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THE GEOLOGY OF BURLINGTON PENINSULA, NEWFOUNDLAND

(REPORT AND MAP)

By

D. M. Baird

OTTAWA

1951

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Preliminary map - Burlington Peninsula, Nfld. ..... In envelope

THE GEOLOGY OF BURLINGTON PENINSULA, NEWFOUNDLAND

INTRODUCTION

LOCATION AND EXTENT

Burlington Peninsula map-area is on the north coast of Newfoundland between White Bay and Notre Dame Bay, and includes that land to the north of a line joining Western Arm, White Bay, to Middle Arm, Green Bay. The centre of the area is at approximately latitude 49°53' north and longitude 56°03' west.

This report presents the results of field work for the Geological Survey of Newfoundland in 1944 and 1945, during which some 140 square miles of previously unmapped country were systematically traversed. In addition, it includes a correlation of earlier work in the area, for which purpose reconnaissance trips were taken into the previously described areas.

PURPOSE OF THE INVESTIGATION

The copper mines in the Tilt Cove-Bett Cove region and southward along the coast of Notre Dame Bay were operated until the close of the nineteenth century. Minor lead-zinc and molybdenite deposits near Fleur de Lys have long been known. The present study was made to ascertain the geological settings of the known mineral deposits, and to integrate the work of the several writers who have contributed to the geology of small parts of Burlington Peninsula.

ACCESSIBILITY

Travel in this part of Newfoundland is entirely by water, except in the winter months when some overland travel is possible by dog-team. For short trips, small, open motor-boats may be hired in any of the villages, and larger boats for longer sea trips are available for charter at several Notre Dame Bay ports. During the ice-free months, May to December, the government steamer Northern Ranger, running between St. John's and Corner Brook, calls at ports in White Bay District on both eastbound and westbound trips. The government steamer Clyde calls weekly at several points in Notre Dame Bay. Another route, commonly used by field parties, is via (the Newfoundland) railway to Badger, by taxi from Badger to South Brook, and thence by chartered boat to Burlington Peninsula. This is the most dependable route and involves a minimum of delay. At present there are no through-going roads in the area.

CULTURE

Burlington Peninsula is sparsely settled. Agricultural land is scarce in the district. Coachman's Cove, Baie Verte, La Scie, and Burlington each have a few acres, and small gardens in the other settlements can supply only part of the local demand for vegetables.

Short roads and trails are found near the villages and along some of the main brooks. Elsewhere, travel is difficult because of the dense, scrubby forests and abundant lakes and bogs.

FORESTS

A large part of Burlington Peninsula is occupied by open bogs and lakes with boggy margins. Forest distribution in the better drained areas is irregular, partly as a result of forest fires. The peninsula between Mings Bight and Pacquet was swept by fires some 45 years ago. Nowhere do the serpentinized, ultrabasic rocks support forest growth. In the Burlington district, forests fires have laid bare large areas of rock, and on the high hills southwest of Burlington and along Middle Arm Ridge mossy upland vegetation, with no trees, prevails. As is usual in other parts of Newfoundland, the greenstone areas are thickly wooded. In the granite country, trees grow only where glacial drift is thick enough to support growth. Most of the pulpwood and pit-props cut in the district have come from such granite areas and the greenstone belt.

Spruce and fir are the most common trees, with some large birch in the protected valleys.

SOILS

Prospecting for arable land is one of the purposes of a geological survey in those parts of Newfoundland as poor in agricultural resources as is Burlington Peninsula. The incredible barrenness of some of the inhabited places on this coast is illustrated in such villages as Pacquet and Nippers Harbour, both major settlements, where there is not a single field more than 50 feet square. Burlington, La Scie, Woodstock, Baie Verte, and Coachmans Cove have enough cultivated ground to supply their basic needs, but other villages must import a large part of their staple foods.

There is little hope in Burlington Peninsula for the discovery of any large areas of agricultural land. Most of the known, useful soil is made up of washed, sorted glacial debris, with varying proportions of forest rot, along the sides of inlets or at the mouths of streams. The forested areas are usually underlain by heavy boulder drift, and other areas by either bogs or barren rock. Small patches of soil will perhaps be found in some of the greenstone areas.

HISTORICAL RÉSUMÉ

Attention was first drawn to the geology of Burlington Peninsula by the discovery of the Tilt Cove and Betts Cove copper deposits. The former deposits were discovered in 1857 by Smith MacKay, who was then exploring the coast, and those of Betts Cove were found shortly thereafter (71, p. 116)[1]. Since the beginning

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[1] Numbers in parentheses are those of references in Bibliography at end of this report.

