indicated on dyke surfaces by a darker brown colour and small pits from which the sulphide has been leached. The plagioclase grains are considerably altered to dusty clay minerals, flakes of secondary mica, and chlorite, and their composition cannot be determined. The pyroxene is commonly less altered than the plagioclase, although some alteration to chlorite is generally evident. Magnetite is locally etched by chlorite and/or carbonate.

A few dykes of a titanium-enriched variety of gabbro occur in the Newman Sound area. They are characterized by the presence of ilmenite-magnetite intergrowths (with Widmanstätten structure) and pink titaniferous augite. The dykes with these two minerals are slightly less altered than the other gabbroic dykes in the Connecting Point Group rocks.

Other than the above-mentioned mineral alterations, these gabbroic dykes are unmetamorphosed.

Structural Relations

The dykes in the Connecting Point Group appear to have been emplaced along lines of structural weakness. This is suggested particularly in the Newman Sound area where the dykes strike dominantly northwestward. Their occurrence in dyke swarms locally in Newman Sound and Sweet Bay suggests an additional local structural control. For example, the Newman Sound swarm lies chiefly along the west flank of the Clode Sound fault (*see* Figure 9). Strikes and dips of the faulted sediments differ markedly on opposite sides of this fault line. Another swarm of dykes occurs along the south shore of Sweet Bay close to a somewhat similar marked change in strikes and dips of the Connecting Point Group rocks, which occurs between Sweet Bay and Southern Bay. The dyke swarms in these two regions may fill tensional fractures produced in the adjoining rocks when they were folded and/or faulted.

Age

The similar composition of the many gabbroic dykes in the Connecting Point Group rocks, their apparent absence in the immediately overlying Musgravetown

Group rocks, and the porphyritic texture of many of them, suggest their sudden upward emplacement from a slowly cooling chamber during or immediately following a period of folding of the Connecting Point rocks. Their abundance geographically near basic volcanic upper members of the Connecting Point Group at the west end of Newman Sound and in the Sweet Bay area strongly suggests a relationship between the dykes and these volcanic rocks. If this is true the dykes are of late Connecting Point age. Alternatively the dykes may be related to the basal and near-basal, basic volcanic rocks in the Bull Arm Formation of the Musgravetown Group, as has been suggested by McCartney (1958). As no dykes have yet been observed in the basal conglomerate (Canning Cove Formation) of the group, however, the latter hypothesis appears less probable than the former, at least within Bonavista map-area. In any case, the basic dykes in the Connecting Point rocks were emplaced in Precambrian time before much, if any, of the Musgravetown Group was deposited.

The occurrence of gabbroic dykes of another age is indicated by a titanium-enriched dyke that cuts down the centre of the more common variety of gabbro dyke on the north shore of Newman Sound 3½ miles west of Swale Island (Jenness, 1958b). It is probably only slightly younger than the host dyke.

Dykes in the Musgravetown Group

Distribution

Few dykes cut rocks of the Musgravetown Group, and those that do are restricted in their geographic and stratigraphic distribution. Almost without exception they occur within a 3-mile radius of volcanic members of the Bull Arm Formation. Most occur around the southern half of Goose Bay, where they cut conglomerates and lavas of the Cannings Cove and Bull Arm Formations. Elsewhere a few dykes cut rocks in the lower part of the Musgravetown Group on the north shore of Clode Sound between Bread Cove and Charlottetown, at the falls on the Terra Nova River 6 miles above its mouth, on shore near Traytown, on the Lower Shoal Harbour River south of Clarenville, on the east side of the bay at Summerville, and at British Harbour.

A member of A. M. Christie's field party in 1949 reported a 20-foot basic dyke in green siltstone at Amherst Cove, near Cape Bonavista. As far as the writer knows, this is the only dyke within the two map-areas that lies more than 3 miles from Musgravetown lavas of similar composition, and that also apparently lies in a formation well above the Bull Arm volcanic rocks.

Lithology

Most of the dykes cutting rocks of the Musgravetown Group are medium greenish grey, intermediate-compositioned rocks. A few are porphyritic, with white plagioclase phenocrysts, up to ⅜ inch long, in a fine-grained groundmass of plagioclase, chlorite, and magnetite. The plagioclase is partly altered to clay minerals and secondary mica. The ferromagnesian mineral, presumably originally hornblende, is completely altered to chlorite. Even magnetite is partly replaced by secondary minerals, including chlorite. Small amounts of pyrite occur in some of

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the dykes, and quartz occurs in the andesite dyke at Bloomfield. At least two of the dykes have metamorphosed adjoining red shaly members of the Musgravetown Group. All but the Bloomfield dyke, which is about 50 feet wide, are less than 25 feet wide, and most of them are less than 10 feet wide. The dykes are chiefly andesites or quartz andesites. One basaltic dyke, 3 feet thick, cuts basalt of the Bull Arm Formation on the north shore of Clode Sound 3 miles east of Charlottetown. It contains slightly altered plagioclase laths and pyroxene grains, and has a faintly diabasic texture.

A single rhyolitic dyke cuts rocks of the Musgravetown Group on the north side of the peninsula at Charlottetown, Clode Sound. It is an orange-pink colour, 5 feet wide, and lies along the foot-wall of a small fault in Musgravetown red argillite. It consists of small phenocrysts of quartz and plagioclase in a very fine-grained groundmass of feldspar, quartz, chlorite, sericite, minor carbonate, and magnetite, and a widespread scattering of minute red hematite specks.

Variations in the compositions of the different dykes cutting Musgravetown Group rocks probably reflect differences in parent lava source material.

Structural Relations and Age

The dykes in the Musgravetown Group rocks show no apparent structural alignment, nor any recognizable relationship to structural elements. However, all but one of them occur within or geographically close to volcanic rocks of the Bull Arm Formation near the base of the group. None has been recognized in upper members of the group in the two map-areas, and no similar dykes occur in the overlying Cambro-Ordovician rocks. It is probable, therefore, that the dykes represent offshoots of the same magmatic reservoirs that fed the lavas in the Bull Arm Formation. If this is so, they are of early Musgravetown age.

Younger Gabbroic Dykes

Distribution

Gabbroic dykes are fairly plentiful in the Northern Bight (Devonian) granitic rocks in the southeast corner of Terra Nova map-area, and a lone gabbro dyke cuts Middle Cambrian limestone near Fosters Point on the west end of Random Island. Narrow basaltic dykes also cut Lower Cambrian shales on the north shore of Smith Sound and Middle Cambrian shales a short distance south of Elliotts Cove. All occur within a radius of 18 miles of the gabbroic dykes near Northern Bight railroad station.

Lithology

The younger gabbroic dykes are dark brown to black weathering rocks, fine to medium grained, and contain partly altered plagioclase, pyroxene, and magnetite, with small amounts of clay minerals and chlorite. Circular patches of yellow interwoven serpentine in one thin section presumably indicate the replacement of small olivine phenocrysts. The dykes display chilled borders against the granite near Northern Bight station.

A fine-grained basic dyke, 4 feet thick, that intrudes the Middle Cambrian pink limestone near Fosters Point, Random Island, displays most of the characteristics of the gabbroic dykes that cut the Northern Bight granite, even including the small circular patches of serpentine. It differs, however, in that the plagioclase grains are unaltered, and the serpentine patches contain cores of calcite. These cores are large enough to leach out on the weathered surface leaving small pits several millimetres in diameter scattered throughout the dyke. No thermal effect was noticed in the enclosing limestone.

Structural Relations and Age

As the attitudes of the dykes in the folded Cambrian rocks are nearly vertical it can be assumed that they were injected after the folding of the Palæozoic basin rocks, hence at sometime after the deposition of the Lower Ordovician rocks. As similar dykes also cut cleanly across the coarse-grained granite near Northern Bight, have chilled margins, and enclose small blocks of granite, they are undoubtedly younger than the granite. As the granite is tentatively regarded as an offshoot of the Ackley batholith to the west, which is of Middle to Late Devonian age, the younger gabbroic dykes may be of post-Middle Devonian age.

Chapter V

STRUCTURAL GEOLOGY

Introduction

Faults have had a major effect on the distribution of the rock units in Terra Nova and Bonavista map-areas. Folds are important only locally, as on the east end of Bonavista Peninsula where faults appear to be less numerous than in areas farther west. A few unconformities have been recognized, and some of these are important in interpreting the geological history of the area. Smaller scale structures, including cleavage, schistosity, gneissosity, and lineation are locally well developed and worth brief descriptions. Some of the structures can be fairly readily interpreted; others are little known. The main structural elements in the two map-areas are shown on Figure 9.

Unconformities

Two interformational unconformities[1] have been observed in the map-areas, one a sharply defined angular unconformity at the base of the Precambrian-aged Musgravetown Group, the other a rather unimpressive disconformity (or possibly a slight angular unconformity) at the base of the Lower Cambrian strata. Three intraformational disconformities[1], of uncertain importance, have also been observed, two within the Connecting Point Group and one in the Musgravetown Group. Several paraconformities[1] probably exist within the Cambro-Ordovician rocks in the Random Sound region. A pronounced angular unconformity also separates the unconsolidated Pleistocene sediments from all consolidated rocks.

These unconformities indicate major tectonic activities between the times of deposition of the Connecting Point and Musgravetown Groups, and after the deposition of the Ordovician strata. Small scale tectonic activity may also have occurred at the end of the Precambrian.

Interformational Unconformities

Connecting Point-Musgravetown Angular Unconformity

A pronounced angular unconformity separating the basal Musgravetown Group rocks from the Connecting Point Group rocks is excellently exposed for several hundred feet along a shoreline cliff on the east side of Southward Head peninsula in Southern Bay, Bonavista Bay (Plate IV A). Both erosional and structural discordance are readily apparent in this exposure. The underlying rocks are mainly indistinctly bedded, light pink quartzitic rocks (possibly metamorphosed acidic tuffs) and purplish felsite belonging to (but not typical of) the

[1] As defined by Rodgers and Dunbar, 1957.

Connecting Point Group. These rocks strike N35°W and dip 55°NE. Above and irregularly truncating them is the gently dipping reddish boulder to pebble conglomerate of the basal Cannings Cove Formation in the Musgravetown Group. Bedding in the conglomerate is crudely developed, but the attitude of overlying thin lava beds confirms a strike of approximately N50°W and a dip of 20°NE. The Musgravetown beds appear to lie on the east limb of a small northerly trending and northerly plunging syncline. Both the conglomerate and the unconformity at its base are cut off by a fault near the middle of the peninsula and do not appear on the west limb of the syncline. The conglomerate consists largely of pebbles and sands, with about 30 per cent cobbles and boulders. The boulders are subangular, up to 16 inches long, and consist chiefly of reddish lavas and sandstones, with minor amounts of a greenish quartzitic rock. The conglomerate above the unconformity is about 100 feet thick, and is overlain by several relatively thin-bedded basic lavas of the Bull Arm Formation.

All other shoreline contacts between the Musgravetown and Connecting Point Group rocks in Bonavista map-area are either faulted or concealed, and inland contacts are invariably concealed. No contact areas occur within Terra Nova map-area.

The Southward Head angular unconformity thus provides irrefutable field evidence that some of the Connecting Point Group rocks were folded prior to the deposition of the Musgravetown basal conglomerate. However, no angular discordance has been recognized north of Traytown, nor in the Random Sound region, and in the Dildo area (south of Random Sound) the Connecting Point Group rocks are apparently conformably overlain by the Bull Arm Formation, the basal formation of the Musgravetown Group in that region (McCartney, 1957). The folding of the Connecting Point Group rocks may, therefore, have been local, corresponding roughly to the localized distribution of the Musgravetown basal conglomerate in the southern part of Bonavista Bay.

Random-Lower Cambrian Unconformity

A disconformity, which may actually be a slightly angular unconformity, is exposed on the northwest shore of Smith Sound near Smith Point, between the Random Formation (of presumed latest Precambrian age) and the overlying Lower Cambrian rocks (*see* Plate VI). A few feet of pinkish white Random quartzite that outcrops at the base of the exposure is overlain by a white calcareous granule sandstone about 1½ feet thick, above which lies the grey silty shales of the lowermost Cambrian strata in this region. An undulating surface separates the Cambrian silty shale from the underlying granule sandstone at this locality, and is a more obvious feature than the contact at the base of the granule sandstone. However, this undulating surface is evidently of a local nature, as it does not appear at equivalent horizons below the Cambrian shale in contacts elsewhere in Trinity and Bonavista Bays. The granule sandstone, on the other hand, has been recognized in several of these areas, and is not everywhere underlain by the same type of rock.

The contact between Lower Cambrian strata and the underlying Random Formation in Bonavista map-area is thus an erosional unconformity at the base of a very thin calcareous granule sandstone. Farther south, on parts of Avalon Peninsula, there may also be a slight angular discordance (Hutchinson, 1962).

Intraformational Unconformities

Unconformities within the Connecting Point Group

Two local disconformities have been observed within rocks of the Connecting Point Group. Both appear to lie in the upper half of the group, but their stratigraphic significance is not fully known.

The first of these is exposed on the south shore of Random Island about 1 mile west of Hickmans Harbour. There a greyish green pebble conglomerate overlies a thin-bedded greenish grey sandstone, and the contact between them is distinctly irregular, with the conglomerate filling small depressions in the upper surface of the sandstone. The pebbles within the conglomerate are less than ¼ inch in diameter, are subrounded, and are mostly green cherty material such as occurs in many parts of the Connecting Point Group. Lenses of indistinctly bedded, greenish grey coarse sandstone occur within the conglomerate.

The second disconformity occurs on the west shore of Kate Harbour, between Sweet Bay and Southern Bay, where the plane of the disconformity is exposed on the face of a 100-foot cliff. The surface of the disconformity strikes east and dips southward at approximately 35 degrees. The rocks above and below the disconformity are both fine-grained, dark red siltstones, with parallel bedding. The overlying strata, however, are somewhat massive, with individual beds about 1 foot thick separated by thin shaly beds, whereas the underlying beds are 1 inch to 2 inches thick. The contact between the two units is locally undulant and a few fragments of the lower, thin-bedded unit appear within the basal part of the overlying unit. The erosional surface cuts across the bedding planes of the underlying formation.

Unconformities within the Musgravetown Group

Three disconformities (erosional unconformities) have been observed within rocks of the Musgravetown Group. Two of these occur in the section of the Crown Hill Formation north of Kings Cove Head in Bonavista Bay; one lies 148 feet above the base of the formation, the other 389 feet above the base. Neither of the two has a prominent erosion surface, and both are probably minor local features.

The third disconformity is exposed on the north shore of Smith Sound, just east of Tilton Head, about 150 feet from the fault between Lower Cambrian rocks (on the west) and Musgravetown Group rocks on the east. At this locality, an undulose surface separates a well-bedded, buff-green sandstone from the underlying, intermediate-compositioned, amygdaloidal lava, and lenses of sandstone fill the depressions in the lava. Both rock units are thought to belong to the Bull

Arm Formation, and the erosional unconformity probably is of only local significance.

Unconformities within the Cambro-Ordovician Basins

Several paraconformities (indicating time breaks without prominent stratigraphic breaks) probably occur within the Cambro-Ordovician rocks in the Random Sound region. Their existence is suggested by the occurrence of recognizable faunal breaks in several parts of the section, accompanied locally by slight lithological changes. The distribution of fossils is unfortunately too limited to permit close placement of the paraconformities in exposed sections.

Other Intraformational Unconformities

Pebble conglomerate bands that occur within the Gander Lake Group on the northeast shore of Home Pond, near the fossil localities on Gander Lake, and in a few other localities within Terra Nova map-area and north of it (Jenness, 1958b) undoubtedly mark small unconformities, but it is not possible at present to evaluate them. Similarly, exposures of recognizable conglomerate within the Love Cove Group, such as at Thorburn Lake, Shoal Harbour Pond, and in the Pitt Sound Island area, may represent small unconformities within that group, but their significance is not known.

Folds

All consolidated rocks in the two map-areas have been folded, but the extent to which they have been folded depends chiefly on their age, gross lithological characteristics, proximity to later intrusions, and geographic position. Older rocks are, in general, more deformed than younger rocks, but exceptions do occur, as for example near the east end of Random Island, where the late Precambrian Musgravetown Group rocks are nearly flat-lying, whereas nearby Cambrian sediments are tightly folded and overturned. In this case, however, the younger sediments are incompetent shales and were more readily deformed than the older Musgravetown sandstones. Similarly, argillaceous beds within the Connecting Point Group along Newman Sound are more strongly folded than accompanying beds of greywacke.

Several broad structural elements have been recognized, most of which are in Bonavista map-area, where exposures are better and the rocks relatively simple lithologically. These include: (1) the strongly folded basins of Cambro-Ordovician rocks in the southwest quarter of Bonavista map-area; (2) the domes and basins in the Musgravetown Group rocks near Bonavista; (3) a structural terrace passing through Gander; and (4) the probable axis of a major synclinorium along Gander River valley in the northwest corner of Terra Nova map-area.

Basins of Cambro-Ordovician Rocks

Probably the most striking regional fold structures in the two map-areas are the basins of Cambro-Ordovician rocks that are downfolded into the Connecting Point and Musgravetown Group rocks in the Random Island region. There are

three principal basins: a fairly broad western basin that extends northward from the northwest end of Random Island towards Clode Sound; a narrow central basin that extends from the centre of Random Island northward almost to Bonavista Bay; and a third smaller eastern basin that lies along the east side of the central basin and extends for about 6 miles north and south of Random Island. There is, in addition, a fourth small partial basin on the south side of Bonavista Bay at Keels. Ordovician rocks are preserved only in the western basin. Small patches of recognizable Cambrian strata occur in several other parts of the Random Island area, but owe their present position to faulting rather than to folding and erosion.

Of the three principal basins, the western one is the least disturbed structurally, but locally it is tightly drag-folded, and moderate to steep dips are common along its eastern flank. The basin is asymmetric, with the fold axis lying near its western side and the axial plane dipping steeply to the west. Beds along its west side are steeply overturned to the east. Much of the basin, unfortunately, is poorly exposed, so that knowledge of it is obtained chiefly from the good exposures along the west shore of Random Island and the northwest shore of Smith Sound. In the latter area the sediments dip to the west at a moderate angle for about 2 miles across strike towards the centre of the basin, but the actual position of the fold axis cannot be located owing to the homogeneity of lithology and the disappearance of exposures in the axial region. Several local drag-folds are visible on the west side of Random Island just south of Elliotts Cove and similarly folded strata are probably the rule rather than the exception elsewhere within the basin. Indeed, unless the strata have been repeated by faulting, somewhat complex folding must be envisaged to explain the occurrence of rocks containing an Upper Cambrian fauna at the northwest end of Random Island, apparently surrounded by rocks containing a Lower Ordovician fauna (*see* Figure 6). Again, Lower Ordovician fossils recovered a few hundred feet south of Elliotts Cove and bounded by rocks bearing an Upper Cambrian fauna (*see* Figure 6) mark another structural anomaly. There again, however, the rocks may be faulted rather than isoclinally folded.

The structure of the central Cambro-Ordovician basin appears to be more complex than that of the western basin. The Cambrian sediments in this basin are tightly folded into a nearly isoclinal syncline, the east limb of which is overturned to the *west,* whereas the west limb of the western synclinal basin is overturned to the *east.* Faults have further complicated the structural picture of the central basin. The structure of this basin north of Smith Sound is not well known, but from A. M. Christie's unpublished maps and notes (on file, Geological Survey of Canada) it appears to be relatively simple and more open than it is on Random Island. The principal synclinal axis can be located on the south shore of Random Sound and Random Island, but its exact position farther north is still in doubt. It has apparently been offset to the west by a northeast-trending fault that crosses Random Island, and may be further offset between Lady Pond and Ocean Pond by another northeast-trending fault. The complex folding of the incompetent Lower Cambrian shales in the Random Sound region is in striking contrast to the relatively simple folding of the more competent Connecting Point and Musgrave-

town Group rocks on either side. In fact the Musgravetown rocks about 2 miles to the east are essentially flat-lying. The central basin trends from the middle of Random Island northward almost to the railroad tracks near Princeton (Southern Bay), a total length of about 18 miles.

The central and eastern basins appear to have been thrown into juxtaposition through faulting in the central Random Island region. The eastern basin is tightly folded and extends northward from the Southwest Arm of Random Sound across Random Island to Burn Point on the north shore of Smith Sound, a total distance of 17 miles (if the underlying Random Formation is included in the measurement). At Burn Point, on the north shore of Smith Sound, Lower Cambrian rocks of the Bonavista Formation are squeezed into a tight syncline with the east limb overturned to the west. The structure at Burn Point is thus similar to that exposed on the south side of Random Island near Hickman's Harbour. The synclinal axis of this eastern basin trends north-northeast and lies along the west side of the Cambrian rocks exposed at Burn Point. Rocks of the underlying Random Formation are folded with the Cambrian strata in this eastern basin.

The southern half of a small Cambrian basin occurs at Keels in Bonavista Bay. The rocks included in this basin are the Random Formation and the Lower Cambrian Bonavista Formation. They have been less intensely folded than in the Random Island region, and are not overturned.

Yet another Cambrian basin may occur in the northwest part of Bonavista map-area, where it is unfortunately largely concealed by the ocean. Evidence for such a basin is of two types: structural and lithological. Structural evidence is the presence of a north-northeasterly plunging synclinal structure 4 miles southeast of Hare Bay, which appears to continue northeasterly past Lockers Flat Island. Lithological evidence consists of the following: (1) the occurrence, at the southwestern end of the synclinal structure mentioned above, of rocks that are thought to be part of the top two formations of the Musgravetown Group; (2) the occurrence on Lockers Flat Island of white crossbedded quartzites lithologically similar to white quartzites in the Random Formation farther south and not known in any other formation in the two map-areas; and (3) the occurrence of light grey shale with limy concretions on two small islands at the southwest end of Lockers Flat Island, stratigraphically above the rocks on Lockers Flat Island. Limy concretions in shales are unknown in the Precambrian strata of the two map-areas, but are common in the Lower Cambrian strata of eastern Newfoundland, e.g. just above the base of the Bonavista Formation at Smith Point in Smith Sound. The scarcity of fossils in the lower part of the Bonavista (Lower Cambrian) Formation elsewhere in eastern Newfoundland makes it unlikely that fossils will be found on these two islands of limy shale. This is unfortunate because palæontology may be the only way to prove or disprove the existence of a Cambrian basin in this region.

Synclinal axes for the three principal Cambro-Ordovician basins, the partial basin at Keels, and the possible basin near Lockers Flat Island all trend approximately N25°E, locally slightly closer to north. This direction also coincides closely (1) with the strike of major fold axes in the Musgravetown Group rocks on Bonavista Peninsula farther east, (2) with the general trend of major faults near

Clarenville, as well as south and west of it, and (3) with the regional orientation of the granitic rocks along the west half of Terra Nova map-area. There is probably some genetic connection between these various structural elements.

Domes and Basins in the Musgravetown Group

Two basins and one dome, each 3 to 4 miles wide and about 8 miles long, occur in rocks of the Musgravetown Group at the eastern end of Bonavista Peninsula. The fold axis of the northernmost basin is offset along the Port Union fault about 2 miles west of the axis for the other two enclosed structures. This offset basin is of geomorphological interest, for the area underlain by the basinal structure now protrudes above the surrounding relatively level terrain as an elliptical-shaped ridge, and constitutes a good example of reversed topography. The structural trend of the basins and domes in this part of Bonavista map-area is parallel with the axial direction of the Cambro-Ordovician basins that extend across Random Island.

Another gentle basinal structure, parallel with those described above, has been partly outlined 4 miles west of the town of Trinity. The southern end of this structure appears to have been cut off by a fault 5 miles north of Smith Sound.

Gander Structural Terrace

Gander Airport is situated on one of the flattest pieces of land within the two map-areas. This topographic feature extends for several miles around the town, and with slight modifications of elevation continues to the south for several miles. Exposures along Gander Lake and inland indicate that the chief cause of this topographic plain is a local near-horizontal attitude of the underlying bedrock structures, which has produced a structural terrace in the midst of the steeply west-dipping Gander Lake Group. The terrace appears to trend about N35°E, parallel with the regional strike of the enclosing strata. The nearly horizontal structure can be observed best along the north shore of Gander Lake near Gander Airport. The terrace is cut off just south of Gander Lake by a body of granite, but nearly horizontal beds that may indicate its southward continuation have been observed in the following three areas: (1) the west end of Rodney Pond, (2) 6 miles west of North Pond, and (3) 5 miles west of Deer Pond. Some bending of the terrace around the eastern margin of the leucogranite near Dead Wolf Pond is indicated by alignment of these three areas. It is not known whether the terrace continues south of Deer Pond, or north of Gander.

Gander River Synclinorium

As seen along Gander Lake, almost all the rocks of the Gander Lake Group dip steeply to the west. Locally the beds have been drag-folded and overturned to the east, but no significant change in direction of dip other than the broad terrace at Gander appears east of Gander River. This westward dip of the Gander Lake strata continues north of Gander Lake almost to the coast (Jenness, 1958a), again with local indications of overturn to the east, and from available data con-

tinues south of Gander Lake possibly as far as Conne River near Bay d'Espoir (Moore, 1953). Beds dip steeply *east*, however, around Glenwood in the northwest corner of Terra Nova map-area, possibly as a result of overturning[1], but more likely indicating the western limb of a large regional synclinal fold. The axis of this major fold, tentatively called the Gander River synclinorium, is believed to roughly follow Gander River and to cross the southwest corner of Gander Lake, with a trend of about N20°E (*see* Figure 9). It may form the southern continuation of the synclinal structure reported at Gander Bay some 30 miles to the north-northeast (Twenhofel, 1947, p. 80). The western limb has not yet been studied, but its width, as presently known, is not nearly as great as that of the eastern limb.

Other Fold Structures

In addition to the large scale fold structures described on the previous pages, numerous small folds have been observed in rocks belonging to all the sedimentary groups.

In rocks of the Love Cove Group strongly developed cleavage or schistosity in most of the bedded rocks has made the recognition of folds difficult. However, folding is indicated by the fact that bedding lies at a large angle to the direction of regional foliation in some exposures, and parallel with it in others. Dips of the beds are everywhere fairly high. Tight chevron-like drag-folds were observed in an outcrop along the railroad tracks just north of Maccles Lake, and several folds were observed in sandstones exposed along the shores of Rocky Bay and the Northwest Arm of Alexander Bay. Numerous opposing dips have been recorded in the Alexander Bay region, where clastic sedimentary members of the group are plentiful, but there are not enough exposures to determine whether dips represent simple folds, or parts of a much more complicated type of structure.

More than three dozen small folds have been observed in the Connecting Point Group rocks, but all are of local occurrence and are not readily traceable inland from shoreline exposures. In some localities the folds consist of several tightly spaced drag-folds, and have been shown on the geological map with a special multiple fold symbol. These small multiple folds invariably occur within the easily deformed argillaceous members of the group, and are particularly common along the shores of Newman Sound. No major fold has yet been recognized within the group, although a pronounced change in strike directions and dips occurs along a probable fault line that passes through the head of Eastport Bay, across Newman Sound and southwestward into Clode Sound (Jenness, 1958b). East and south of this line the Connecting Point beds trend for the most part northeast to east-northeast and dip southward at moderate angles, with few folds. Northwest of this line the beds trend west of north to northward, dip at steep angles, largely to the west, and contain locally numerous small drag-folds.

[1] Data collected west of Glenwood by H. Williams' field party in 1962 have given further support to the idea that the rocks there are overturned rather than synclinally folded, as suggested here. Several steep, eastward dips were found in Gander Lake Group strata, and two outcrops yielded evidence of overturning. In addition, eastward-dipping Silurian strata immediately to the west are also locally overturned to the east. These findings thus cast doubt on the existence of the Gander River Synclinorium. (*See also* footnote to Table of Formations.)

Small folds are locally plentiful within the Musgravetown Group, but large areas underlain by the group appear to have a monoclinal structure. In addition to the broad folds on Bonavista Peninsula, some of which have already been described, local anticlines and synclines have been observed in the Random Island region, on the shores of Clode Sound, at Keels, and on Deer Island. All fold axes trend between N15°E and N40°E. Two prominent fold axes, which McCartney (1958) has traced for 12 to 15 miles in Sunnyside map-area immediately south of Bonavista map-area, continue northward as far as Random Sound. At this point they appear to terminate against some of the many faults on Random Island, but may possibly continue across Random Island and north of Smith Sound.

The degree of folding of the Musgravetown Group rocks appears less than that of the older Connecting Point Group rocks in the Bonavista Bay region, but farther south there is little structural difference between the two groups. The marked divergence in the directions of fold axes at the southern end of Southern Bay is an important structural feature from the point of view of regional interpretation; there, the axes of the folds in Connecting Point Group rocks trend northwest, whereas those of the Musgravetown Group trend north-northeast. Next to the angular unconformity at Southward Head, this relationship provides the best indication of a period of deformation, albeit local in aspect, at the end of Connecting Point time.

Folding of the Random Formation is similar to that of the Cambro-Ordovician rocks in the basins around Random Island and at Keels, as previously described. The rocks of this formation thus appear in steeply-dipping, locally overturned synclinal folds. They are overturned to the west near Hickmans Harbour, and overturned to the east near Shoal Harbour.

Folds within the Gander Lake Group are exposed best along Gander Lake. Much of the group appears to be monoclinal, dipping steeply west. However, a few small folds appear west of Gander, becoming more abundant at that part of Gander Lake where the ultrabasic rocks occur and from there west for 6 miles, beyond which the structure again appears monoclinal, dipping steeply west. Multiple folds (drag-folds), most of which are simple and open, are well displayed along the north shore of the lake within the 6 mile stretch west of the ultrabasic rocks. Small drag-folds, isoclinally overturned to the east occur on the south shore of Gander Lake just east of Hunts Cove (*see* Plate IX A). These exposures are of particular interest in the interpretation of the probable direction of the forces that produced the folding in the Gander Lake Group.

Bedding of rocks in the Gander Lake Group has a distinctly north-northeasterly regional strike. This trend seems to have been somewhat diverted around the Ackley granite at Deer Pond, and around the east side of the leucogranite near Dead Wolf Pond a few miles farther north, but elsewhere the beds of the group strike into the granitic bodies, and maintain their regional orientation moderately well even as inclusions within some of the granitic masses.

Small scale, parallel, surface markings, which have been interpreted as "b" lineations, occur on the cleavage planes of many of the slates in the Gander Lake Group. These are plentiful along the shores of Gander Lake, Home Pond, Soulis

Pond, and west of Lake St. John and Deer Pond. They are parallel with regional strike directions, and plunge both north and south. Small folds in the slates on Gander Lake west of the ultrabasic rocks also plunge both north and south (in different exposures). Several of the folds at the northwest end of Gander Lake plunge as much as 70 degrees north. It is thus concluded that the folds in the Gander Lake Group are warped along their crests, but it is not yet known to what extent they are warped.

Faults

More than 77 faults are known in the two map-areas, most of them in the eastern half where rock exposures are more abundant and permit better recognition of faults. Only 17 fault planes have actually been seen, all of which are in coastal exposures, but the existence of the unexposed faults has been established from other geological evidences. Many more faults probably exist in the two areas. Only about half of the faults are shown on the accompanying geological maps, owing to the small size and relative unimportance of the others. All faults recognized to date are of the high angle type. This is also the principal type of fault reported in adjoining areas to the south and southeast (Bradley, 1962; McCartney, in press).

Faults within the two map-areas have been grouped into the following four general fault systems for ease of description: (1) high-angle faults trending about N45°E, (2) near-vertical faults with great length trending about N15°E, (3) high-angle faults of short extent, trending about N75°E, and (4) high-angle faults trending about N25°W. Two small faults have been observed that do not fit into any of the above systems. Stratigraphic displacements along some faults suggest that the four fault systems may have developed in the order listed, from oldest (1) to youngest (4). The four fault systems are in reasonable agreement with the fault systems reported by Bradley (1962) in Gisborne Lake-Terrenceville map-areas a few miles to the south.

Faults in the oldest system offset Lower Cambrian rocks on Random Island, and are probably post-Early Ordovician in age, as the local stratigraphy of the Cambro-Ordovician rocks gives no indication of any significant deformation during their deposition. The youngest faults are believed to be related to the time of intrusion of the granitic batholiths in Terra Nova map-area, although two small faults have been observed within the granites. Thus it is probable that all faults shown on the present maps developed between Middle Ordovician and Late Devonian times. Some post-Devonian movement along fault planes may have occurred, but cannot be readily recognized.

Faults of the N15°E system have had the greatest effect of any structural element in the present distribution of the Precambrian rock units in the two map-areas. They are, for example, primarily responsible for the long thin sandwich-like bands of alternating Musgravetown and Love Cove Group rocks that cross both map-areas from north to south. They have also played an important role in the juxtaposition of the Musgravetown and Connecting Point Groups in the Southern Bay and Random Sound regions.

N45°E Fault System

Seventeen faults are included in the N45°E fault system. Only three of these have been seen in outcrops; the rest are inferred from stratigraphic and/or topographic evidences. These faults are straight and almost vertical and strike within 10 degrees of northeast. All but two of them lie within Bonavista map-area. Faults belonging to a similar N45°E fault system in Terrenceville map-area to the south are reportedly steep reverse faults (Bradley, 1962).

Swale Tickle Faults

Two faults are exposed along the south shore of Swale Tickle in Newman Sound. The first of these is a normal fault in a small cove 1 mile south of the west end of Swale Island. The fault is marked by a shear zone 20 feet wide, striking N45°E and dipping 50°NW. The rocks involved are thin-bedded medium-grey sandstones of the Connecting Point Group, which strike in the same direction as the fault, but dip 40°S. Drag-folds alongside the fault zone indicate normal movement, and stratigraphic displacement appears to be only a few tens of feet. A small valley marks the inland continuation of this fault for several hundred feet.

A fault with the same strike and approximately the same dip has been observed about a mile farther east along the same shore. Its stratigraphic displacement is probably not greater than 100 feet.

Cutler Head Faults

A group of six parallel faults occurs on the narrow peninsula separating Sweet Bay from Southern Bay. Only one of these is actually exposed.

The most important fault in this group separates volcanic rocks and underlying coarse-grained clastic sediments of the Musgravetown Group from steeply dipping Connecting Point arenaceous rocks near the head of the peninsula known as Cutler Head. This fault strikes N45°E, is vertical, and is exposed on both sides of the peninsula. Movement along the fault had a large horizontal component, judging from the rock types thrown into juxtaposition. This fault may continue across the mouth of Sweet Bay and along its west shore, passing between Wolf Island and the adjoining shore, for the lithology of the Connecting Point rocks on Wolf Island differs markedly from that of the rocks on the adjoining shore.

Five other faults with the same direction and vertical attitude have been recognized by topographic lineaments (on aerial photographs) and lithological changes along shore within 2 miles to the south, along the same peninsula. Several longer, parallel topographic lineaments occur still farther south along the same peninsula.

Clode Sound Fault

A fault with a strike of about N55°E is believed to lie underwater along the north shore of Clode Sound 2 miles west of Bread Cove (Jenness, 1958b). Its presence is indicated by the occurrence of Connecting Point quartzitic rocks on Platter Island and an adjoining tiny rock exposure, within 300 feet of vol-

canic rocks of the Bull Arm Formation (Musgravetown Group). The Connecting Point rocks are, in addition, of a type found no closer than 3 miles to the east, that is, about a mile east of Bread Cove. A lineament extending northeastward from Dumpling Cove (1 mile east of Bread Cove) across Newman Sound, Eastport Bay, and past the islands farther northeast, a distance of more than 32 miles from Platter Island, may mark the continuation of this fault. Connecting Point strata on the southeast side of this lineament dip gently southeast, whereas those on its northwest side are strongly folded and have different trends. This 'structural break' may be one of the most important structural elements in the entire Bonavista Bay area.

Other N45°E Faults

Locations of, and evidences for, eight additional faults belonging to the N45°E fault system are tabulated below.

Location	Evidence
Lockers Flat Island	1. Topographic lineament trending N50°E across island 2. Left-handed offset of quartzite beds about 3,300 feet horizontally
Open Hall to Broad Cove	1. Topographic depression striking N50°E for 6 miles 2. Change of structure on opposite sides of topographic lineament 3. Drag-folds on southeast side of lineament at Broad Cove
Halfway Pond to Port Union	1. Topographic lineament trending N55°E for 6 miles 2. Bending of strata near Port Union, which suggests left-handed displacement 3. Offsetting of north-northeasterly trending fold axis at Port Union
Lady Pond to Trinity	1. Straight topographic lineament crossing structure for 16 miles 2. Several elongated lakes with connecting streams lying along lineament 3. Some structural disruption along lineament, as seen on aerial photographs
Fosters Point (Random Island)	1. Shear zone and crumpling of Connecting Point quartzites against Random Formation 2. Entire Musgravetown Group missing 3. Topographic lineament extends N40°E for 11 miles to Lady Pond
Red Head Cove, Bay de Verde Peninsula	1. Topographic depression trending almost 90° to strike of strata 2. Change or offset of fold axis (axes?) 7 miles southwest of Red Head Cove 3. Distinct change in structure and lithology about 11 miles southwest of Red Head Cove

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Location	Evidence
Black River Pond, east shore	1. Topographic lineament trending N35°E for 1 mile from lake shore 2. Steep scarp on east side of lineament with granitic rocks having a north-striking gneissosity
One mile southeast of mouth of Dead Wolf Pond, on gravel road	1. Sheared pyroxenite, schistosity striking N55°E dipping 60°W 2. Quartz veins with minor sulphides

N15°E Fault System

The most extensive faults in the two map-areas belong to the N15°E fault system. These include six boundary faults that separate the three Precambrian rock groups and twenty-two additional faults of lesser importance. All appear to strike within 15 degrees of N15°E, and to be nearly vertical in attitude. Principal movement along these faults appears to have been in a vertical direction. Only seven of the twenty-eight have actually been seen in outcrops.

The six boundary faults are the Salmon Brook, Platter Cove, Charlottetown, Smith Sound, Come By Chance, and Long Beach faults (*see* Figure 9). The Come By Chance and Long Beach faults have been traced for several miles southward into the Sunnyside map-area (McCartney, 1958).

Salmon Brook Fault

The westernmost boundary of the Musgravetown Group rocks is marked by a fault that has been traced from the granite contact near Whitehead Pond, at the southern boundary of Terra Nova map-area, north-northeastward along the west side of Clode Sound and Alexander Bay and into Freshwater Bay. Nowhere along this 60-mile length has the fault been observed in outcrops, but its position can be located within a few tens of feet at several localities. Throughout most of its course, the Salmon Brook fault separates gently folded unmetamorphosed Musgravetown rocks on its east side from strongly folded, regionally metamorphosed Love Cove greenschists on its west side. Its straightness regardless of topography indicates that it is vertical or nearly vertical in attitude throughout most of its extent.

At its southernmost-known locality in Terra Nova map-area, 1½ miles east of Whitehead Pond, the position of the fault can be traced for over a mile across the top of a small ridge and located within about 50 feet. It lies in a small gully, flanked by red sandstone and shale of the Musgravetown Group along the east side, sericite schists of the Love Cove Group along the west side. The curve of the fault-trace over the hillside, when plotted against topographic contours, permits calculation of a fault dip of about 45°W, the lowest known dip along the entire length of the fault.

In the Port Blandford area, 6 miles southwest of the mouth of Southwest

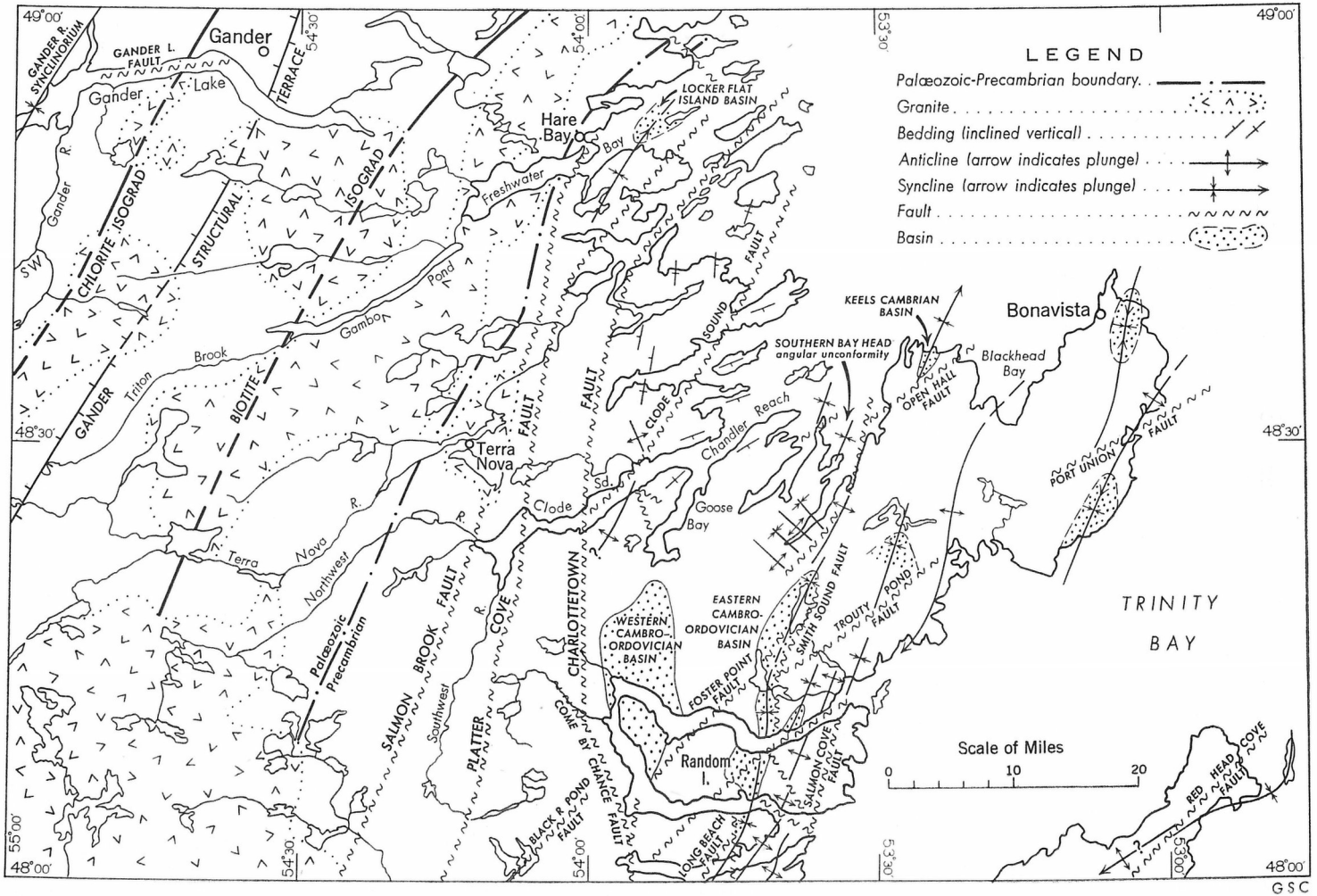

Figure 9. *Principal structural elements in the Terra Nova and Bonavista map-areas.*

River, the position of the Salmon Brook fault is defined by a narrow depression containing several elongated stream-connected lakes. The fault apparently forks at this locality, with one segment veering slightly to the west where its position has been ascertained within 400 feet in each of three localities, 3, 6, and 8 miles farther north. In each of these localities the strike of the Love Cove rocks on the west side of the fault differs from that of the Musgravetown rocks on the east side. About 1,000 feet south of the small railway bridge across Salmon Brook the position of the fault can be located within 50 feet. The fault at this locality separates thinly bedded, very schistose andesitic tuffs of the Love Cove Group from unmetamorphosed, crossbedded, pinkish arkosic sandstones of the Musgravetown Group.

The position of the fault can be ascertained where it crosses Terra Nova River, because of the presence of Love Cove sericite-chlorite schist a few tens of feet west of unmetamorphosed, light greyish green Musgravetown sandstone on the west bank of the river. The fault position can be further established, within 300 feet, 1¼ miles south of Maccles River, where it lies along a small, straight ravine with a vertical cliff along the east side.

Two miles west of Glovertown near a small bay on an unnamed lake, the Salmon Brook fault is flanked on its east side by a high, steep knoll displaying a somewhat sheared red pebble conglomerate. Farther north the fault passes through the centre of the large lake (locally known as Cat Bay Pond) immediately west of Cat Bay, thence along a narrow, but strongly delineated, gully into a small embayment on the south shore of Freshwater Bay just west of the mouth of Cat Bay. Gently dipping Musgravetown red sandstones lie on the east side of this embayment, steeply dipping Love Cove chlorite-sericite schists on the west side.

The Salmon Brook fault branches near the southern end of Cat Bay Pond, with the branching fault trending northward to the shore of Freshwater Bay, where its position is indicated by an intensely shattered zone at a granite-quartzite (Love Cove Group) contact. It may then continue northerly across the neck of the peninsula at Hare Bay where a small body of granite is intensely fractured.

Platter Cove Fault

The north to north-northeast trending Platter Cove fault is roughly parallel with the Salmon Brook fault and between 1¼ and 8 miles east of it. The principal evidence for its existence, like that for the Salmon Brook fault, is the occurrence in juxtaposition of rocks of different metamorphic facies. The fault has not been observed in outcrops.

The position of the southernmost occurrence of the Platter Cove fault in Terra Nova map-area is indicated by a straight, steep cliff 2 miles north of latitude 48°00′. Farther north, the position of the fault can be located within a few tens of feet in the following places: 1 mile northwest of Shoal Harbour Pond; at Thorburn Lake; along the east shore of the head of Clode Sound; and in Platter Cove on the north side of Clode Sound. In each locality its position is indicated by the differences in lithology, structure, and metamorphism of the rocks adjoining it.

From Platter Cove north the fault position can be identified only with difficulty because of the scarcity of outcrops, because of an apparent decrease in the metamorphic grade of the Love Cove rocks in this central band north of Clode Sound, and because of the lithological similarity (the rocks being chiefly buff-green sandstones) on both sides of the fault in Alexander Bay. In consequence the following somewhat generalized regional factors were used to place the fault position north of Clode Sound: (1) the fact that the structure of the Musgravetown rocks is simple, being either monoclinal or gently folded, whereas that of the Love Cove rocks is commonly steeply folded and complex, and (2) the Musgravetown rocks generally consist of thick lithologically uniform beds, whereas the Love Cove rocks are typically thin-bedded and lithologically diverse, composed of both sedimentary and volcanic rocks.

The Platter Cove fault and the Salmon Brook fault are believed to form the two sides of an elongate graben structure. Both appear to be nearly vertical, perhaps locally with a steeply westward dip. In addition, both may actually be fault zones consisting of several en échelon or off-shooting faults rather than single faults. Scarcity of outcrops prevents a more accurate interpretation.

Charlottetown Fault

A north-trending, apparently vertical fault, which passes through the village of Charlottetown in Clode Sound, separates Love Cove rocks from relatively undeformed and unmetamorphosed members of the Musgravetown Group. The southern end of this fault is probably near the railway tracks 1½ miles west of Shoal Harbour, where lavas of the Bull Arm Formation (Musgravetown Group) lie alongside chlorite and sericite schists and volcanic rocks of the Love Cove Group. This fault continues northward along a minor topographic lineament, marked by small streams, to a pronounced straight, narrow valley leading into the head of Bunyan's Cove in Clode Sound. The position of the fault can be located within 50 feet on the east side of Bunyan's Cove, where purplish rhyolite of the Musgravetown Group is separated from buff-coloured sericite schist of the Love Cove Group by a small sandy beach. The rhyolite near the fault zone is shattered. At Charlottetown, the position of the fault can be determined within 50 feet owing to the presence of gently dipping red Musgravetown sandstones almost abutting against rubbly Love Cove sericitic schists along the shore around the village, and in the brook in the middle of the village.

North of Charlottetown the fault is concealed beneath widespread glacial drift, but it may follow a strong topographic lineament across the peninsula north of the Louil Hills and emerge in a small bay on the east side of Bloody Reach.

The Charlottetown fault, like the Salmon Brook fault, separates greenschist facies of the Love Cove Group on its west side from unmetamorphosed Musgravetown lavas and sediments. In contrast to the Salmon Brook fault, however, the Charlottetown fault cuts chiefly rocks of the Bull Arm Formation (near the base of the Musgravetown Group), whereas the Salmon Brook fault cuts formations

higher in the group. The Love Cove rocks west of the Charlottetown fault may represent a horst block, separating two grabens of Musgravetown rocks.

Smith Sound Fault

The Smith Sound fault extends from Smith Sound north-northeastward to Ocean Pond, a distance of about 10 miles. Its position can be determined within 20 feet on the north shore of Smith Sound opposite Britannia, where Lower Cambrian red shales and limestones are dragfolded down against Musgravetown amygdaloidal lava. North of Smith Sound, it separates Lower Cambrian rocks from sedimentary members of the Musgravetown Group for a distance of about 5 miles, beyond which it apparently lies wholly within the Musgravetown Group.

Come By Chance Fault

McCartney (1958) recognized an essentially vertical fault that trends north-northeasterly from the south side of Come By Chance harbour for about 7 miles, then veers closer to north for another 7 miles where it enters the southwest corner of Bonavista map-area along a narrow valley at Queens Cove. In McCartney's area the west side of the fault consists of Random and Cambrian sediments and some complex dioritic rocks, with Musgravetown rocks on the east side. On the south side of Random Sound, the fault is flanked on the east by Connecting Point Group rocks and on the west by Bull Arm volcanic rocks (Musgravetown Group).

The exact position of the fault north of Queens Cove is not known, but it probably lies along the base of a steep hill just west of the highway for 6 miles, as far as Deep Bight. From Deep Bight the fault may follow a north-northwesterly course along a minor topographic lineament to the valley of Dark Hole Brook 1½ miles west of Clarenville South, thence along this valley to the railroad tracks and the Shoal Harbour River. Bull Arm volcanic rocks appear to be faulted against Love Cove schists along the valley of Dark Hole Brook and also across the Lower Shoal Harbour River, but the connection between this fault and the Come By Chance fault at Deep Bight and Queens Cove is not yet established.

A small branch fault from the Come By Chance fault has brought into view a small wedge-shaped block of Lower Cambrian shale and limestone and some Random quartzite on the shore at Adeyton.

Long Beach Fault

McCartney (1958) mapped the Long Beach fault from Great Southern Harbour in Sunnyside map-area to Long Beach in the Southwest Arm of Random Sound, a distance of 17 miles. This fault separates the Connecting Point Group rocks on the west side from Musgravetown Group rocks (chiefly volcanic rocks of the Bull Arm Formation) on the east side. It is exposed on the north shore of Southwest Arm of Random Sound as a narrow vertical break (*see* Plate XII). At this locality Connecting Point quartzites on the west side are much fractured,

probably because their steeply inclined beds are almost parallel with the fault plane. The fault continues north from this locality for 2 miles to St. Jones Within, and probably northward an additional 2¾ miles to the south shore of Northwest Arm of Random Sound, where its exact position is not known because of the close spacing of at least three almost parallel faults. Complexity of structure in the Hickmans Harbour region has to date prevented recognition of the Long Beach fault on Random Island, but it may cross the island and connect with the Smith Sound fault on the north side of Smith Sound.

McCartney (1958) suggested that the Long Beach fault and the Come By Chance fault mark the east and west flanks of a horst structure involving the Connecting Point Group rocks. This possibility also exists in Bonavista map-area, although the structural picture is complicated by other faults in the Random Sound region, and by the lack of exposure in critical areas farther north.

Other N15°E Faults

Locations of, and evidences for, twenty-two additional faults belonging to the N15°E fault system are tabulated below.

Location	Evidence
Salmon Cove to Long Harbour, Random Island	1. Narrow, straight valley, trending north-northeasterly for 7 miles 2. Some intraformational stratigraphic displacement
On small peninsula near northwest end of Sweet Bay	1. Narrow gully 800 feet long between two tiny bays 2. Green Musgravetown conglomerate on east side strikes north, dips 55° east; Connecting Point sedimentary and volcanic rocks on west side strike and dip differently nearby.
1½ miles east of Hillview to 1¼ miles east of Magotty Cove	1. Straight topographic lineament trending north-northeasterly for 4½ miles across Connecting Point strata 2. Steep-walled cliffs with contorted and fractured rocks occur at shore in Northwest Arm of Random Sound
3 miles east of Magotty Cove	1. Steep, narrow ravine, with fractured rock walls, trends southwesterly from shore of Northwest Arm of Random Sound 2. Topographic lineament trending N25°E for about 3 miles, and northeasterly across Random Island to Britannia
Unnamed cove 1¾ miles south of Hickmans Harbour	1. Two faults, indicated by stratigraphic displacement of Random and Cambrian beds in one shore exposure, and of Random and Bull Arm rocks a few tens of feet to the west.

Location	Evidence
¾ mile west of Hodges Cove in Southwest Arm, Random Sound	1. Deep ravine trending south 1 mile, which separates red siltstone on east from andesite, both of Musgravetown Group 2. Stratigraphic irregularities suggest probable continuation to north past St. Jones Within to Northwest Arm of Random Sound
South shore of Southwest Arm of Random Sound, between Hodges Cove and Long Beach	1. Four straight narrow ravines all trending a few degrees east of north and cutting Musgravetown rocks
2½ miles west of Long Beach	1. Straight, narrow, steep-walled ravine, trending south across strike of Connecting Point sediments 2. Much shattered rock alongside ravine
Just east of Salmon Cove, Random Island	1. Two small faults striking northerly along narrow ravines and cutting across red Crown Hill sandstones 2. Minor stratigraphic displacements
1½ miles west of Hickmans Harbour	1. Narrow ravine trending north-northeasterly 2. Shattered rock and minor stratigraphic displacement along shore 3. Drag folds along shatter zone suggest east side of fault moved down relative to west side, with approximately vertical dip on fault
On tip of small point just east of above fault, and perhaps forming an off-shoot from it (same locality as minor disconformity described on previous page)	1. Minor fault exposed, trending N30°E, vertical dip 2. Displacement about 6 feet, with west side down relative to east
1¼ miles west of Hickmans Harbour	1. Fault exposed, vertical dip, northerly strike 2. Stratigraphic displacement 50 + feet, west side down relative to east side. May be offshoot of larger fault in region
1 mile south of Clarenville	1. Shattered contact between Musgravetown lavas and granite, striking northerly
1 mile southwest of Charlottetown, on north shore of Clode Sound	1. Shear zone, 6 feet wide, in chloritic rocks of Love Cove Group 2. Andesitic dyke along shear zone, strike N30°E, dip 75°W 3. Suggested displacement, west side up relative to east side, by 10 + feet
Gander Lake, north shore, between 7 and 8 miles west of airport	1. Three fault zones, northerly trends, nearly vertical dips, two in serpentinite, third just west of ultrabasic rocks 2. Splintery serpentine rubble 3. Reddish slate faulted against greenish slate, with high westerly dip and strata on west side displaced down relative to east side 20 + feet

Location	Evidence
Small bay, northeast end of Pitt Sound Island	1. Two fault zones trending northerly 2. One strikes N10°E, dips 75°W, and contains minor copper minerals (see also chapter VI); is marked by 3-foot shear zone in Love Cove andesite 3. Other fault lies on west side of bay, separating cherty quartzite beds from andesite; strikes N25°E, dips 70°W, has slickensides on west (andesitic) side suggesting almost vertical movement, with west side up; one-foot shear zone, with shattering through a greater width. Both faults may be offshoots of Charlottetown fault
North shore, Northwest Arm of Alexander Bay	1. Exposed fault, trending N20°E, dipping 65°W, 3-foot shear zone mineralized with chlorite, quartz, epidote, calcite, and minor pyrite, in Rocky Harbour greenish sandstone 2. Slickensides indicate west side moved down and slightly to north relative to east side.

N75°E Fault System

Nineteen faults with strikes ranging within 15 degrees of N75°E and with either left- or right-handed stratigraphic displacements occur in the two map-areas. Only two of the nineteen have been seen in outcrops; the rest have been inferred from the offsetting of recognizable stratigraphic horizons, or from pronounced topographic lineaments seen on aerial photographs. Only a few of the nineteen have been shown on the accompanying geological maps, owing to space limitations. None has yet been recognized in the southern half of Bonavista map-area, and McCartney (personal communication) has not found faults of this system on Avalon Peninsula to the southeast.

Bloody Reach Faults

The east side of Bloody Reach is one of the few parts of either Terra Nova or Bonavista map-area where both stratigraphic control and rock exposures are good enough to permit recognition of the kind and amount of faulting that is found in this region. The nature and effect of the faults are shown diagrammatically in Figure 10.

Field relationships indicate the presence of at least six relatively small faults along the east side of Bloody Reach in Alexander Bay. Four of these have right-handed displacements, the other two left-handed (*see* Figure 10). All appear to strike about N75°E and to dip vertically or very steeply. The northernmost of these occurs between the southwestern end of Cottel Island and a small island immediately south of it. Southwesterly striking red sandstones and pebble conglomerates on Cottel Island are separated by a mere 50 to 60 feet of water

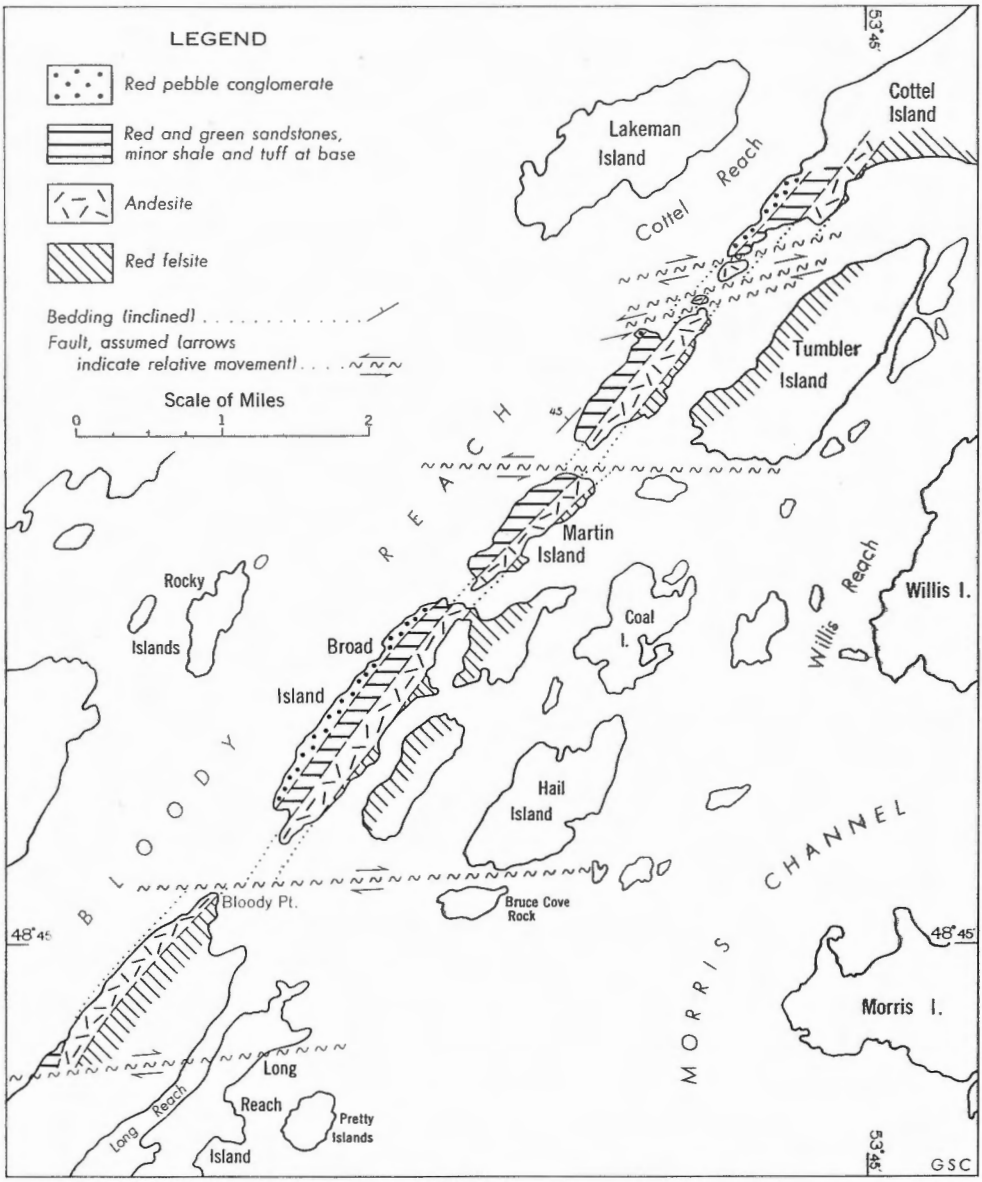

Figure 10. *The offsetting of Musgravetown sediments and volcanic rocks by faults of the N75°E system, Bloody Reach region.*

from medium grey, amygdaloidal andesite of the Bull Arm (?) Formation (Musgravetown Group) on the small island. This lava, which has proven to be a valuable stratigraphic horizon marker in the Bloody Reach region, occurs farther east along the south shore of Cottel Island underneath a succession of stratigraphic units, each less than 200 feet thick, which are, from west to east (apparently downwards stratigraphically): red conglomerate; red sandstone; green slate; red silty slate; green silty slate; and a dark grey tuff. Stratigraphic offset of the grey lava indicates a right-handed strike slip of about 2,000 feet.

The grey andesite is displaced by another fault between the small second island just mentioned and a smaller, third island 300 yards to the southwest. Reddish lava exposed on the east side of the smaller island is part of the lithological unit that lies stratigraphically below (i.e. east of) the grey andesite, and permits the determination of the displacement by the fault. Stratigraphic offset is right-handed and about 1,000 feet.

The same grey andesite is again displaced between the third island and its large, unnamed neighbour island a few yards to the south. The fault that passes between the two islands has a left-handed displacement of about 750 feet, as determined by the offsetting of the contact between red and grey lavas.

A fourth fault separates the large unnamed island just mentioned from Martin Island to the south, with the grey lava horizontally offset by about 500 feet. The relative displacement in this locality is again left-handed, and the north end of Martin Island appears to have been rotated about 7 degrees clockwise. Evidence for this fault was not observed east of Martin Island so it is believed to strike about N90°E. The position of the grey lava on Martin Island is about 1,750 feet west of the position it would have, if extended along strike south of Cottel Island; that is, the net effect of the four faults just described has shifted the grey lava band westward approximately 3,000 feet and returned it approximately 1,250 feet on Martin Island (Figure 10). There is no apparent displacement of beds between Martin and Broad Islands.

A fifth fault lies just south of Broad Island as indicated by a further displacement of the andesite band between Broad Island and Bloody Point. The relative displacement there is right-handed, with a horizontal offset of about 2,500 feet. Two miles to the east the probable extension of this fault passes between Hail Island and Bruce Cove Rock, for the strata on these two adjacent islands are dissimilar. Because of this fault the sediments lying stratigraphically above the grey lava lie offshore for 1⅓ miles southwest of Bloody Point, where they reappear alongshore for ½ mile, only to be faulted west again by another right-handed fault (*see* Figure 10). The horizontal displacement of this sixth fault must be nearly a mile, for the grey lava band does not reappear farther south along Bloody Reach. The two faults south of Broad Island strike N80° to 85°E. The southernmost of these is marked by both the stratigraphic displacement just noted and a sharp topographic lineament that crosses the peninsula between Bloody Reach and Long Reach, then passes across Long Reach Island to the east. Other as yet unrecognized faults probably occur in this same region with similar orientations and relative displacements.

Other N75°E Faults

Locations of, and evidences for, thirteen additional faults (or possible faults) belonging to the N75°E fault system are tabulated below.

Location	Evidence
Southernmost part of Rocky Bay, west of Bloody Reach	1. Topographic lineament trending N80°E, traceable to the west for almost 4 miles 2. Apparent right-handed displacement of about ¼ mile in the contact between Love Cove and Musgravetown Groups 2 miles south of Rocky Bay
Deer Island region	1. Three faults, suggested by parallel topographic lineaments trending almost due east 2. Apparent horizontal displacement of sediments
Centre of Gander Lake	1. Apparent offsetting of beds of 'middle unit' in Gander Lake Group by almost 2 miles suggests fault trending N80°E along lake
About 1 mile southeast of Mollyguajeck Lake	1. Four closely spaced, nearly parallel, narrow, straight-walled, shallow ravines crossing rock structure of paragneisses for about ½ mile; three strike N70°E, the fourth N55°E, but it is an offshoot of one of the other three 2. Lithological differences indicate some horizontal stratigraphic displacement. Fault planes probably nearly vertical
6 miles north of Mollyguajeck Lake	1. Narrow, straight, ravine, 20 feet deep, 50 to 70 feet wide, trending about N80°E across structure of underlying paragneisses for almost 1 mile
Gorge of Terra Nova River near mouth of Mollyguajeck Lake	1. Narrow gorge trending about N70°E for nearly 1 mile across rock structure (see also Chapter VI). However, diamond drill hole directed beneath the river during early 1950's reportedly revealed no sign of a fault
Southward Head Peninsula	1. One or two faults striking N70°E, dipping 80° – 90°N; one on east side of peninsula cuts andesitic lava that lies above the basal Musgravetown conglomerate, and produced some stratigraphic offset 2. Second (?) fault is exposed on west side of peninsula, with dissimilar lavas of Musgravetown Group in juxtaposition. Both faults appear to have north side down relative to south, with some horizontal component of movement. This fault may be same one as on east side of peninsula

Location	Evidence
West side of Southward Head Peninsula	1. Gently dipping andesite of Musgravetown Group in contact with steeply dipping quartitic sandstones of Connecting Point Group 2. Fault gouge and drag folds in Connecting Point beds suggest north side moved down relative to underlying south side 3. Strike of fault plane at shore is easterly, dip 50°N
3¼ miles NE of railway bridge over Terra Nova River	1. Distribution of outcrops and topographic lineament indicate fault trending N65°E 2. Right-handed offset of intrusive contact of granite and Musgravetown sediments, with strike slip about 600 feet 3. Thermal metamorphic zone in sediments, being offset, indicates fault is post-granite in age, one of best examples of post-granite structural activity in the two map-areas
Southeast shore Maccles Lake	1. Small right-handed displacement in metamorphosed sedimentary beds of Love Cove Group; fault is apparently vertical, and strikes N75°E

N25°W Fault System

Twelve faults or probable faults have been assigned to a composite N25°W fault system. All strike within 20 degrees of N25°W and all but one occur in Bonavista map-area. In contrast to the N15°E faults, which appear to have an essentially vertical direction of movement, the faults in the N25°W system appear to have their displacement chiefly in a horizontal direction. Only three of the twelve have been seen in outcrops. Left-handed movement occurred on at least five of the faults. A similar fault system has been reported by McCartney (in press) on the western half of Avalon Peninsula south and east of the present areas, and by Bradley (1962) in Terrenceville map-area to the southwest.

Milners Cove Fault

The best example of a fault in the N25°W system is the one that separates Musgravetown and Connecting Point rocks in two adjoining outcrops on the south shore of Clode Sound opposite Bread Cove, ½ mile east of a V-shaped cove known locally as Milners Cove. The fault plane exposed there strikes N45°W and dips about 50°SW. The footwall consists of a greyish black, thin-bedded quartzite of the Connecting Point Group; the hanging-wall is a poorly consolidated greyish green pebble conglomerate of the Cannings Cove Formation (Musgravetown Group). An inch of fault gouge, derived mainly from the conglomerate, lies along the contact. Small drag-folds in the quartzite beds alongside the fault indicate that the east side moved northwest relative to the west side, hence displacement was left-handed.

The Milners Cove fault is exposed only in this one locality. Its continuation northward, however, is suspected from the following lithological and structural evidence. (1) On the north shore of Clode Sound, just west of Bread Cove, Musgravetown red cobble conglomerate (which lies stratigraphically several tens of feet above the green conglomerate at the fault contact just described) is exposed within a few tens of feet of grey slate of the Connecting Point Group. As the conglomerate and the slate strike almost at right angles to each other, and as the basal members of the Cannings Cove Formation are not present, the contact is interpreted as a fault rather than as an angular unconformity. (2) One mile to the northwest of Clode Sound, on the southeast shore of the pond (locally known as Bread Cove Pond) that drains into Bread Cove, the entire Cannings Cove Formation is missing, and the lowest exposed member of the Musgravetown Group is a purplish acid lava of the Bull Arm Formation, which lies within 100 feet of Connecting Point grey silty slates. The strikes of the lava and slate there are almost identical, but their dips are in opposite directions. (3) Red conglomerate of the Cannings Cove Formation reappears a mile farther north, a few hundred feet west of the nearest outcrop of Connecting Point rocks (interbedded dark grey argillite and impure quartzite rather than grey slates, in this locality). Thus structural and lithological variations along the Musgravetown-Connecting Point contact north of Clode Sound favour the extension of the Milner Cove fault northward. The curve of the contact line across local relief north of Bread Cove suggests that the fault dips westward at a moderate angle. Continuation of the fault north of Newman Sound is uncertain.

Other N25°W Faults

Eleven other faults with attitudes referable to the N25°W fault system have been seen or inferred from geological evidence. Several of these are too small to indicate on the geological maps. The locations of, and evidences for, these faults are tabulated below.

Location	Evidence
Lower Lance Cove, Random Island	1. Pronounced straight topographic lineament striking N17°W across eastern part of Random Island for 5 miles. Lies in creek bed at north end (Lower Lance Cove), along ravine at southern end 2. Apparent stratigraphic displacement, left-handed, for 1 mile, of Crown Hill Formation
1¼ miles NE of Little Hearts Ease, SW Arm Random Sound	1. Narrow straight ravine trends N15°W for a mile from small cove in Hearts Ease Inlet 2. Horizontal displacement of Musgravetown sandstone beds, left-handed, at least 1,000 feet

Location	Evidence
West side of Little Hearts Ease Harbour	1. Narrow valley trending N25°W on west side of harbour for ¾ mile 2. Left-handed horizontal offset of red and green Musgravetown sandstone, at least 2,000 feet. Fault appears to be vertical 3. Near-vertical gash on cliff on north side of SW Arm Random Sound may be northern continuation of fault
Britannia, Random Island	1. Juxtaposition of Crown Hill conglomerate and Lower Cambrian strata along a northwesterly direction near village. Has northeasterly trending fault along south side
Deep Bight	1. Three small faults; one alongside mouth of Deep Bight River separates Connecting Point siltstones from Bull Arm (?) grey lava with contact marked by gully trending N45°W and much fractured rock 2. Second fault is exposed on north shore, ⅓ mile east of mouth of same river, where it separates Connecting Point quartzitic sandstone from Musgravetown grey sandstone and pebble conglomerate, and strikes N10°W, dips 85-90°E. Fault zone contains minor fault gouge, and drag folds suggest left-handed displacement, which appears to be large 3. Third fault occurs few feet to west, where Connecting Point quartzitic sandstones are offset with right-handed displacement of a few feet at least. Fault is not exposed but appears to strike N45°W and to dip almost vertically
Peninsula between Goose Bay and Clode Sound	1. One strong topographic lineament trends N15°W from Musgravetown village to Milners Cove, a distance of 3½ miles, with enough curve to suggest fault plane with dips at moderate angle to SW. May be some stratigraphic displacement 2. Another strong topographic lineament strikes N30°W from east side of Northwest Pond to Clode Sound. This lineament is 1½ to 2 miles west of adjoining lineament
Baccalieu Island	1. Pronounced lineament trends N25°W
Peninsula at Charlottetown	1. Fault exposed, striking N50°W and dipping 70°W, with 2 to 6 inches of fault gouge. Red argillite above fault, pinkish felsite beneath. May be minor offshoot of Charlottetown fault nearby

Faults with Other Orientations

At least two fault zones have been observed, the orientations of which differ from those of any of the four previously described fault systems. Neither of the two are major structures. One is a small fault striking N60°W and dipping 80°NE, which is exposed in a creek bed 4 miles southwest of Port Blandford. Red and buff sandstone of the Musgravetown Group have been cut by the fault with a right-handed displacement of 3 feet. Slickensides indicate a dip-slip angle of 10 degrees.

The other fault occurs on the north shore of Newman Sound, about 1 mile west of North Broad Cove, and immediately east of a group of closely spaced anticlines and synclines. The fault strikes N80°W and dips 45°N as exposed, and cuts black slate and greywacke of the Connecting Point Group. Fault gouge obscures the fault plane relationships, but from stratigraphic evidence the fault appears to be normal with the north side dropped down at least 60 feet relative to the south side. A narrow valley marks the probable inland continuation of this small structure.

Schistosity and Gneissosity

Schistosity is an important structural feature within the Love Cove Group. In most of the areas underlain by Love Cove rocks, bedding cannot be determined, and schistosity is the only structural data obtainable. Enough data have now been collected and plotted on the geological map to indicate that the schistosity directions are of a regional nature, roughly parallel with the direction of the two elongate belts of Love Cove rocks. In addition, the dips of the schistosity planes generally exceed 50 degrees, although the actual directions of dip (easterly or westerly) show no recognizable pattern. In a few places both bedding and schistosity are recognizable in outcrops, and are found to differ in orientation by from 15 to 60 degrees. Such is the case in the exposures of greenish schistose sandstones on the east side of the narrows in Alexander Bay 1¼ miles north of Traytown, and again in reddish sandstones a few yards east of Salmon Pond. Schistosity is best developed in the chlorite- and sericite-rich metasediments of the group, especially along Clode Sound, but is absent from the acidic volcanic rocks that are locally abundant, as in the Tug Pond region.

Schistosity is also well developed in the metamorphosed argillaceous rocks of the Gander Lake Group, especially between Terra Nova Lake and Lake St. John. It has a regional orientation but unlike the schistosity of the Love Cove rocks this orientation is generally parallel with bedding directions.

Gneissosity is well developed in the paragneisses of the Gander Lake Group, and along part of the eastern margin of the Ackley batholith. *Lit-par-lit* gneissosity is well displayed on the south shores of Terra Nova Lake and Maccles Lake. The gneissosity in the paragneisses is caused chiefly by the layering of the oriented mica flakes and the plagioclase grains, but locally it is caused by the marked alignment of large pink porphyroblasts of potassic feldspar parallel

with the orientation of the mica and plagioclase. Similar large crystals of aligned, pink potassic feldspar occur in marginal parts of the Ackley granite, as for example along the southeast shore of Gander Lake, and in some exposures near Terra Nova Lake and west of Whitehead Pond. Gneissosity is also developed in some of the Love Cove quartz-chlorite schists northeast of Black River Pond, where the schists contain large rectangular-shaped crystals (up to 1 inch long) of pink potassic feldspar in such quantity that they resemble schistose granite. The gneissosity generally trends parallel with the regional strike of the metasedimentary rocks or roughly parallel with the margins of the granite bodies. Schistosity and gneissosity are parallel in the interbedded mica schists and paragneisses of the Gander Lake Group west of Terra Nova Lake.

Cleavage and Lineation

Slaty cleavage is well developed in many of the argillaceous rocks of the Gander Lake Group, the Connecting Point Group, and the two groups in the Cambro-Ordovician basins. It is developed sufficiently well in the Cambro-Ordovician rocks on Random Island and adjoining areas to have yielded high quality roofing slates. Cleavage has supplied much structural data where bedding was unrecognizable, as, for example, in most exposures of the Gander Lake Group rocks. It is well developed in the argillaceous rocks of this group, and generally strikes closely parallel with the regional direction of fold axes. Dips are commonly fairly steep, although in a few places cleavage with a low dip has been observed. Cleavage thus has proven a useful structural supplement in mapping the Gander Lake Group.

In a few localities finely etched lines identified as "b" lineations, have been observed on cleavage planes of Gander Lake slates. These lineations have indicated that there are many rolls, some rather steep, along the crests of the fold axes in the Gander Lake Group. This interpretation has been verified in a few places on Gander Lake by plunge readings made on bedding planes of small drag folds.

Crossbedding and Ripple-Marks

Crossbedding has been observed in rocks of all major groups in the two map-areas. It is most extensively developed in parts of the Musgravetown Group, however, especially in the buff-green sandstone of the Rocky Harbour Formation. In exposures on the peninsula separating the Northwest and Southwest Arms of Random Sound, the attitude of the crossbeds in the flat-lying Rocky Harbour sandstones indicates an eastward-flowing current direction at the time of deposition. Crossbedding is likewise well displayed in buff-green sandstones (which are believed to be part of the same Rocky Harbour Formation) on the south shore of the Northwest Arm of Alexander Bay and on the ridge west of Terra Nova River 8 miles south of Glovertown. In both of these localities, the attitude of the crossbeds indicates a direction of stream flow to the northeast. Crossbedding within other members of the Musgravetown Group is on a less pronounced

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scale. Crossbedding has also been observed in a few sandstone members of the Connecting Point Group on the shores of Newman Sound, in the Random quartzites in most exposures around Random Sound, and in a few sandy members of the Gander Lake Group.

Ripple-marks are well displayed in grey sandstones of the Halls Town Formation alongside the road just south of Caplin Cove, on Bay de Verde Peninsula. They are oscillation-type ripple-marks, with an orientation northwest-southeast, indicating wind direction at the time of formation in a northeast-southwest direction. Ripple-marks have also been observed in red sandstones of the Musgravetown Group at the mouth of the Northwest River in Clode Sound. They have not been observed in rocks of the other major groups in the two map-areas.

Orogenic History

Structural observations recorded on the preceding pages permit a few remarks on the times of tectonic activities in the two map-areas. Field evidences indicate that three and probably four important periods of deformation have occurred in the map-areas, two of which were in Precambrian times and two during the Palæozoic Era.

The oldest deformation occurred between Love Cove and Connecting Point times and is clearly marked in most localities by the regionally higher metamorphic grade and probable greater structural complexity of the Love Cove rocks, even though rocks of these two great stratigraphic units are not in juxtaposition. Most of the evidence that would provide an insight into the nature of this earliest-known Precambrian orogeny has been obscured or obliterated by the later orogenies. The development of the greenschist facies of metamorphism in the Love Cove rocks, however, is regarded as of pre-Connecting Point age. Certainly it was pre-Musgravetown age, for fragments of schist similar to rock types in the Love Cove Group occur in basal Musgravetown conglomerates in Clode Sound.

The second major deformation took place towards the end of Connecting Point time (perhaps extending into early Musgravetown time). This is indicated by the pronounced angular unconformity on Southward Head between rocks of these two groups, by the coarse basal conglomerate of the Musgravetown group (which includes fragments of many types of Connecting Point rocks), by differences in fold-axes trends and structural complexity in the two groups, and by the widespread occurrence of basic dykes in the Connecting Point rocks and not in Musgravetown or younger rocks. Yet most of this evidence is localized within 20 miles of the village of Musgravetown. Beyond this there are no known basal conglomerates, and no established angular unconformities or significant structural discordances between the two rock groups. It may well be, therefore, that the deformation at the end of Connecting Point time, though intense, was of a local or areally restricted nature.

The next major period of deformation in the two map-areas post-dates the deposition of Lower Ordovician rocks in Bonavista map-area and the Middle Ordovician Gander Lake Group in Terra Nova map-area. All rocks in Bonavista

map-area, from the late Precambrian Musgravetown Group to the Lower Ordovician, were deformed together by forces acting in a northwest-southeast direction, resulting in the pronounced north-northeasterly trend of the fold axes of these rocks, together with local overturning to the east around Clarenville and to the west near Hickmans Harbour. This north-northeasterly trend is present also to the south and southeast across Avalon Peninsula. Rocks of the Middle Ordovician Gander Lake Group were also strongly folded by forces acting in a generally northwest-southeast direction, but this deformation was accompanied or followed by the intrusion of concordant bodies of ultrabasic rocks prior to the intrusion of the Devonian Ackley granite batholith, for the ultrabasic rocks have been metamorphosed by the granite. In the absence of evidence to the contrary, it is suggested that this deformation and the intrusion of ultrabasic rocks occurred between Middle Ordovician and early Silurian times, corresponding to the Taconic orogeny farther southwest in New England.

Subsequently the rocks of the Gander Lake Group underwent regional metamorphism, and contact metamorphism by the intrusion of large masses of granitic material. The granitic rocks so developed extend from the north to the south coast of Newfoundland, but have intruded or otherwise affected only rocks of the Gander Lake, Musgravetown, and Love Cove Groups in the two map-areas. These granitic rocks are 365 ± 15 m.y. old[1], thus Middle to Late Devonian in age. Many of the faults in Bonavista map-area may have developed during the period of granitic intrusion, but at least a few are post-granite in origin. The intrusion of the granites may have been accompanied by local warping of the pre-existing folds in the Gander Lake Group, thereby producing the steep plunges recorded locally within parts of that group.

[1] Potassium-argon dating on micas.

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Chapter VI

ECONOMIC GEOLOGY

There is at present no mining of metallic minerals in either Terra Nova or Bonavista map-areas. Only one mineral deposit has been developed, the Workington Iron Mine in the extreme southeast corner of Bonavista map-area, and it did not get beyond the exploratory stage. The limited size of known metallic mineral showings, together with the scarcity of signs of mineralization, make it appear unlikely that a flourishing metallic mineral industry can be anticipated in either of the two map-areas.

The possibilities of an expansion of the non-metallic mineral industry appear somewhat brighter. Several such industries were in operation in 1957 (when field investigations by the writer were completed) making use chiefly of the extensive deposits of glacial material for construction purposes. The market for these is as yet very limited in Newfoundland, but with an expansion in the size of communities and in the number of roads, demand for them should increase. Heretofore the discovery of such deposits has been largely fortuitous. It is hoped, however, that this report will help to guide the future search for similar deposits.

Although channelways for mineralizing solutions abound today in most of the rocks in the two map-areas, and large bodies of granite have intruded many of the stratigraphic units throughout Terra Nova map-area, indications of mineralization are exceedingly scarce. Quartz veins are plentiful, but most are barren. Sulphides occur in minor amounts in a few places, but are almost totally absent over large parts of both map-areas. Occurrences of sulphide minerals are more numerous west of the Ackley granite batholith than east of it, which suggests that the west side offers more hope for the discovery of deposits of consequence. Only base metal sulphide deposits have been observed. Pegmatites south and west of Freshwater Bay are of the simple quartz-feldspar type and offer little hope of commercial possibilities. However, crystals of black tourmaline and red garnet have been seen in small pegmatites along Freshwater Bay, suggesting the possibility of other more interesting pegmatite minerals farther north.

Independent prospecting by individuals in the two map-areas has been almost non-existent during the past few years, as much of the land has been under concession to mining or development companies. Since 1957, however, a few large tracts of land have been released for public staking, particularly in Bonavista map-area, so that private investigations may increase.

Description of Properties and Mineral Occurrences

Metallic Mineral Deposits

Copper

References: Christie, A. M.: Geology of Bonavista map-area, Newfoundland; Geol. Surv., Canada, Paper 50-7 (1950).
Murray, Alexander: Report of the Geological Survey of Newfoundland for the years 1864-1880; Ed. Stanford, London (1881).
Snelgrove, A. M., and Baird, D. M.: Mines and Mineral Resources of Newfoundland; Geol. Surv., Newfoundland, Inf. Circ. 4 (revised edn.) (1953).

Three small occurrences of chalcopyrite, none of economic value, have been observed by the writer. Two of these are in Bonavista map-area, and were reported for the first time by Christie (1950). In one of these, small amounts of chalcopyrite accompany quartz crystals in a joint plane in the westernmost band of Random quartzite on the south shore of Random Sound opposite Hickmans Harbour. In the second occurrence small amounts of chalcopyrite are associated with quartz and chlorite in a narrow fault zone at the northeast end of Pitt Sound Island. The fault strikes N10°E, and dips 75°-80°W, and is marked by a shatter zone 2 to 3 feet wide in much fractured andesitic lava of the Love Cove Group. The quartz veins along the fault zone are only a few inches wide and extend about 10 feet into the side of the cliff, where they have been blasted. The chalcopyrite occurs chiefly in the chloritic gouge and in the wall-rock. Christie (1950) reported the presence of bornite and calcite in this occurrence.

The only copper minerals seen by the writer in Terra Nova map-area were in a small abandoned test pit on the east shore of Terra Nova River, a mile south of Glovertown (Jenness, 1958b). Small patches of chalcopyrite accompanied by chlorite occur along a 2- to 3-foot wide quartz vein that cuts across the regional strike of the andesitic host rock. A prospect pit was sunk at this locality prior to 1869 (Murray, 1881), but the deposit was considered too small to be commercially attractive.

A small specimen of native copper with abraded and rounded corners was shown to the writer in 1955 by Mr. William Short of Deep Bight (5 miles south of Clarenville). The specimen was discovered on the side of a small gully on the Short property 25 to 30 years ago. Bedrock in the gully is a greenish grey, massive bedded, cherty quartzite of the Connecting Point Group. It shows no sign of mineralization and few fractures or joints. The specimen may, therefore, have been in the glacial deposits that lie on the sides of the gully, and which were brought to their present position from the west. The only known occurrence of native copper in eastern Newfoundland is on Oderin Island in Placentia Bay, where the copper is present as amygdules or small sheets in basic lava flows, supposedly of Harbour Main affiliation (Baird, 1953).

Lead-Zinc

References: Hayes, A. O.: Geology of the Area between Bonavista and Trinity Bays, Eastern Newfoundland; Geol. Surv., Newfoundland, Bull. 32, pt. 1, p. 26 (1948).
Snelgrove, A. K., and Baird, D. M.: Mines and Mineral Resources of Newfoundland; Geol. Surv., Newfoundland, Inf. Circ. 4 (revised edn.) (1953).
Wiseman, R.: Bloomfield, Bonavista Bay, lead, zinc, prospect; unpub. report, Geol. Surv., Newfoundland (1942).

Galena has been observed at three places in Bonavista map-area, and at one in Terra Nova map-area. Two of the showings are accompanied by sphalerite. None appears to be of economic importance.

Christie (1950) reported on two of the occurrences in Bonavista map-area, of which the better exposed lies about ½ mile northwest of Hatchet Cove (Southwest Arm of Random Sound) on the south side of a small pond. His description of this prospect follows:

> A scarp here strikes south 80 degrees east and is visible as a lineament in air photographs for a mile on each side of the pond. This scarp is the surface expression of a fracture or fault. South of the pond is a vein about 1 inch thick consisting of almost solid galena, with little calcite. The vein strikes north, dips nearly vertically, and is well exposed for 50 feet in an adit driven southward into the cliff. The vein is continuous for this distance, and shows at the end of the drift. The wall-rock is a fine-grained massive flow or intrusion of andesitic composition. Seven hundred feet to the east along the scarp a 1 inch vein of almost pure galena is exposed in the cliff, and has the same strike and dip as the other vein. These narrow and fairly continuous veins appear to be in tension fractures related to the fault or fracture. A similar lineament striking south eighty degrees east occurs 4,000 feet to the north.

A second occurrence of galena reported by Christie is in a vein on the east side of the village of Bloomfield, in Goose Bay. Hayes (1948) earlier had described the vein and its host rock, and mentioned the existence of a prospect pit, which is now filled with water and debris. The vein appears on the shore, where it strikes approximately N35°E and dips 75°W. It lies along a narrow shear zone in a grey, porphyritic basic dyke, the strike of which coincides with that of the vein. The dyke is roughly parallel with the strike of adjoining red conglomerate of the Musgravetown Group, but dips in the opposite direction. The writer observed a small amount of galena, calcite, pyrite, and quartz localized within the most intensely sheared part of the dyke, for a length of 5 feet and a width of about 2 inches. The shear zone in this exposure is visible for about 25 feet at the shoreline, but the sulphides appear to be restricted to only a part of this length. The vein continues several hundred yards to the southwest, and contains some sphalerite accompanying the galena (Hayes, 1948). The deposit appears to be a replacement type confined to local pockets in a narrow brecciated fault zone. Selected specimens have yielded the following assay values (Snelgrove, 1953):

copper	0.31%
lead	3.7 %
zinc	9.99%
gold	0.005 oz/ton
silver	17.14 oz/ton

A third showing of galena occurs on the shore at Little Catalina, near Cape Bonavista. The sulphide there occurs in a quartz and carbonate vein 6 inches to 1 foot wide, but its abundance varies along the vein. The deposit was prospected by local persons several years ago, but was found undeserving of further work. The quartz veins trend in a northwest direction, making an acute angle with the north-northeast trend of the fold axis of the enclosing grey Musgravetown sandstones.

Only one occurrence of galena in Terra Nova map-area is known to the writer. This is a very small showing 1 mile south of the junction of Dead Wolf Brook and Southwest Gander River, on the side of an abandoned private road. The showing was discovered in 1955 by personnel of the Newfoundland and Labrador Corporation (NALCO), who subsequently did some diamond drilling in the immediate vicinity. The sulphide minerals are sphalerite and galena, which occur in small en échelon gash openings in a 5-foot wide quartz vein, with limonitic boxworks marking the former position of the sulphides at the surface. The vein strikes N55°E and dips 70°W, and is flanked on the east by a large body of leucogranite, on the west by a small body of schistose pyroxenite and metamorphosed Gander Lake sediments. The deposit appears to be of very limited extent.

Iron

References: Howland, A. L.: Precambrian Iron Ores of Southeastern Newfoundland; unpub. report, Geol. Surv., Newfoundland (1938).
Jenness, S. E.: Geology of the Newman Sound map-area, Northeast Newfoundland; Geol. Surv., Newfoundland, Report 12 (1958).
Snelgrove, A. K., and Baird, D. M.: Mines and Mineral Resources of Newfoundland; Geol. Surv., Newfoundland, Inf. Circ. 4 (revised edn.) (1953).
Geol. Surv., Newfoundland, Reports for 1898, 1899, 1904, 1926, 1929.

Two small occurrences of iron oxide are known in the map-areas. The principal one is the Workington iron prospect near Lower Island Cove in the southeast corner of Bonavista map-area. This deposit occurs within the Halls Town Formation of the Late Precambrian Hodgewater Group. The mineralized zone is not now exposed, but according to Howland (1938) occurred as "a vein with a steep dip and a maximum width of 7 feet" wherein the red hematite and goethite occur in large lumps "up to 2 or 3 feet in diameter, with stalactitic (and colloform) structures". An average sample of dump ore yielded 60.37 per cent iron, with almost no phosphorus and sulphur (Snelgrove, 1953). The deposit was prospected in 1898, when the Newfoundland Iron Ore Company sank seven prospect shafts, ranging from 40 to 170 feet deep, in an attempt to recover the rich red hematite. Operations ceased the following year when the company exhausted its funds in the erection of surface facilities and a 7-mile railway to the coast. At the time of the writer's visit (1957) only a small amount of dump ore, water-filled pits, and the outlines of the former foundations of buildings were to be seen. Despite the occurrence of hematite float for many miles to the southwest, the mode of occurrence of the hematite at Workington does not favour a deposit of commercial size. Early interest in the showing was undoubtedly influenced by the nearby occurrence of the well-bedded, Ordovi-

cian iron ores at Wabana. Far from being a bedded deposit, however, the Workington iron oxide is merely a local fracture filling in the Halls Town Formation, which is a subgreywacke facies not favourable to the occurrence of widespread sedimentary iron-formation.

Hematite stains are widespread in acidic and basic Musgravetown volcanic rocks just west of Bread Cove in Clode Sound (Jenness, 1958). A small local concentration of hematite was observed in a boulder on the side of a ridge parallel with the shore, a mile west of Bread Cove. The boulder contained an 8-inch breccia zone, consisting of angular fragments of acidic lava embedded in a hematite matrix, which in places is ½ inch thick. The boulder probably came from a part of the ridge immediately to the west where similar acidic lavas are exposed. As hematite also occurs as amygdules in nearby basic lavas and is widely disseminated through the matrices and groundmass accompanying both sediments and lavas, it probably originated during early Musgravetown volcanic activity. As in the case of the Workington deposit no appreciable quantity of iron oxide is likely to be present here.

A dull brown "limonite" stain coats many of the tight fractures in the acidic volcanic rocks in the hills on the north side of Bread Cove Pond, giving the rocks a deep brown surface colour.

Manganese

References: Dale, N. E.: The Cambrian Manganese Deposits of Conception and Trinity Bays, Newfoundland; Am. Philos. Soc. Proc., vol. 54, pp. 371-456 (1915).
Hayes, A. O.: Geology of the Area between Bonavista and Trinity Bays, Eastern Newfoundland; Geol. Surv., Newfoundland, Bull. 32, Pt. 1, pp. 26-29 (1948).
Mattinson, C. R.: Manganiferous and Calcareous Sediments at Broad Cove, Trinity Bay, Newfoundland; unpub. B.Sc. Thesis, Queen's University, Kingston, Ontario (1950).

Manganese-bearing strata occur at the palæontological boundary between Lower and Middle Cambrian rocks in shore exposures along the east side of the western basin of Cambro-Ordovician rocks, and the west side of the central basin of Cambro-Ordovician rocks in the Smith Sound area. In addition some manganiferous limestone is present in a thin band in the Lower Cambrian strata at Smith Point in Smith Sound. These occurrences have been described in some detail by Dale (1915) and Mattinson (1950). The manganese is generally present as a very fine pinkish or greenish FeCaMn-carbonate, which on the surface weathers to a soft black oxide. Although the manganese oxide band at the base of the Middle Cambrian rocks occurs in several shoreline exposures in the Clarenville region as well as in various other localities around the major bays on Avalon Peninsula, it is nowhere more than a few inches thick, a factor that renders economic exploitation unfeasible at the present time.

Soft mucky bog manganese reportedly occurs at the outlet of Lake St. John and along Gambo River, where it forms a coating on boulders and locally fills the spaces between them (Hayes, 1948).

Gold and Silver

References: Murray, Alexander, and Howley, J. P.: Reports of the Geological Survey of Newfoundland from 1864 to 1880; Ed. Stanford, London (1881).
Reports of the Geological Survey of Newfoundland from 1881 to 1909; St. Johns, Newfoundland (1918).

In 1894 Howley reported traces of gold in a quartz vein cutting the silky, bluish slates on the southwest branch of Gander River (Murray, 1918, p. 307), and suggested that quartz veins along the railway from Thorburn Lake (just south of Clode Sound) to Gander Lake looked promising. The writer has found that the quartz veins throughout this eastern part of Terra Nova map-area are quite barren, notwithstanding their proximity to intrusive granites. It is suggested, however, that the region *west* of the granites appears to be mineralogically more hopeful, and the possible presence of gold, as Howley reported, cannot be overlooked. None was seen during the present studies, although most quartz veins were carefully examined.

Murray (1881, pp. 195-196) also reported the presence of a trace of gold in an analysis of arsenopyrite from a quartz-carbonate vein on one of the Inner Gooseberry Islands. This same analysis included a report of 2.72 ounces per ton of silver.

The occurrence of silver in the lead-zinc mineralized zone at Bloomfield has already been mentioned.

Non-Metallic Mineral Deposits

Crushed Stone

At Gander, the McNamara Construction Company of Toronto, Ontario, operated[1] a stone crushing plant capable of producing over 300,000 tons of crushed stone product annually. The stone used was from the lower part of the Gander Lake Group, and consisted of grey slates and feldspathic quartzites, thinly bedded, flat-lying, locally faulted, and considerably shattered (as seen on the quarry walls). Production was dependent on the demands of the International Airport at Gander, and quarrying ceased seasonally when the annual quota was reached. Quarrying was carried on between May and November of each year. The stone was drilled, blasted, and processed through a crusher and screens, ultimately being sorted into three sizes—6-inch or greater for runway fill, 3-inch minus for rough fill, and ½-inch for preparation of concrete for the airport runways. Only a small amount of fine dust, which invariably develops during the crushing of the rock, was wasted in processing. Reserves are limited only by property restrictions on the surface, and by the depth below which recovery ceases to be economically feasible. The principal control of the operation was the limited market for the product.

[1] In 1957, when the writer completed field investigations in the Gander area.

The company also operated an asphalt plant at Gander for the production of surfacing for runways. Operation in 1957 was 450 tons per day, with a maximum quota of approximately 12,000 tons for the year. This plant utilized the crushed stone from the stone quarry. It is expected to supply the asphalt needs of the Trans-Canada Highway in the Gander region.

The Canadian National Railways has utilized crushed stone for railroad ballast from a stone quarry at Gleneagles, on the east shore of Gander River 1½ miles south of the railway bridge at Glenwood. The material is chiefly silty black slate, locally graphitic and pyritiferous, and belongs to the upper part of the Gander Lake Group. Ordovician graptolites have been recovered from the southern end of the quarry.

A small quarry alongside the Canadian National Railways tracks just west of Benton was operated in the late 1930's and early 1940's to supply material for the construction of runways and hangars at Gander. The quarry has not been used since 1942 and is largely overgrown with shrubs. The rock quarried was a greenish grey to black, impure feldspathic quartzite (or greywacke) from the lower part of the Gander Lake Group.

Sand and Gravel

References: Carr, G. F.: Industrial Minerals of Newfoundland; Mines Branch Report 855, Dept. Mines and Tech. Surveys, Ottawa, pp. 126-129 (1958).
Hayes, A. O.: Geology of the Area between Bonavista and Trinity Bays, Eastern Newfoundland; Geol. Surv., Newfoundland, Bull. 32, Pt. 1, p. 26 (1948).

Deposits of sand and gravel, chiefly of glaciofluvial origin, have been utilized at several places along the Trans-Canada Highway. Most of them were developed for local road construction only, but two quarries have supplied construction materials for the town and airport at Gander, and one at Shoal Harbour has yielded aggregate for the manufacture of concrete pipes and culverts for roads.

The largest[1] quarry was located between the highway and the railway 3 miles southeast of Gambo; it was locally known as Grant's Siding quarry. Operated by Concrete Products (Newfoundland) Ltd., a subsidiary of McNamara Construction Company, the quarry yielded sized sands for shipment to Gander to be used in the preparation of concrete for the airport runways, and for the manufacture of concrete blocks, pipes, etc., for use in the company's extensive construction works. The operation thus was controlled by the demands of the airport and town of Gander. The sand and gravel that supplied the initial material to the company's screens form part of a broad band of outwash material that has been traced discontinuously eastward from Gambo Pond to the Northwest Arm of Alexander Bay. Reserves are large, for the surface extent of the deposit at this locality is several acres, and the outwash has a depth of more than 20 feet. The proximity to the railroad tracks and the Trans-Canada Highway provides a ready means of transport. A considerable tonnage of gravel from this quarry was used as fill and surfacing during the construction of the Trans-Canada Highway in 1956.

[1] When the writer completed the field investigations in 1957.

A second quarry, with a smaller production, occurs alongside the highway at the east end of Gander Lake. It was opened up following accidental discovery in 1955 and was owned and operated by John Denty and Sons under the name Quarry Material Company of Gander. The sands and gravels there, like those at Grant's Siding, are outwash material, traceable from Gander Lake southeastward into Freshwater Bay near Gambo. The deposits that were being quarried at the time of the writer's visit in 1957, were perched on the north side of a small stream valley; similar deposits occurred on the south side but had not been utilized. Although outwash once apparently filled the stream valley to a height of 70 feet at this locality, subsequent stream erosion evidently removed all but the small residuals on each side of the valley. The residual deposits thus were relatively small in volume, roughly wedge-shaped in section, and of irregular width. Maximum thickness appeared to be about 30 feet, with the deposits thinning into the hillsides. The sands and gravels were mechanically crushed (to reduce the few boulders to smaller size) and coarse screened. Two sizes of material were produced; the coarse material was sold for crushed stone, and the finer material was sold as concrete sands. The company shipped 40,000 tons of product by truck to Gander in 1956 for use in the construction of the townsite. Reserves are somewhat limited by the irregular type and nature of the deposit.

Several gravel deposits were formerly quarried along the railway to supply railroad ballast. Pits were opened in outwash deposits at Butts Pond (north of Gambo) and in Shoal Harbour River valley. A gravel pit almost 100 feet thick that flanks the railroad tracks at Gambo also supplied many tons of material for railroad maintenance.

Eskers have been utilized locally for road construction by the Anglo-Newfoundland Development Company. Their road west of Gambo follows along the crest of an esker for several miles between Masons Pond and North Pond, and their road west of Terra Nova utilizes esker material along the south side of Terra Nova Lake and at the west end of Lake St. John.

Because of the abundance of gravelly material throughout much of the two map-areas, local road needs are fairly easily met, with the result that production from individual gravel pits is small. As the population increases and the demand for construction sands and gravels increases correspondingly, it is probable that some of these small pits may develop into larger operations, particularly those pits in glacial outwash along the various valleys leading into Bonavista Bay (*see* Figure 4).

Brick Clays and Shales

References: Carr, G. F.: Industrial Minerals of Newfoundland; Mines Branch Report 855, Dept. Mines and Tech. Surveys, Ottawa, pp. 42-46 (1958).

Hayes, A. O.: Geology of the Area between Bonavista and Trinity Bays, Eastern Newfoundland; Geol. Surv., Newfoundland, Bull. 32, Pt. 1, pp. 26-28 (1948).

Matthews, S.: Preliminary Test Data on Clays and Shales from Pelly's Brickyard and Vicinity, Newfoundland; unpub. rept. Ceramic Section, Ind. Min. Div., Mines Branch, Dept. Mines and Tech. Surveys, Ottawa, January 30, 1951.

Matthews, S., and Shonk, R. A.: A New Shale for Structural Clay Products in Newfoundland; unpub. rept., Investigation No. 36440, Ceramic Section, Ind. Min. Div., Mines Branch, Dept. Mines and Tech. Surveys, Ottawa, May 15, 1952.

Lower Ordovician grey shales at the northwest end of Random Island were being utilized (at the time of the writer's visit in 1957) for the production of dry-press face brick at the C. and M. Pelly Limited brick plant (locally known as Pelly's Brickyard) at Milton, about 6 miles north of Clarenville. Brick manufacture commenced in 1886, using varved clays near the mouth of Georges Brook for raw material, common brick made by the soft mud process being the product. In 1954, following tests made by the Ceramic Section of the Mines Branch, Department of Mines and Technical Surveys, Ottawa, the plant changed over to make dry-press brick from shale, utilizing the well-shattered shale from a pit alongside the road on Random Island. The plant was (in 1959) the only brick producer on the Island of Newfoundland. In 1957 the owners commenced a modernization of the plant. This was completed in mid-summer of 1958, and the plant was then capable of meeting the demands of the province for brick, with an ultimate production potential of about 100,000 bricks per week. Demand, however, was far below this figure, and the 1956 annual production was just under 1 million bricks. As shown on Figure 6, the Lower Ordovician shales, which provide the raw material for the brick plant, are fairly extensive both on Random Island and farther north, so that reserves are nearly unlimited. In 1957, production came from a shale quarry at the northwest tip of the island. Tests by the Mines Branch, however, show that the Lower Ordovician shales at the mouth of Ryders Brook (the northern continuation of the same biostratigraphic unit as that being quarried) are equally suitable; indeed this material ranks "well above the average in materials generally used in Canada for the production of structural products" (Matthews, S., and Shonk, R. A., 1952, p. 5). The quarry was under lease from the British Newfoundland Company, who held the mineral rights to much of the surrounding area.

Several other brick manufacturing plants have operated in the Smith Sound and Random Island area. These were all small scale operations, and like early operations at the Pelly brickyard utilized surficial clayey deposits as raw material. The clays are actually interlayered sands, silts, and clays, with pronounced laminated structure. Plants were established near Harcourt on the north shore of Smith Sound, at Snooks Harbour on the south side of the same Sound, and at Elliotts Cove on Random Island. The Harcourt plant closed in 1920, that at Snooks Harbour in 1951, and the Elliotts Cove plant in 1904.

The varved clay deposits 2 miles northwest of Port Blandford, in the Northwest Arm of Clode Sound, have been examined as possible material for the production of structural clay products, but marketing demands have not merited development.

Slate

References: Carr, G. F.: Industrial Minerals of Newfoundland; Mines Branch Report 855, Dept. Mines and Tech. Surveys, Ottawa, pp. 135-137 (1958).
Gillars, Owen: Newfoundland Slate Quarries and Deposits; unpub. rept., Geol. Surv., Newfoundland, St. John's (1947).

Slates of the Lower Cambrian Bonavista Formation were quarried intermittently at four localities in the eastern Cambro-Ordovician basin of the Random Island region, between the years 1865 and 1909. These deposits, of greyish red

slate locally interbedded with light green slate, have been called "one of the finest slate deposits of the world" (Gillars, 1947). Similar Lower Cambrian slates occur in the small Cambrian basin at Keels. The largest quarry is on the north shore of Smith Sound, a mile west of Burn Point. The slates there comprise both limbs of an isoclinally folded syncline, plunging southwest and slightly overturned towards the west. Smaller quarries were opened at two closely spaced localities on the south shore of Random Island just east of Hickmans Harbour (known as the Winter and Allison quarries), and on the south shore opposite Hickmans Harbour, the smallest of the four, known as Grieves quarry. Production was mainly from the Smith Sound quarry during the years of operation, most of the product being shipped to England. All four quarries are conveniently located alongside tidewater, but present demands for slate have not merited their reopening.

Asbestos

A very small showing of asbestos occurs in an altered ultrabasic rock 1 mile south of the junction of Southwest Gander River and Dead Wolf Brook, just a few feet from the small lead-zinc showing mentioned on a previous page. Small veinlets ($\frac{1}{16}$ inch to $\frac{3}{16}$ inch wide) of cross-fibre asbestos occur in serpentine that lies along a 6-inch wide shear zone in pyroxenite. The asbestos veins are parallel with the direction of the narrow band of serpentine, both striking about N55°E, and dipping about 60°W. This strike corresponds with the direction of the schistosity observed in a pyroxenite body 100 yards to the west and probably marks the trend of a local fault. The asbestos appears to be restricted to an area of only a few inches. The pyroxenite is partly altered to actinolite and contains a few minute grains of chalcopyrite. The property was covered by a mineral claim at the time of the writer's visit (1957).

Talc

Several small stringers of talc, up to $\frac{3}{4}$ inch wide, cut across a small body of serpentinite at the base of a ridge of pyroxenite on the south side of a sharp bend in Dead Wolf Brook, 0.4 mile above its mouth. The talc is brownish yellow, moderately coarse grained, and is apparently of very limited extent. The property was covered by a mineral claim at the time of the writer's visit (1957).

Graphite

References: Christie, A. M.: Geology of Bonavista map-area, Newfoundland; Geol. Surv., Canada, Paper 50-7 (1950).
McKillop, J. H.: Fair and False Bay Graphite Prospect; unpub. rept., Geol. Surv., Newfoundland (1952).

Christie (1950) reported an occurrence of graphite about half a mile southwest of Fair and False Bay in Bonavista Bay, over a width of 4 feet in graphitic shales along a fault zone. The writer has not seen the prospect, but its location would indicate that it lies along a probable fault separating lavas of the Mus-

gravetown Group (on the west side) from tuffaceous sediments of the Connecting Point Group on the east side. The occurrence is of little economic interest.

Limestone

Reference: McCartney, W. D.: Geology of Sunnyside map-area, Newfoundland; Geol. Surv., Canada, Paper 58-8 (1958).

Limestone is present in the rocks of Early Cambrian age in the two Cambro-Ordovician basins near Clarenville, where it comprises one 26-foot bed (the Smith Point Limestone) and several thinner overlying and underlying beds. It occurs chiefly as an easily recognized pinkish red massive variety, which has been recognized at 14 different localities in Bonavista map-area. The thickest sections occur at Smith Point on the northwest shore of Smith Sound, at Adeyton, and just west of Britannia on the north shore of Random Island. The limestone in these three exposures is about 26 feet thick, and includes the entire Smith Point Formation. The Adeyton bed is part of a small fault wedge and is not likely to continue inland for more than a few hundred feet. The bed at Smith Point (the type locality of the formation), however, appears to extend for several miles to the north, and the bed on Random Island has been traced half-way across the island. McCartney (1958) recently pointed out the possible economic value of the Smith Point Limestone for agricultural lime. Beds of similar-appearing pink limestone have been seen in eleven other places in Random and Smith Sounds, approximately equally divided between the Bonavista and the Brigus Formation below and above the Smith Point Limestone, respectively, but almost all of these limestone beds are only a few inches thick and are not regarded as economically interesting.

Granite

Reference: Carr, G. F.: The Granite Industry of Canada, Mines Branch, Dept. Mines and Tech. Surveys, Publication 846, pp. 22-31 (1958).

During the 1890's a small amount of granite was quarried at two places in the map-areas,—near Benton and near Shoal Harbour. In both places the blocks quarried were utilized for railway-bridge pier-and-abutment work. The granite quarried near Benton is light pink, coarse grained, and porphyritic, and is a variety typical of the marginal areas of the Ackley granite batholith. The granite in this small, now water-filled, quarry was evidently cut by rectangular joints, judging from the shape of the large granite blocks flanking the railway tracks near the quarry site. The number of blocks removed was small. The rock is regarded as suitable for building stone but unsuitable for monumental stone (Carr, 1955). The writer did not find the site near Shoal Harbour from which granite was reportedly quarried (Carr, 1955), but from the appearance of the granite blocks on the railway bridge 5½ miles northwest of Shoal Harbour the quarry was not in the dark red granite near Shoal Harbour and Clarenville but in the porphyritic granite along the railway between Clarenville and Northern Bight. No granite is at present being quarried in the map-areas. The extensive bodies of granitic rocks underlying much of Terra Nova map-area offer a vast reserve of building stone should a demand ever arise.

Water Power Resources

Reference: Water Powers of Canada; Water Res. Branch, Dept. of Northern Affairs and National Resources, Ottawa (1958).

Much of the two map-areas is without electricity, largely because of the scattered distribution of the population and the consequent lack of demand. Large communities, such as Gander and Clarenville, obtain their electricity mainly through the combustion of fuels; smaller communities with electricity obtain it from privately-owned, fuel-operated generators. In 1957 there were only three water driven power houses in the two map-areas, one on Lower Shoal Harbour River to supply a part of the needs of Clarenville, a second on Trinity Brook to supply the electrical demands of Trinity and several neighbouring villages, and the third at Port Union. Maximum power output of the Clarenville plant was only 165 H.P., of the Trinity plant 2,000 H.P., and of the Port Union plant 1,000 H.P.

During the mid-1950's consideration was given by the Newfoundland government to the diversion of the waters of Terra Nova River from Terra Nova Lake into Pitts Pond and thence to Clode Sound. Such a project would have provided a water drop of nearly 300 feet, capable of yielding several thousand horsepower of electricity. It would, however, have flooded the village of Terra Nova, several miles of railroad tracks and many acres of low-lying terrain around Terra Nova Lake and Pitts Pond.

The best potential power dam site in Terra Nova and Bonavista map-areas, and perhaps in all of eastern Newfoundland (east of Bay d'Espoir) occurs about 10 miles upstream from Terra Nova Lake, at the mouth of Mollyguajeck Lake. There the waters of Terra Nova River are funnelled along a narrow steep-walled, almost straight gorge, which culminates where the river flows over a 25- to 30-foot waterfall. Factors supporting its suitability are as follows:

1. Terra Nova River is the largest river and has the largest drainage basin in eastern Newfoundland east of Gander River, and has a much steeper gradient than that river.
2. Only a few minor streams enter Terra Nova River below this locality, so that much of the water that passes the railway bridge at Terra Nova comes from above the gorge.
3. The river flows along a natural gorge for almost a mile (*see* Plate XIII), within which it falls almost 70 feet. A head of 70 feet could thus be obtained, without affecting the river above the gorge, by the construction of a dam at the eastern end of the gorge.
4. Bedrock is exposed on both sides of the gorge and consists of a hard, seemingly impermeable biotite-quartz paragneiss, striking obliquely across the gorge and dipping very steeply to the west. This rock should be satisfactory for dam foundation purposes.
5. Mollyguajeck Lake, at the upstream end of the gorge, is a natural catchment basin, the level of which could be raised without appreciable land flooding if a small saddle on its south side was dammed.

6. A private pulp and paper company road from the town of Terra Nova passes within 3 miles of the gorge, making access fairly easy.
7. The power potential of this site is about 6,000 H.P. at ordinary six months flow.[1]

Waterfalls of 25 and 40 feet occur between Terra Nova village and the mouth of Terra Nova River. In these two sites, however, the river valley is so much broader than at the gorge by Mollyguajeck Lake that damming without widespread flooding is virtually impossible. Waterfalls occur on other rivers and streams in eastern Newfoundland, but the quantity of water available is insufficient in most instances for commercial consideration.

[1] Data provided by the Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa, November, 1960.

REFERENCES

American Commission on Stratigraphic Nomenclature

1961: Code of Stratigraphic Nomenclature; *Bull. Am. Assoc. Petrol. Geol.*, vol. 45, pp. 645-665

Bradley, D. A.

1962: Geology of the Gisborne Lake-Terrenceville Map-Areas, Newfoundland; *Geol. Surv., Canada,* Mem. 321.

Buddington, A. F.

1919: Pre-Cambrian Rocks of Southeast Newfoundland; *J. Geology,* vol. 27, pp. 449-479.

Christie, A. M.

1950: Geology of Bonavista Map-Area, Newfoundland; *Geol. Surv., Canada,* Paper 50-7

Cormack, W. E.

1824: Account of a Journey Across the Island of Newfoundland; *Edinburgh Phil.* J., vol. 10, pp. 156-162.

Crosby, D. G.

1962: Wolfville Map-Area, Nova Scotia; *Geol. Surv., Canada,* Mem. 325.

Dale, N. C.

1915: The Cambrian Manganese Deposits of Conception and Trinity Bays, Newfoundland; *Am. Phil. Soc. Proc.,* vol. 54, pp. 371-456.

Fairbairn, H. W., Hurley, P. M., Pinson, W. H. Jr., and Cormier, R. F.

1960: Age of the Granitic Rocks of Nova Scotia; *Bull. Geol. Soc. Amer.,* vol. 71, pp. 399-414.

Flint, R. F.

1957: Glacial and Pleistocene Geology; New York, John Wiley and Sons, Inc.

Hayes, A. O.

1948: Geology of the Area between Bonavista and Trinity Bays, Eastern Newfoundland; *Geol. Surv., Newfoundland,* Bull. 32, pt. 1.

Hess, H. H.

1949: Chemical Composition and Optical Properties of Common Clinopyroxenes; *Am. Mineralogist,* vol. 34, pp. 621-666.

Hess, H. H., and Phillips, A. H.

1940: Optical Properties and Chemical Composition of Magnesian Orthopyroxenes; *Am. Mineralogist,* vol. 25, pp. 271-285.

Heyl, G. R.

1936: Geology and Mineral Deposits of the Bay of Exploits Area; *Dept. Nat. Res., Geol. Sec., Newfoundland,* Bull. 3.

Howell, B. F.

1926: The Cambrian-Ordovician Stratigraphic Column in Southeastern Newfoundland; *Canadian Field-Naturalist,* vol. 40, pp. 52-57.

Hutchinson, R. D.

1953: Geology of Harbour Grace Map-Area, Newfoundland; *Geol. Surv., Canada,* Mem. 275.

1962: The Cambrian Stratigraphy and Trilobite faunas of Southeastern Newfoundland; *Geol. Surv., Canada,* Bull. 88.

Jenness, S. E.

1954: Geology of the Gander River Ultrabasic Belt, Newfoundland; unpub. Ph.D. dissertation, Yale Univ., New Haven.

60402-5—11

Jenness, S. E. (*cont'd.*)
1957: Gander Lake (East Half), Newfoundland; *Geol. Surv., Canada,* Map 3-1957 (with marginal notes).
1958a: Geology of the Gander River Ultrabasic Belt, Newfoundland; *Geol. Surv., Newfoundland,* Rept. 11.
1958b: Geology of the Newman Sound Map-Area, Northeastern Newfoundland; *Geol. Surv., Newfoundland,* Rept. 12.
1960: Late Pleistocene Glaciation of Eastern Newfoundland; *Bull. Geol. Soc. Amer.,* vol. 71, pp. 161-180.

Jewell, W. B.
1939: Geology and Mineral Deposits of the Baie d'Espoir Area; *Geol. Surv., Newfoundland,* Bull. 17.

Johannsen, Albert
1938: A Descriptive Petrography of the Igneous Rocks, vol. 4; Chicago, Univ. of Chicago Press.

Jukes, J. B.
1843: General Report of the Geological Survey of Newfoundland; John Murray, London.

Kuenen, Ph. H., and Sanders, J. E.
1956: Sedimentation Phenomena in Kulm and Flozleeres Greywackes, Sauerland and Oberhalz, Germany; *Am. J. Sci.,* vol. 254, pp. 649-671.

Livingstone, D. A., and Livingstone, B. G. R.
1958: Late-Glacial and Post-Glacial Vegetation from Gillis Lake in Richmond County, Cape Breton Island, Nova Scotia; *Am. J. Sci.,* vol. 256, pp. 341-359.

Lowdon, J. A.
1960: Age Determinations by the Geological Survey of Canada, Report 1, Isotopic Ages; *Geol. Surv., Canada,* Paper 60-17.
1961: Age Determinations by the Geological Survey of Canada, Report 2, Isotopic Ages; *Geol Surv., Canada,* Paper 61-17.

MacClintock, Paul, and Twenhofel, W. H.
1940: Wisconsin Glaciation of Newfoundland; *Bull. Geol. Soc. Amer.,* vol. 51, pp. 1729-1756.

Matthew, G. F.
1899a: The Etcheminian Fauna of Smith Sound, Newfoundland; *Prel. Trans. Roy. Soc., Canada,* vol. 5, pp. 97-119.
1899b: A Palæozoic Terrane Beneath the Cambrian; *N.Y. Acad. Sci.,* Annals, vol. 12, pp. 41-56.

McCartney, W. D.
1954: Holyrood Map-Area, Newfoundland; *Geol. Surv., Canada,* Prel. Map, Paper 54-3 (with marginal notes).
1956: Argentia, Newfoundland; *Geol. Surv., Canada,* Prel. Map, Paper 55-11 (with marginal notes).
1957: Dildo Map-Area, Newfoundland; *Geol. Surv., Canada,* Map 13-1956 (with marginal notes).
1958: Geology of Sunnyside Map-Area, Newfoundland; *Geol. Surv., Canada,* Paper 58-8.
In press: Geology of the Whitbourne Area, Newfoundland; *Geol. Surv., Canada,* Memoir.

Moore, T. H.
1953: Geology of the Garrison Hills Granite Contact East of Baie d'Espoir; *Geol. Surv., Newfoundland,* Report 3.

Murray, Alexander, and Howley, J. P.
1881: Geological Survey of Newfoundland, Reports for 1864 through 1880; London, Edward Stanford.

Neale, E. R. W.
1960: Kings Point, Newfoundland; *Geol. Surv., Canada,* Prel. Map 35-1960.

Olson, E. A., and Broecker, W. S.
1958: Lamont Natural Radiocarbon Measurements V; *Am. J. Sci.,* Radiocarbon Supplement, vol. 1, pp. 1-28.

Pettijohn, F. J.
1949: Sedimentary Rocks; New York, Harper and Brothers.
1957: Sedimentary Rocks, 2nd Ed.; New York, Harper and Brothers.

Read, H. H.
1957: The Granite Controversy; London, Thomas Murby and Co.

Rodgers, John, and Dunbar, C. O.
1957: Principles of Stratigraphy; New York, John Wiley and Sons.

Rose, E. R.
1948: Geology of the Area between Bonavista, Trinity, and Placentia Bays, Eastern Newfoundland; *Geol. Surv., Newfoundland,* Bull. 32, pt. 2.
1952: Torbay Map-Area, Newfoundland; *Geol. Surv., Canada,* Mem. 265.

Snelgrove, A. K.
1934: Chromite Deposits of Newfoundland; *Dept. Nat. Res., Geol. Soc., Newfoundland,* Bull. 1.
1938: Mines and Mineral Resources of Newfoundland; *Geol. Surv., Newfoundland,* Inf. Circ., No. 4.

Stevenson, I. M.
1959: Shubenacadie and Kennetcook Map-Areas, Colchester, Hants, and Halifax Counties, Nova Scotia; *Geol. Surv., Canada,* Mem. 302.

Tuttle, O. F., and Bowen, N. L.
1958: Origin of Granite in the Light of Experimental Studies in the System $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O; *Geol. Soc. Amer.,* Mem. 74.

Twenhofel, W. H.
1947: The Silurian of Eastern Newfoundland with some data relating to Physiography and Wisconsin Glaciation of Newfoundland; *Am. J. Sci.,* vol. 245, pp. 65-122.

Twenhofel, W. H., and MacClintock, Paul
1940: Surfaces of Newfoundland; *Bull. Geol. Soc. Amer.,* vol. 54, pp. 1665-1728.

Van Ingen, Gilbert.
1914: Table of the Geological Formations of the Cambrian and Ordovician Systems about Conception and Trinity Bays, Newfoundland, and their Northeastern American and Western European Equivalents, based upon the 1912-1913 Field Work; Broadside, Princeton, N.J. (priv. pub.) (reproduced in Hayes, A. O., 1948).

Walcott, C. D.
1900a: Random, a pre-Cambrian Upper Algonkian Terrane; *Bull. Geol. Soc. Amer.,* vol. 11, pp. 3-5.
1900b: Lower Cambrian Terrane in the Atlantic Province; *Wash. Acad. Sci. Proc.,* vol. 1, pp. 301-399.

Weeks, L. J.
1957: The Proterozoic of Eastern Canadian Appalachia; *in* The Proterozoic in Canada, J. E. Gill, *editor*; *Roy. Soc., Canada,* Spec. Pub. 2, pp. 141-149.

White, D. E.
1940: The Molybdenite Deposits of the Rencontre East Area, Newfoundland; *Econ. Geol.,* vol. 35, pp. 967-995.

Widmer, Kemble.
1949: Glovertown-Clode Sound Area, Newfoundland; unpub. geol. map, scale 1 inch to 1 mile, on file, *Geol. Surv., Canada.*
1950: Geology of the Hermitage Bay Area, Newfoundland; *Princeton Univ.,* unpub. Ph.D. dissertation.

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APPENDIX A

DATA ON THE ORIENTATIONS OF GLACIAL STRIATIONS AND GROOVES IN TERRA NOVA AND BONAVISTA MAP-AREAS

GLACIAL STRIATIONS AND GROOVES

Terra Nova Map-Area

No.	Orient'n	Striations	Grooves	Geog. Location Lat.	Geog. Location Long.	General Location	Reference Source[1]
1	S60°E	x		48°03.5′	54°02.5′	4 miles NW of Northern Bight station	JN1, p. 10½
2	N75°E		x	48°11′	54°10′	SW of Shoal Harbour Pond	FN, p. 4
3	S80°E		x	48°12.3′	54°03.5′	3 miles E of Shoal Harbour Pond	JN4, p. 14
4	N75°E	x		48°11.5′	54°07.5′	South shore Shoal Harbour Pond	JN4, p. 15
5	S85°E		x	48°06.5′	54°11′	South of Sleigh Pond	JN4, p. 21
6	S70°E		x	48°05′	54°05.5′	South of Tug Pond	JN4, p. 23
7	S70°E		x	48°05.5′	54°06′	South of Tug Pond	JN4, p. 22
8	S75°E		x	48°04.7′	54°10′	North of Black River Pond	JN4, p. 24
9	S75°E		x	48°03′	54°09.5′	NW arm of Black River Pond	JN4, p. 24½
10	S55°E		x	48°02.5′	54°09.5′	NW arm of Black River Pond	JN4, p. 24½
11	S60°E	x	x	48°01.5′	54°09′	West side, Black River Pond	JN4, p. 24½
12	S60°E	x	x	48°01′	54°09′	West side, Black River Pond	JN4, p. 24½
13	S75°E		x	48°04.5′	54°08.5′	Southeast of Frost Pond	JN4, p. 26½
14	S65°E		x	48°04.3′	54°30′	On brook NW of Whitehead Pond	JN4, p. 27½
15	S75°E		x	48°03.7′	54°25′	On Pipers Hole River	JN4, p. 29
16	N83°E	x		48°13′	54°28.5′	½ mile SE of Esker Pond	JN4, p. 33½
17	N90°E		x	48°12.6′	54°30.5′	South shore Esker Pond	JN4, p. 33
18	N90°E		x	48°12.5′	54°30.5′	½ mile S. of Esker Pond	JN4, p. 38
19	N70°E	x		48°23.5′	54°11′	NW arm of Clode Sound	JN1, p. 17
20	N80°E	x		48°16.4′	54°08.8′	East shore Thorburn Lake	JN1, p. 33
21	N80°E		x	48°16.3′	54°08.3′	East shore Thorburn Lake	JN1, p. 33
22	N80°E		x	48°16′	54°08.4′	East shore Thorburn Lake	JN1, p. 34
23	N80°E		x	48°16′	54°08.2′	East shore Thorburn Lake	JN1, p. 34
24	N80°E		x	48°15.8′	54°07.8′	East shore Thorburn Lake	JN1, p. 34
25	S70°E	x		48°23.5′	54°12′	Northwest River	JN1, p. 38
26	N85°E	x		48°24′	54°12.5′	Northwest River	JN1, p. 39
27	N70°E	x		48°28′	54°10′	Pitts Pond	JN2, p. 14½
28	N75°E	x	x	48°19′	54°15′	SE of Salmon Pond	JN5, p. 16½
29	N75°E	x	x	48°19.5′	54°14.5′	SE of Salmon Pond	JN5, p. 17
30	N65°E	x	x	48°21.5′	54°18.5′	Shore of Salmon Pond	JN2, p. 1
31	N75°E		x	48°21′	54°19′	Shore of Salmon Pond	JN2, p. 2
32	N75°E	x		48°20.5′	54°20′	Shore of Salmon Pond	JN2, p. 3
33	N75°E	x		48°24.4′	54°29.2′	On road 8 miles SW of Terra Nova L.	JN2, p. 12½
34	N75°E	x		48°24.4′	54°29.3′	On road 8 miles SW of Terra Nova L.	JN2, p. 12½
35	N80°E		x	48°16.5′	54°26′	West shore of Terra Nova Lake	JN4, p. 36½
36	N73°E	x	x	48°21.6′	54°17.7′	Island on NE side of Salmon Pond	JN5, p. 12
37	N75°E	x	x	48°21.5′	54°17.5′	NE shore of Salmon Pond	JN5, p. 12
38	N75°E		x	48°22′	54°17′	Island at E end of Salmon Pond	JN5, p. 12½
39	N78°E	x		48°22′	54°16.4′	East end of Salmon Pond	JN5, p. 13
40	N73°E	x		48°21.8′	54°16.8′	Small point near E end of Salmon Pd.	JN5, p. 13½
41	N75°E	x	x	48°21.7′	54°17.3′	Island near E. end of Salmon Pond	JN5, p. 12
42	N80°E	x	x	48°18.5′	54°24.5′	SW of Salmon Pond	JN5, p. 15
43	N83°E		x	48°22.3′	54°21.5′	NW of Salmon Pond	FN, p. 19
44	S80°E	x		48°18.5′	54°23.5′	SW of Salmon Pond	JN5, p. 15
45	N85°E	x	x	48°23.5′	54°17′	North of Salmon Pond	FN, p. 21
46	N83°E		x	48°22.5′	54°16.5′	North of Salmon Pond	FN, p. 21½
47	N85°E		x	48°20.5′	54°17′	SE of Salmon Pond	JN5, p. 16
48	N85°E	x		48°22′	54°43.5′	Road, ½ mile SW of L. St. John	JN2, p. 16
49	N75°E	x		48°22.5′	54°48′	Road, 3 miles W. of L. St. John	JN2, p. 17½
50	N90°E	x		48°23′	54°50.5′	Road at pond, 5 miles W. of L. St. John	JN2, p. 18
51	N83°E	x		48°42′	54°48.5′	Road at south end of Deer Pond	JN2, p. 19½
52	N85°E	x		48°25.5′	54°06.5′	N. shore Clode Sound by Narrows	JM

[1]Code to references is given at the end of Appendix A

No.	Orient'n	Striations	Grooves	Geog. Location Lat.	Geog. Location Long.	General Location	Reference Source
53	N80°E	x		48°28.5′	54°06′	N. shore of Dunphy's Pond	JM
54	N75°E	x		48°26.5′	54°02.5′	2 miles NW of Charlottetown	JM
55	N70°E	x		48°26′	54°01.5′	½ mile west of Charlottetown	JM
56	N70°E	x		48°28′	54°09.5′	Pitts Pond, east end	JM
57	N73°E	x		48°27.5′	54°09′	Pitts Pond, east end	JM
58	N80°E		x	48°25′	54°33′	4 miles ENE of L. St. John	JN5, p. 22
59	N75°E		x	48°26.3′	54°33′	4½ miles NE of L. St. John	JN5, p. 22½
60	N77°E		x	48°30.5′	54°28′	West of Georges Pond	JN5, p. 26
61	N85°E	x	x	48°29.7′	54°29′	West of Georges Pond	JN5, p. 26½
62	N78°E		x	48°29.5′	54°28.7′	West of Georges Pond	JN5, p. 27
63	N80°E		x	48°30.2′	54°27′	West of Georges Pond	JN5, p. 27
64	N80°E		x	48°28.7′	54°46′	South shore of Deer Pond	JN5, p. 28
65	N85°E		x	48°28.7′	54°45′	South shore of Deer Pond	JN5, p. 28
66	N75°E	x		48°29.5′	54°47′	NW shore of Deer Pond	JN5, p. 28½
67	N80°E		x	48°30.5′	54°52.5′	Road, west of Deer Pond	JN5, p. 30
68	N70°E		x	48°26.5′	54°47′	South of Deer Pond	JN5, p. 33
69	N75°E		x	48°26.5′	54°46′	South of Deer Pond	JN5, p. 33
70	N75°E	x		48°40.5′	54°07.5′	Shore of pond near Alexander Bay Stn.	KN2, p. 24½
71	N85°E	x		48°40.5′	54°07.5′	Shore of pond near Alexander Bay Stn.	KN2, p. 26½
72	N75°E	x		48°36′	54°19′	West shore of Rocky Pond	KN2, p. 28
73	N75°E	x		48°40.5′	54°11′	Shore of pond near Alexander Bay Stn.	KN2, p. 35½
74	N75°E	x		48°38′	54°28′	N. shore of Gambo Pond	KN3, p. 8
75	N85°E		x	48°24.5′	54°16.5′	S. shore of Northwest Pond	JN1, p. 21
76	S70°E		x	48°29.9′	54°21.4′	Shore of brook to Georges Pond	JN2, p. 7½
77	S70°E		x	48°30.1′	54°21.9′	E. end Georges Pond in brook	JN2, p. 7½
78	N90°E		x	48°30′	54°20.5′	NW shore Terra Nova Lake	JN2, p. 8
79	N80°E		x	48°30′	54°17′	Island, N. side of Terra Nova L.	JN2, p. 8
80	N75°E	x	x	48°30′	54°16′	Island, Terra Nova Lake	JN2, p. 9
81	N80°E	x?		48°30.3′	54°14′	Point near mouth of brook to Pitts Pond	JN2, p. 14
82	N75°E		x	48°33′	54°14′	Outcrop area on SE side Chain Pond	JN2, p. 21½
83	{N80°E, S60°E}		x	48°40.5′	54°07′	50 yds E. of Alexander Bay RR Stn	JN2, p. 24½
84	S70°E		x	48°38.5′	54°08′	⅕ mile W. of RR bridge, Maccles L.	JN2, p. 27
85	N80°E	x		48°38′	54°11′	North shore of Maccles Lake	JN2, p. 27½
86	S85°E		x	48°37.5′	54°12′	North shore of Maccles Lake	JN2, p. 28
87	N70°E		x	48°37.5′	54°15.5′	NW shore of Maccles Lake	JN2, p. 28½
88	N75°E	x		48°37′	54°17.5′	SW shore of Maccles Lake	JN2, p. 29
89	N80°E	x	x	48°36.5′	54°16′	SW shore of Maccles Lake	JN2, p. 29
90	N70°E		x	48°38.5′	54°13.5′	South shore of Maccles Lake	JN2, p. 29½
91	N75°E	x		48°36′	54°10.5′	SE shore of Maccles Lake	JN2, p. 30½
92	N80°E	x		48°36.5′	54°10′	N. shore, SW arm of Maccles Lake	JN2, p. 31
93	N80°E		x	48°36.5′	54°11.5′	SW tip of peninsula, Maccles Lake	JN2, p. 31
94	N75°E	x		48°36′	54°10′	SE shore of Maccles Lake	JN2, p. 30½
95	N80°E	x		48°41′	54°03.5′	1 mile west of Glovertown	JN2, p. 32½
96	N80°E	x		48°41.5′	54°04′	1½ miles west of Glovertown	JN2, p. 33
97	N90°E	x		48°41.5′	54°01.5′	NW shore of Alexander Bay	JN2, p. 36
98	N87°E	x		48°42′	54°01′	NW shore of Alexander Bay	JN2, p. 36
99	N75°E	x		48°44.3′	54°00′	S. shore, NW Arm Alexander Bay	JN2, p. 38
100	N90°E		x	48°44′	54°16′	On road, at bridge over Mint Brook	JN3, p. 5½
101	N90°E		x	48°44′	54°06′	NE of Alexander Bay station	JN4, p. 4
102	S50°E		x	48°17.5′	54°55.5′	SE shore of Kepenkeck Lake	JN5, p. 1
103	S70°E		x	48°18′	54°53′	E. shore of Kepenkeck Lake	JN5, p. 2

No.	Orient'n	Striations	Grooves	Geog. Location Lat.	Geog. Location Long.	General Location	Reference Source
104	S85°E	x	x	48°18.5′	54°52′	E. shore of Kepenkeck Lake	JN5, p. 3
105	S85°E		x	48°19′	54°51.5′	E. shore of Kepenkeck Lake	JN5, p. 3½
106	N73°E		x	48°21.3′	54°35′	W. of Mollyguajeck Lake on river	JN5, p. 10
107	N85°E		x?	48°21′	54°35′	Terra Nova R., W. side Mollyguajeck L.	JN5, p. 9½
108	S70°E		x?	48°20′	54°31.5′	⅔ mile SE of Mollyguajeck Lake	JN5, p. 8½
109	S45°E	x	x	48°21.5′	54°30.5′	NW of Mollyguajeck L. at dam	JN5, p. 11
110	N80°E		x	48°44.3′	54°07.5′	2½ miles W. of NW Arm, Alexander Bay	JN4, p. 8½
111	N80°E	x	x	48°44.5′	54°05.5′	2 miles W of NW Arm Alexander Bay	JN4, p. 8½
112	N90°E		x	48°40.7′	54°54′	Road, NE of Caribou Lake	JN5, p. 43
113	S85°E		x	48°39.7′	54°56.5′	Ridge, NE of Caribou Lake	JN5, p. 44
114	S75°E	x		48°50′	54°05.5′	On shore of pond	KN3, p. 1
115	N70°E	x		48°51′	54°07.5′	Shore of pond	KN3, p. 1½
116	N80°E		x	48°47.5′	54°13′	Gambo	JN2, p. 41
117	N90°E	x		48°50′	54°06.5′	Road south of pond	JN2, p. 42
118	N85°E	x		48°49′	54°02.5′	South shore of Freshwater Bay	JN2, p. 46
119	N70°E	x		48°48.5′	54°06′	Doctors Island, Freshwater Bay	JN2, p. 46½
120	N80°E		x	48°48′	54°06.5′	South shore of Freshwater Bay	JN2, p. 47
121	N90°E		x	48°48′	54°09′	West end of Air Island, Freshwater B.	JN3, p. 1
122	N85°E		x	48°50′	54°04′	North shore of Freshwater Bay	JN3, p. 2½
123	N90°E	x		48°49′	54°07′	North shore of Freshwater Bay	JN3, p. 3½
124	N80°E	x	x	48°49′	54°08.5′	North shore of Freshwater Bay	JN3, p. 4
125	N90°E	x		48°48.5′	54°11′	North shore of Freshwater Bay	JN3, p. 4
126	N80°E	x		48°48′	54°15.5′	E. shore of Square Pond	JN3, p. 6
127	N75°E	x		48°47.5′	54°16.5′	E. shore of Square Pond	JN3, p. 6
128	N80°E	x		48°46.5′	54°17.5′	SE shore of Square Pond	JN3, p. 6½
129	N78°E, S70°E	x		48°47′	54°18.5′	Small island, W side of Square Pond	JN3, p. 6½
130	N78°E, S75°E	x		48°47.5′	54°18′	West shore of Square Pond	JN3, p. 7
131	N80°E	x		48°43′	54°19′	Road west of Gambo to North Pond	JN3, p. 12
132	N75°E	x		48°41.5′	54°35′	Road SW of North Pond	JN3, p. 12½
133	N90°E		x	48°52′	54°01′	North of Hare Bay village	JN4, p. 6
134	S85°E		x	48°52′	54°01.5′	Northwest of Hare Bay village	JN4, p. 6½
135	N85°E		x	48°48.5′	54°42′	SW end of Rodney Pond	FN, p. 32½
136	N75°E		x	48°30.7′	54°17.5′	N. of Terra Nova Lake	JN5, p. 19
137	S70°E		x	48°57.5′	54°15′	SE end of Home Pond	JN5, p. 36
138	S77°E		x	48°59′	54°23′	NW shore of Home Pond	JN5, p. 37
139	S85°E	x		48°58′	54°18.5′	West shore of Home Pond	JN5, p. 37½
140	S80°E	x		48°57.5′	54°18′	West shore of Home Pond	JN5, p. 37½
141	S70°E		x	48°55.5′	54°14.5′	West side of Gull Pond	JN5, p. 38
142	N90°E	x		48°55.5′	54°13.5′	SW side of Gull Pond	JN5, p. 39
143	N90°E	x		48°56.5′	54°06.5′	West end of Fox Pond	JN5, p. 40½
144	S70°E	x		48°57.1′	54°31.8′	Road northeast of Gander	JN6, p. 1½
145	S85°E	x		48°55.5′	54°31.5′	East shore of Deadmans Pond	JN6, p. 5
146	S75°E	x	x	48°55.4′	54°31.5′	East shore of Deadmans Pond	JN6, p. 5
147	S85°E	x		48°52.8′	54°25.1′	Northeast shore of Gander Lake	JN6, p. 7½
148	S85°E	x		48°52.1′	54°27.5′	Southeast shore of Gander Lake	JN6, p. 8½
149	N90°E	x		48°52′	54°28.1′	Southeast shore of Gander Lake	JN6, p. 8½
150	S85°E	x		48°52.3′	54°28.4′	Southeast shore of Gander Lake	JN6, p. 9
151	N20°E	x		48°57.5′	54°54.1′	N. shore of lake W. of Gander River	JN6, p. 21
152	N20°E	x		48°57.5′	54°54.2′	N. shore of lake W. of Gander River	JN6, p. 21

GLACIAL STRIATIONS AND GROOVES

Bonavista Map-Area

No.	Orient'n	Striations	Grooves	Geog. Location		General Location	Reference Source
				Lat.	Long.		
1	S76°E	x		48°59′	53°52′	Trinity Bay	CAP, NFL8–19
2	N65°E	x		48°58′	53°56′	Trinity Bay	CN, #309
3	S75°E	x		48°58.3′	53°51′	Trinity Bay	CN, #306
4	S75°E	x		48°57.7′	53°51′	Drake Is., Trinity Bay	JN7, p. 5
5	N80°E	x	x	48°57.5′	53°50′	West shore, Lewis Island	JN7, p. 5½
6	S85°E	x		48°58.5′	53°53′	East shore, Trinity Bay	CN, #303
7	N50°E		x?	48°53.3′	53°59′	Point in Lockers Bay	SN, #240
8	N85°E	x		48°49.5′	53°51.7′	Little Content Cove	JN7, p. 12½
9	S80°E	x		48°47.3′	53°47.5′	Northeast end of island	JN7, p. 21
10	N83°E	x	x	48°39.7′	53°53.7′	North shore, opp. mouth of SW Tickle	JN7, p. 2
11	N83°E	x	x	48°39.6′	53°55′	North shore, opposite Louil Hills	JN7, p. 2
12	S85°E	x		48°46.8′	53°53′	South end of Long Reach	JN7, p. 22
13	N60°E		x	48°49.8′	53°52.5′	Island in Great Content Cove	DN, p. 17½
14	N75°E		x	48°44.5′	53°59.5′	Tip of prominent point, NW Arm, Alexander Bay	JN2, p. 38
15	N75°E	x	x	48°43.5′	53°59.7′	Norton Cove, NW Arm, Alexander Bay	JN2, p. 38
16	N85°E		x	48°43.5′	53°59′	Norton Cove, NW Arm, Alexander Bay	JN2, p. 37½
17	N90°E	x		48°49.6′	53°43.7′	SE shore Cottel Island	JN7, p. 9½
18	N80°E	x		48°50.5′	53°44.2′	SW shore Cottel Island	JN7, p. 7½
19	S80°E	x		48°49.2′	53°45.8′	SW end of Cottel Island	CN, #325
20	N90°E	x		48°49.3′	53°37.2′	N. side Great Black Island	SN, #265
21	N90°E	x		48°39.2′	53°56.5′	Louil Hills	JM
22	N80°E	x		48°31.4′	53°57.6′	Pond south of Newman Sound	JM
23	N70°E	x		48°33.4′	53°54.6′	On shore of Pond	JM
24	N65°E	x		48°33.8′	53°53.7′	Cove in Newman Sound	JM
25	N75°E	x		48°34.3′	53°52.3′	Cove in Newman Sound	JM
26	N90°E	x		48°30.5′	53°59′	Bread Cove Hills	JM
27	N65°E	x	x	48°31.5′	53°50.8′	Park Harbour Hill	JM
28	N 5°E	x		48°26.4′	53°33.4′	Summerville	JN8, p. 26
29	N15°E	x		48°23.8′	53°35.3′	Road to Trinity, E. of Southern Bay	JN8, p. 28
30	N90°E	x		48°23.3′	53°29.4′	Southwest of Trinity Pond	JN8, p. 29
31	S55°E	x		48°24.3′	53°27.5′	Trinity Pond, S. shore, by RR tracks	CAP, NFL6–204
32	S77°E	x		48°22.6′	53°24.8′	RR tracks, SE of Trinity Pond	CAP, NFL6–206
33	N 5°E	x		48°36.3′	53°23.5′	Keels	CAP, NFL6–182
34	S75°E	x		48°12.8′	53°36.7′	2 miles SW of Popes Harbour	CN, #663
35	N90°E	x		48°18.5′	53°37.8′	Ocean Pond	CAP, NFL7–226
36	S80°E	x		48°14.9′	53°35.2′	Popes Harbour Pond	SN, #641
37	S80°E		x	48°14.9′	53°35.4′	Popes Harbour Pond	SN, #642
38	S80°E	x		48°14.6′	53°34.9′	Popes Harbour Pond	SN, #649
39	N65°E	x		48°40.2′	53°03.5′	Spiller's Point, SE of Bonavista	RN, #137
40	S45°E		x	48°32′	53°04′	1 mile north of Catalina, on road	MN, #55
41	S10°E	x?		48°21.2′	53°13.7′	Shore, east of English Harbour	CAP, NFL6–172
42	N15°E	x?		48°25′	53°34.2′	On RR tracks, S. of Summerville	CAP, NFL6–227
43	N90°E	x?		48°23.2′	53°31.6′	On lake, SE of Summerville	CAP, NFL6–227
44	N60°E	x		48°20.8′	53°43.7′	On RR, 5 miles E. of Lethbridge	CN, #90
45	N55°E	x		48°25.3′	53°38.3′	On road SE of Sweet Bay	SN, #4+2
46	N50°E	x		48°25.8′	53°47.5′	On road just east of Jamestown	SN, #1+2,000
47	N53°E	x		48°24.9′	53°45.3′	On road, just west of Winter Brook	SN, #1+12,000
48	N45°E	x		48°21.2′	53°47′	On RR. east of Lethbridge	CN, #88
49	S75°E	x		48°05.6′	53°46.3′	1½ miles west of Hickmans Harbour	JN8, p. 8
50	S65°E	x		48°06.1′	53°56.5′	On road north of Deep Bight	JN1, p. 3
51	N10°W	x		48°01.3′	53°04′	4 miles ESE of New Melbourne	CN, #734
52	S70°E	x		48°07.3′	52°59.2′	3 miles SW of Grates Cove, on shore	CN, #677

Code of References

CN	A. M. Christie, 1949, field note books, on file, G.S.C. (Note # given)
CAP	A. M. Christie, 1949, aerial photos, on file, G.S.C. (Photo # given)
DN	H. W. Dodge, Jr., 1957, field note book, on file, G.S.C. (*see* under Jenness, 1957)[1]
DAP	H. W. Dodge, Jr., 1957, aerial photos, on file, G.S.C. (*see* under Jenness)
FN	O. L. Franke, 1956, field note book, on file, G.S.C. (*see* under Jenness)
JM	S. E. Jenness, 1958, geological map in Report 12, Newfoundland Geological Survey
JN1	S. E Jenness, 1955, field note book # 1, on file, G.S.C.
JN2	S. E. Jenness, 1955, field note book #2, on file, G.S.C.
JN3	S. E. Jenness, 1955, field note book #3, on file, G.S.C.
JN4	S. E. Jenness, 1956, field note book #1, on file, G.S.C.
JN5	S. E. Jenness, 1956, field note book #2, on file, G.S.C.
JN6	S. E. Jenness, 1957, field note book # 1, on file, G.S.C.
JN7	S. E. Jenness, 1957, field note book # 2, on file, G.S.C.
JN8	S. E. Jenness, 1957, field note book # 3, on file, G.S.C.
KN1	G. de V. Klein, 1955, field note book # 1, on file, G.S.C. (*see* under Jenness)
KN2	G. de V. Klein, 1955, field note book # 2, on file, G.S.C. (*see* under Jenness)
KN3	G. de V. Klein, 1955, field note book # 3, on file, G.S.C. (*see* under Jenness)
MN	C. R. Mattinson, 1949 field note book, on file, G.S.C. (*see* under A. M. Christie)
RN	E. D. Robinson, 1949 field note book, on file, G.S.C. (*see* under A. M. Christie)
SN	I. M. Stevenson, 1949 field note book, on file, G.S.C. (*see* under A. M. Christie)

[1] Items marked "*see* under Jenness", or "*see* under A. M. Christie" refer to notebooks of student assistants working for Jenness and/or Christie. These notebooks are filed with the notebooks of either Jenness or A. M. Christie as noted.

APPENDIX B

DESCRIPTION OF RANDOM FORMATION, STRATIGRAPHIC SECTIONS 1 TO 5

RANDOM FORMATION

Section 1 (type section): South shore Random Island, ¼ mile east of Hickmans Harbour, on west side of syncline. (Data from field notes, A. M. Christie, Sept. 15, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation unconformably (?) overlain by basal Cambrian limy granule conglomerate		
19	Light greenish grey flaggy sandstones	3	359
18	Hard grey quartzitic sandstone	5	356
17	Grey and greenish sandstones and shales, finely interbedded (reported by Walcott to contain several varieties of annelid trails)	50	351
16	Light grey to white sandstone	14	301
15	Finely bedded greenish grey shaly arenaceous beds	25	287
14	White quartzite	14	262
13	Pink sandstone, finely bedded and crossbedded	14	248
12	White quartzite	3	234
11	Red sandstone	7	231
10	White quartzite	5	224
9	Greyish green bedded and crossbedded quartzite	20	219
8	Alternating narrow (6 to 12 inch) white quartzite beds and green sandstone and darker shale beds	25	199
7	Same as unit 3	42	174
6	Same as unit 4	2	132
5	Same as unit 3	7	130
4	Green quartzite with shaly beds	3	123
3	Finely bedded grey-green sandstone alternating with darker coloured, finer grained grey beds of shale or mudstone. Beds commonly average ½ inch to 2 inches each and grade from sandstone upwards into mudstone that commonly displays mud-cracks on the upper surface. Many hundreds of these thin beds are present in this unit. They may represent seasonal deposition	45	120
2	Well-bedded green to white quartzite, partly crossbedded	45	75
1	Pink quartzite, in part crossbedded, containing a few pebble beds, pebbles to 1 inch diameter. Most of the pebbles are quartz, but a few are red felsite	30	30
	Base of formation conformably overlies Musgravetown Group sandstones and conglomerates		

RANDOM FORMATION

Section 2: South shore Random Island, ¾ mile east of Hickmans Harbour, on east side of syncline. (Data from field notes, A. M. Christie, Sept. 15, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation conformably (?) overlain by Lower Cambrian strata		
8	White quartzite	8	266
7	Green-grey shaly sandstone	30	258
6	Pure white quartzite	30	228
5	Light grey sandstone with thin beds of quartzite	40	198
4	Alternating light grey coarse sandstone and darker grey to black, shaly and sandy beds. Mud-cracks visible. Appears to be varved. White to grey quartzite in upper part	90	158
3	White quartzite	54	68
2	Greenish conglomerate, pebbles average about 8 mm. Pebbles are mainly quartz, but include some red felsite	2	14
1	Pinkish white quartzite	12	12
	Formation conformably underlies Musgravetown Group sandstones and conglomerates		

Section 3: Keels, Bonavista Bay, on west side of syncline. (Data from field notes of A. M. Christie, June 24, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation unconformably (?) overlain by Lower Cambrian strata		
10	Fine-grained, green quartzite, impure	5	265
9	Pink quartzite with quartz and red felsite granules about 2 mm diameter	6	260
8	Red crossbedded sandstone, verging on conglomerate; numerous small pebbles of quartz, less of red felsite, with flat angular fragments of red shale in some places	24	254
7	Pink quartzite with reddish fine-grained beds, crossbedded	24	230
6	Green to grey quartzite, ripple-marked and crossbedded	30	206
5	Impure fine-grained green quartzite, with a few shale beds having slaty cleavage at the base	65	176
4	Fine-grained green sandstone or slate, with good cleavage, and with thin beds of quartzite	20	111
3	Pure white quartzite	8	91
2	Green quartzite, impure, interbedded with finer-grained bands showing slaty cleavage	40	83
1	Pure white quartzite, crossbedded; contains a few granules to 2 mm diameter of red felsite at its base	43	43
	Base of formation conformably overlies Musgravetown Group sandstones		

RANDOM FORMATION

Section 4: Keels, Bonavista Bay, on east side of syncline. (Data from field notes of A. M. Christie, June 26, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation conformably (?) overlain by Lower Cambrian strata		
10	Grey to white quartzite	8	340
9	Pink to red sandstone with rare pebble bands, pebbles to 10 mm diameter; quartz pebbles more abundant than red felsite pebbles	110	332
8	Grey to white quartzite with shale partings. Grey quartzite occurs in lower part, whiter quartzite with less shale in upper part. Slaty cleavage in shale bands	88	222
7	Thin pebble beds separated by sandstone and shale beds. The pebbles are grey sandstone and shale, with oval cross-sections. The matrix is sandy and impure	0.7	134.0
6	Green to grey sandstone in ¼ inch to 2-foot beds separated by a lesser thickness of green shale	56	133.3
5	Pure white quartzite	8	77.3
4	Fine-grained green sandstone	20	69.3
3	Conglomerate with quartz sand matrix, with pebbles to ¾ inch diameter	0.3	49.3
2	Fine-grained green sandstone or massive siltstone. Resembles Connecting Point Group strata	16	49
1	White crossbedded quartzite, buff weathering. Grains almost exclusively quartz, maximum diameter 2 mm	33	33
	Base[1] of formation conformable overlies Musgravetown sandstones		

[1] Christie included an additional 169 feet of white, buff, and pink sandstones and conglomerate below unit 1 above in his Random Formation. These strata are now referred to the underlying Musgravetown Group.

Section 5: Milton, approximately 1 mile south of the bridge to Random Island. (Data from field notes of A. M. Christie, June 13, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation unconformably (?) overlain by Lower Cambrian strata		
8	Overburden, believed to conceal green shales	35	271 ±
7	Grey-green shale	25	236 ±
6	Quartzite, relatively pure, crossbedded, pink in places, light grey in other places	20 ±	211 ±
5	Rusty weathering grey-green shale	15	191
4	Green quartzite with minor interbedded shale	102	176
3	Interbedded grey shale and quartzite	50	74
2	Green quartzite with minor shale beds	10	24
1	White quartzite, pink tinge	14	14
	Base of formation concealed; may be faulted against granite		

APPENDIX C

DESCRIPTION OF BONAVISTA FORMATION, STRATIGRAPHIC SECTIONS 6 TO 8

BONAVISTA FORMATION

Section 6: Milton, approximately 1 mile south of the bridge to Random Island. (Data from field notes of A. M. Christie, June 13, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation not exposed		
10	Red-brown shale	4	149.5
9	Nodular limestone and red-brown shale, fossiliferous	4.5	145.5
8	Green and purple shales	9	141
7	Nodular limestone and red brown shale	3	132
6	Red brown shale, limestone nodules	7	129
5	Nodular limestone and shale, fossiliferous	2	122
4	Green shale	12	120
3	Red-brown shale	55	108
2	Purple and green shales[1]	18	53
1	Green shale with limy beds and a few limestone concretions	35	35
	Base of formation not exposed. Underlain by Random Formation, section 5		

[1] In his notes Christie has inserted the following observations between units 2 and 3:

"Interbedded purple and green shales 35 feet
Green shales 18 feet
Green shales with quartzite bands. Narrow overburden. Going up (in section) again. Take highest sandstone band as marker. 45 feet"

A fault (which was not noted by Christie) occurs in the section about this position, and has repeated part of the Random and Cambrian strata. Christie's notes leave doubt as to the status of the three units listed. The thickest one (45 feet) appears to be Random Formation, the other two may be units 1 and 2 repeated by the fault. They are omitted from the above section to avoid possible duplication.

BONAVISTA FORMATION

Section 7: Keels, Bonavista Bay, on west side of syncline. (Data from field notes of A. M. Christie, June 24, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation not exposed		
21	Red-brown and greenish slate	7	405.5+
20	Green slate	7	398.5+
19	Red slate	38	391.5+
18	Green slate with rare limestone nodules	34	353.5+
17	Pink and green slates	4	319.5+
16	Nodular buff limestone, with red shale filling	1.5	315.5+
15	Green slate with limestone nodules	41	314 +
14	(Gap in section)	?	
13	Green slates with limestone nodules	20	273 +
12	Buff grey limestone (fossiliferous, *Hyolithes*)	2	253 +
11	(Gap in section)	?	
10	Green slate	6	251
9	Dark red slate	4	245
8	Nodular limestone with numerous green to buff limestone nodules embedded in red shale or slate	2	241
7	Brown slate with a few limy nodules	4	239
6	Green slate with occasional limy nodules	160	235
5	Red siltstone with slaty cleavage	9	75
4	Green slate	33	66
3	Green slate, with some interbedded green sandstone	5	33
2	Green slate with limy nodules	27	28
1	Conglomerate, with fragments of green shale or slate, and fine-grained green sandstone	1	1
	Base of formation unconformably (?) overlies Random Formation		

60402-5—12

BONAVISTA FORMATION

Section 8: Keels, Bonavista Bay, on east side of syncline. (Data from field notes of A. M. Christie, June 26, 1950.)

		Thickness (feet)	
		Unit	Above base of formation
	Top of formation concealed off-shore		
13	Green slates with limestone nodules	70	464.5
12	Red slate (green in upper part)	80	394.5
11	Green to pink slate	15	314.5
10	Red slate	10	299.5
9	Green slate	16	289.5
8	Red slate	35	273.5
7	Green and red slates; rare limestone nodules	45	238.5
6	Green slate with rare limestone nodules and bands	120	193.5
5	Limy bed, irregular, and nodular	0.5	73.5
4	Red slate, with minor green bands; few nodules	25	73
3	Red slate with pink quartzite bands up to 1 foot in width	8	48
2	Pink to green slate with limestone nodules	20	40
1	Green slate	20	20
	Base of formation conformably (?) overlies Random Formation		

APPENDIX D

LIST OF FOSSILS FOUND AT LOCALITIES SHOWN ON FIGURE 6.

F-1 to F-15 Lower Cambrian Formations

F-1 Bonavista Formation—type locality—3 fossil zones (*see* also Figure 7) (data from Walcott, 1900b).

Zone 3: (30 feet below the Smith Point Limestone)—
Coleoloides typicalis

Zone 2: (41 (?) feet below Smith Point Limestone)—
Hyolithes rugosus Matt.
Coleoloides
Urotheca pervetus Matt.
Crustacean, n. g. n. sp.

Zone 1: (134 feet below the Smith Point Limestone)—*Coleoloides.*

F-2 Smith Point Limestone—type locality (data from Walcott, 1900b)—2 fossil zones.

Zone 2: (6 inches below top)—*Callavia bröggeri*
Solenopleura

Zone 1: (3½ feet below top)—*Iphidea labradorica* (*Kutorgina granulata* M.)
Fordilla troyensis
Scenella reticulata?
Randomia aurorae
Helenia bella
Orthotheca pugeo
Hyolithes princeps
Coleoloides typicalis
Hyolithellus micans?

F-3 Brigus Formation—3 fossil zones (*see* also Figure 7) (data from Walcott, 1900b, and Hutchinson, 1962).

Zone 3: (110 feet below Middle Cambrian manganese zone) trilobite fragments.

Zone 2: (57 feet above Smith Point Limestone.) G.S.C. fossil locality 20388 a small brachiopod, and trilobite fragments

Zone 1: (in lower 30 feet of the formation)
Obolella atlantica
Microdiscus bellimarginatus S. & F.
Microdiscus n. sp.
Callavia bröggeri
Zacanthoides sp. undet.
Agraulos sp.
Micmacca walcotti

F-4 Bonavista and Smith Point ? Formations, in quarry alongside highway, fossil fragments (no collections)

F-5 Bonavista Formation—2 fossil zones (*see* also Figure 7) (data from notes of A. M. Christie)

Zone 2: approx. 145 feet above visible base of formation
fossil fragments (no collections)

Zone 1: approx. 120 feet above visible base of formation
fossil fragments (no collections)

F-6 Bonavista Formation (?)—fossil fragments in pink limestone, *Hyolithes*? (no collections)

F-7 Smith Point Limestone—algal structures, fossil fragments (no collections)

F-8 Bonavista Formation—fossil fragments (*Hyolithes*?) in thin pink limestone (no collections)

F-9 Bonavista Formation above type section of Random Formation—5 fossil zones (*see* also Figure 7) (data from Walcott, 1900b)

Zone 5: (approx. 510 feet above base of formation)—pink nodular limestone

Hyolithes princeps
Coleoloides typicalis

Zone 4: (185 feet above base of formation)—in pink limestone

Coleoloides

Zone 3: (15 feet above base)—in pink to purple limestone

Coleoloides
Obolella?

Zone 2: (4 feet above base)—in pink limestone

Coleoloides

Zone 1: (in basal 6 inches)—calcareous granule conglomerate

Coleoloides
fragments of *Archaeocyathus* ?

F-10 Smith Point Limestone—(data from Walcott, 1900b)

Hyolithes

F-11 Brigus Formation—(approx. 140 feet above Smith Point Limestone)—in green shales(?) —(data from Walcott, 1900b)

Obolella atlantica
Hyolithes sp.
Orthotheca sp.
Microdiscus sp. undet.
Callavia bröggeri
Solenopleura ? *bombifrons*?

F-12 Brigus (?) Formation—3 fossil zones, each in thin pink limestone (no collections)

F-13 Brigus (?) Formation—shell fragments in thin pink limestone (no collections)

F-14 Brigus (?) Formation—shell fragments in thin pink limestone (no collections)

F-15 Bonavista (?) Formation—shell fragments in limestone—(data from notes of A. M. Christie).
(no collections)

F-16 to F-23 Middle Cambrian Formations

F-16 Chamberlain's Brook Formation—4 fossil zones (*see* also Figure 7); (data from Walcott, 1900b, and Hutchinson, 1962).

Zone 4: (287 feet above base of formation or 45 feet below top of exposed part of formation)

Paradoxides
Acrotheta
Obelus (L.) *ferrugineus*
Ptychoparia
Other unlisted fossils

Zone 3: (220 feet above base or 110 feet below top of exposed part of formation) 4 inch band of pink limestone, G.S.C. fossil locality 20391

Paradoxides eteminicus Matthew

Zone 2: (142 feet above base) several layers of pink nodular limestone G.S.C. fossil locality 20390

Paradoxides
Ptychoparia

Zone 1: basal 3 feet of formation; pink, nodular, manganiferous limestone; G.S.C. fossil locality 20389

trilobite fragments

F-17 Chamberlain's Brook Formation—1 fossil zone, 10 feet above base of exposed part of formation near Fosters Point, in red limestone (data from Hutchinson, 1962)

fossil fragments (no collections)

F-18 Manuels River Formation—6 fossil zones (*see* also Figure 7); (data from Hutchinson, 1962)

Zone 6: approx. 80 feet above base of formation (or 15-30 feet below its top)

trilobite fragments (no collections)

Zone 5: 64 feet above base of formation; 1 foot band of grey limestone nodules in black shale; G.S.C. fossil locality 20478

Paradoxides davidis Salter

Zone 4: 28 feet above base of formation; 1 foot band of light grey limestone; G.S.C. fossil locality 20483

Clarella venusta (Billings)

Zone 3: 22 feet above base of formation; 1 foot band of grey limestone; G.S.C. fossil locality 20477

Paradoxides hicksi Salter

Zone 2: 18 feet above base of formation in black shale or slate (Hutchinson's unit 10); G.S.C. fossil locality 19052, 19053 (from notes of A. M. Christie)

Paradoxides hicksi Salter
Bailiella cf. *B. aequalis* (Linnarsson)
Agraulos sp.

Zone 1: basal 5 feet of formation; grey-black shale

fragmentary fossils (no collections)

F-19 Manuels River Formation—stratigraphic position within formation not known

Paradoxides (no collections)

F-20 Manuels River Formation—2 fossil zones (data from notes of A. M. Christie)

Zone 2: stratigraphic position not accurately known; presumably slightly above zone 1; G.S.C. Cat. No. 21093

Paradoxides davidis Salter

Zone 1: approx. 60 feet above base of formation; G.S.C. Cat. No. 21092

Paradoxides hicksi Salter
Agraulos socialis Billings
Bailiella cf. *B. aequalis* (Linnarsson)
Bailiella sp. indet.
Bailiaspis cf. *B. dalmani* (Angelin)

F-21 Chamberlain's Brook Formation—G.S.C. Cat. No. 19055 (data from notes of A. M. Christie)

Paradoxides bennetti Salter

F-22 Manuels River Formation—G.S.C. Cat. No. 19054 (data from notes of A. M. Christie)

Paradoxides davidis Salter

F-23 Manuels River Formation—G.S.C. Cat. No. 19056 (data from notes of A. M. Christie)

Paradoxides davidis Salter
Centropleura cf. *henrici*

F-24 to F-30 Upper Cambrian Strata[1]

F-24 Elliott Cove and Clarenville Formations—G.S.C. Cat. No. 19045

Sphaerophthalmus sp.

F-25 Elliott Cove and Clarenville Formations—G.S.C. Cat. No. 19073

Sphaerophthalmus alatus (Boeck)
Peltura sp.
Ctenopyge sp.

[1] All data from notes of A. M. Christie, on file G.S.C., except where otherwise noted.

F-26 Elliott Cove and Clarenville Formations—G.S.C. Cat. No. 19059

Peltura cf. *scarabaeoides* (Wahlenberg)
Sphaerophthalmus alatus (Boeck)

F-27 Elliott Cove and Clarenville Formations—G.S.C. Cat. No. 19074

Peltura cf. *scarabaeoides* (Wahlenberg)
Geragnostus sp.

F-28 Elliott Cove and Clarenville Formations—G.S.C. Cat. Nos. 19050, 19051

Peltura scarabaeoides (Wahlenberg)
Sphaerophthalmus sp.
Ctenopyge sp.

F-29 Elliot Cove and Clarenville Formations—G.S.C. Cat. Nos. 19061, 19064

Parabolina sp.
Peltura (?) sp.

F-30 Elliott Cove and Clarenville Formations—2 fossil zones (data from Hutchinson, 1962)

Zone 2: approx. 383 feet above base of formation; soft grey to black shale, fossil locality 20480 (*see* also Figure 7)

(fossil identities not recorded)

Zone 1: 61 feet above base of formation; grey and black shale, fossil locality 20479 (*see* also Figure 7)

Agnostus pisiformis (Linnaeus)

F-30 A. M. Christie's notes include the following fauna from this section (G.S.C. Cat. Nos. 19057, 19058)

Olenus cf. *gibbosus*
Phalacroma sp.
Homagnostus sp.

F-31 to F-38 Lower Ordovician Strata[1]

F-31 Elliott Cove and Clarenville Formations—G.S.C. Cat. No. 19066

Niobe homfrayi (Salter)
Parabolina andina (Hock)

F-32 Elliott Cove and Clarenville Formations—G.S.C. Cat. Nos. 19043, 19046

Niobe homfrayi (Salter)
Parabolina andina (Hock)
Plethometropus cf. *microphthalmus* Kobayashi

F-33 Elliott Cove and Clarenville Formations—G.S.C. Cat. No. 19042

Parabolina andina (Hock)
Parabolinella sp.
Plethometropus cf. *microphthalmus* Kobayashi

F-34 Elliott Cove and Clarenville Formations—G.S.C. Cat. Nos. 19044, 19065

Niobe homfrayi (Salter)
Parabolina andina (Hock)
Plethometropus cf. *microphthalmus* Kobayashi

F-35 Elliott Cove and Clarenville Formations—G.S.C. Cat. Nos. 19060, 19063

Parabolina andina (Hock)
Plethometropus cf. *microphthalmus* Kobayashi

F-36 Elliott Cove and Clarenville Formations—G.S.C. Cat. Nos. 19068, 19069, 19070, 19071, 19075

Parabolina andina (Hock)
Plethometropus cf. *microphthalmus* Kobayashi
Niobe homfrayi (Salter)

[1] All data from notes of A. M. Christie, on file G.S.C.

F-37 Elliott Cove and Clarenville Formations—G.S.C. Cat. Nos. 19047, 19048, 19049, 19067

Dictyonema sp. cf. *flabelliforme* Eichwald
Parabolina andina (Hock)
Plethometropus cf. *microphthalmus* Kobayashi
Shumardia sp.

F-38 Elliott Cove and Clarenville Formations—G.S.C. Cat. No. 19062

Niobe homfrayi (Salter)

NOTE: Localities for which no references are given were found by Jenness in 1957.

SEJ 53-3-1

A. View of beach and 50-foot terrace at Eastport, Bonavista Bay.

Plate II

B. Sand beach and elevated delta at Sandy Cove, Bonavista Bay. Top of delta is at 100 feet. White weathering, thin-banded Connecting Point rocks in the foreground.

SEJ 53-5-8

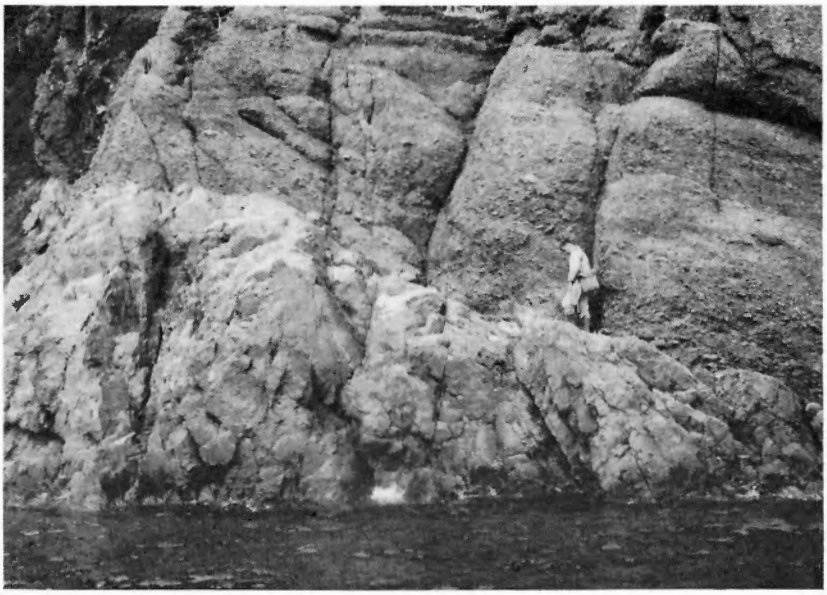
60402-5—13

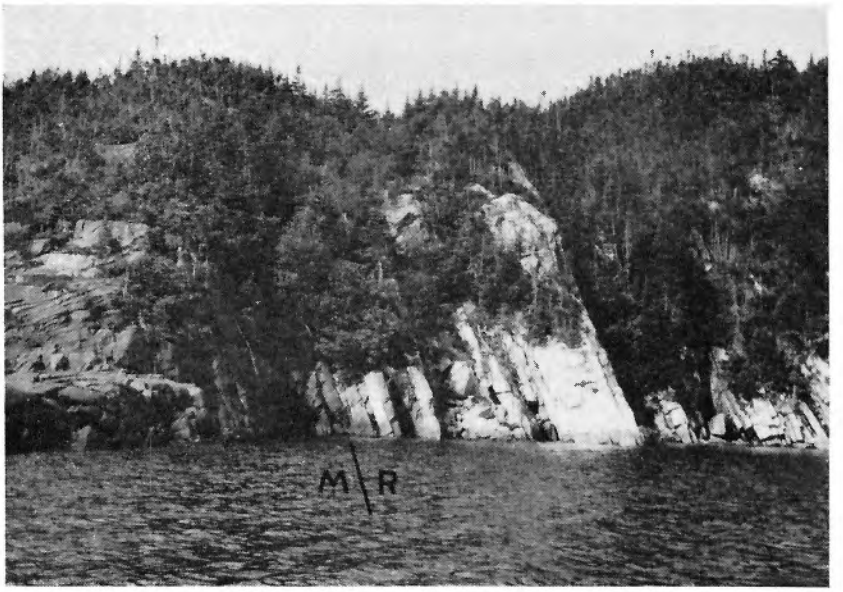
SEJ 53-1-3

Plate III. *Thin alternating beds of impure quartzite and silty slate, typical of much of the Connecting Point Group. Quartzite bands show chalky, white weathered surface, a characteristic of the group. North shore of Newman Sound, Bonavista Bay.*

Plate IV. *Angular unconformity between basal conglomerate (Cannings Cove Formation) of the Musgravetown Group (dipping gently to the lower right) and steeply dipping acidic volcanic rocks of the Connecting Point Group. Southward Head, on the south side of Bonavista Bay.*

SEJ 57-4-5





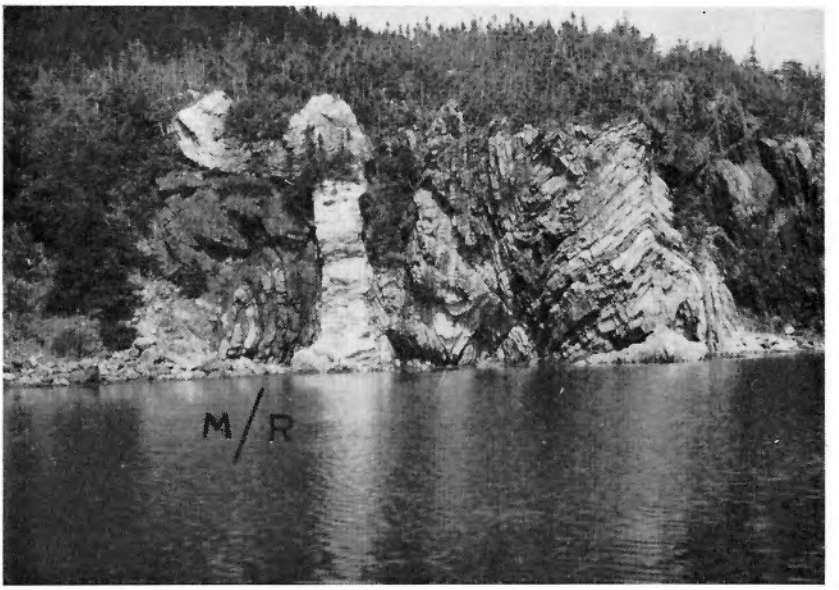
SEJ 57-8-4

A. *Conformable contact between Musgravetown Group (M) and the Random Formation (R) at Hickmans Harbour Point. This is the type section of the Random Formation. The Musgravetown rocks are red sandstones and conglomerates of the Crown Hill Formation, and have been folded into a small asymmetric anticline.*

Plate V

B. *Strongly folded Random Formation (R), in conformable contact with red sandstones (Crown Hill Formation) of the Musgravetown Group (M) on the north shore of the Southwest Arm of Random Sound. Note the tight folding of the 6- to 8-foot bed of white Random quartzite.*

SEJ 57-6-14



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SEJ 57-4-14

Plate VI. *Contact between Lower Cambrian silty shales and the underlying Random quartzite, just east of Smith Point in Smith Sound. A basal Cambrian calcareous granule sandstone, 18 inches thick, lies between the quartzite and the shale.*

Plate VII. *Disk-shaped concretion, 4 inches thick, with cone-in-cone structure, weathered out of Upper Cambrian strata, just south of Elliotts Cove, Random Island.*

SEJ 57-8-7

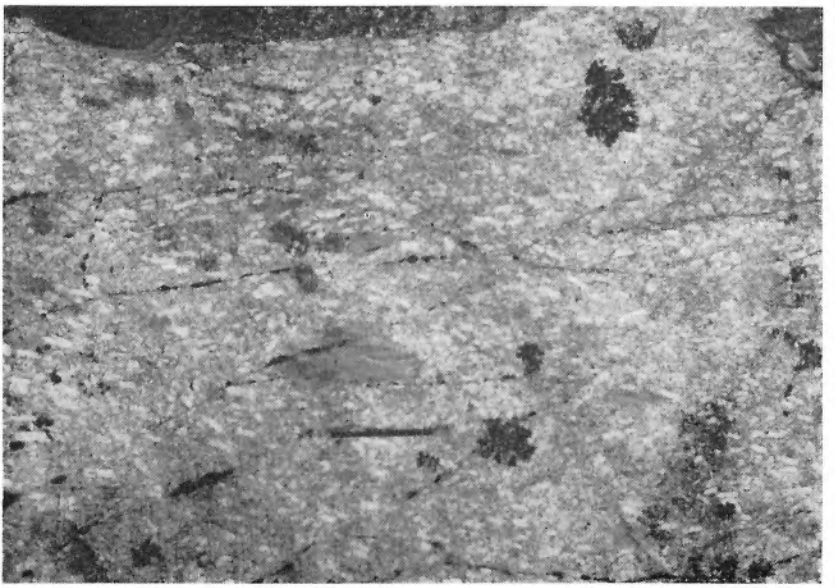
SEJ 57-3-4

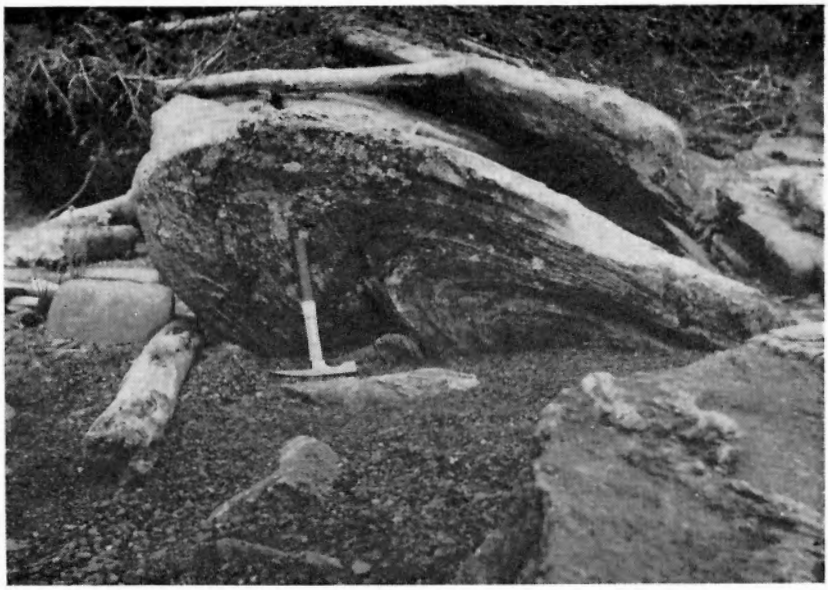
A. Granite stringers in mica paragneiss of the Gander Lake Group, producing an injection or hybrid gneiss. Shore of the Southwest Arm of Trinity Bay, in the northwest corner of Bonavista Bay.

Plate VIII

B. Porphyritic white gneissic granite, with inclusions of Gander Lake Group mica-quartz schist oriented parallel with feldspar laths. Pencil shows scale. Black patches are dead lichen. Southeast shore of Gander Lake.

SEJ 57-1-13





SEJ 57-2-3

A. Tightly overturned isoclinal fold in amphibolite, a local contact metamorphosed member of the 'middle unit' of the Gander Lake Group. South shore of Gander Lake east of Hunts Cove.

Plate IX

B. Small-scale drag-folds in spotted mica-quartz schist, a local metamorphic member of the 'lower unit' of the Gander Lake Group. Southeast shore of Gander Lake.

SEJ 57-1-16

SEJ 57-2-8

Plate X. *Crinkled cleavage in vertical-dipping slate of the Gander Lake Group. East side of Hunts Cove, Gander Lake.*

Plate XI. *Basic dyke (or sill) following the schistosity of sericite schist (Love Cove Group) and both drag-folded. The dyke is more weathered than the schist (note the difference in surface levels). About 3 miles west of Clarenville.*

SEJ 55-2-7

SEJ 57-5-9

Plate XII. *Fault contact between gently dipping Connecting Point rocks (on left) and nearly vertical Musgravetown green sandstones (on right). North shore of the Southwest Arm of Random Sound.*

Plate XIII. *View of the narrow gorge of Terra Nova River at the east end of Mollyguajeck Lake, a potential water-power site.*

SEJ 56-4-3

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