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of active operations at Tilt Cove properties, in 1864 (ibid., p. 116), many reports have been made on the copper-bearing rocks of the eastern side of the peninsula. In 1864, Alexander Murray made a reconnaissance of the eastern side of the northern peninsula of Newfoundland, and in his report alluded in a general way to the rocks of Mings Bight-Baie Verte region, and to the rocks at Western Arm,

White Bay (71, p. 18, etc.). In the report of the Geological Survey of Newfoundland for 1867, Murray described in some detail the rocks in and about the Union mine at Tilt Cove, and mapped an adjoining area of about 14 square miles. In 1875, Murray re-examined certain parts of the Notre Dame Bay district, including the Betts Cove mine, then being opened (71, p. 411). In 1877 and 1878, Murray made a careful triangulation of the coast from Cape St. John to the head of Green Bay. Robinson (77) gave a brief description of the topography and rocks encountered on a traverse from the Southwest Arm of Green Bay to the head of White Bay, at the extreme south of Burlington Peninsula. Various writers contributed to the geology of the copper mines in the following years. They include Marett (67), Wadsworth (97), Garland (40), and de Launay (27).

The Princeton expeditions of 1915, 1916, and 1917 contributed much information, as yet unpublished, on the geology of Burlington Peninsula. In 1923, Sampson (79) discussed the origin of the ferruginous cherts in the volcanic rocks of the Notre Dame Bay region; Eardley-Wilmot (30) described the molybdenite and copper deposits of the Fleur de Lys area in 1925; and Snelgrove's paper (81) on "The Central Mineral Belt of Newfoundland" was published in 1928. In 1931, Snelgrove (83) presented a summary of the available information on the Tilt Cove-Betts Cove-region, and his report of 1935 on the gold deposits of Newfoundland (85) includes descriptions of some of the prospects of the peninsula, in particular the Goldenville mine between Mings Bight and Deer Cove on Baie Verte. In the summer of 1937, Fuller (39) made a study of the rocks of the Fleur de Lys area, the results of which were published in 1941. In 1938, Snelgrove (86) published a résumé of all mineral deposits in Newfoundland, and in it described many of the prospects of Burlington Peninsula. A compilation (28) of all the information on copper prospects in Newfoundland, by Douglas, Rove, Williams, and others, added considerable information, particularly for the region from Tilt Cove southward along the Notre Dame Bay coast. In 1940, MacLean (69) described the geology and mineral deposits of the Little Bay area, which adjoins Burlington Peninsula on the southeast, as did Watson (100) of the Baie Verte-Mings Bight area. In 1942, Livingstone (64) described the Rambler gold prospect. From 1940 to date of writing, 1947, several authors have described, in more or less detail, the mining properties of Burlington Peninsula. In 1944, Rose (78) mapped in detail an area extending about 7 miles to the south of Mings Bight. Much of his work is incorporated in the geological map accompanying this report.

The earliest geological map of Newfoundland, that published by Alexander Murray in 1873, shows Burlington Peninsula underlain largely by "Laurentian" rocks, with no further description. Northeast of a line joining Baie Verte and Stocking Harbour, the rocks are called "Lauzon", except for a thin strip of "Laurentian" along the north coast from Handy Harbour to Cape St. John. In addition, a small mass of granite is shown parallelling the shore of Baie Verte.

Howley's map, published in 1907, shows the peninsula underlain by "Serpentines, Diorites, Dolerites, etc.,", with a long ridge of granite running northeast just inland from the Notre Dame Bay coast, but with no further differentiation of rocks.

ACKNOWLEDGMENTS

The writer is grateful to numerous residents of Burlington Peninsula for their many kindnesses during his stay in the district. Mr. William Stuckless of Coachmans Cove and Mr. Charles Bishop of St. John's gave capable and cheerful assistance in the field. The writer is greatly indebted to the staff of the Geological Survey of Newfoundland in St. John's for many favours. Special thanks are due to Professor J. E. Gill of McGill University, under whose direction the doctorate thesis, from which the present report is derived, was prepared. Professors F.F. Osborne and T.H. Clark also assisted in many ways.

PHYSIOGRAPHY

SURFACE

The surface of Burlington Peninsula is an irregular upland, on which the surface features trend in general northeast, a direction that corresponds with the prevailing trend of the rock structures of most of Newfoundland. In detail, the surface reflects local variations in the underlying rock structure.

The coast along the northeast part of the peninsula is marked by abrupt cliffs, which are indented by fiord-like bays such as Mings Bight, Baie Verte, and Pacquet. Along the shore of White Bay, cliffs extend from Partridge Point to Seal Cove without interruption. Along Notre Dame Bay, the cliffs reach an elevation of 350 feet near Cape St. John, but are considerably lower to the southwest. In some places along the White Bay coast and in the Cape St. John district the cliffs directly truncate the upland surface. In most places, however, the land rises steeply from the cliff-line to the general level of the upland surface in a transition zone up to $\frac{1}{4}$ mile wide. Each of the major indentations of the coast is at the mouth of a river valley cut into the upland surface, and rounded land forms are, therefore, more common in the upper parts of the bays than on the exposed sea coast.

Each of the major rock divisions has a characteristic topographic expression, indicating that the relief of the area is largely the result of differential erosion. Massive intrusions cutting softer rocks stand out as bold hills. Easily eroded rocks, such as talc schist, underlie deep valleys, and zones along the contacts of different rock formations are commonly low-lying.

The peninsula between Baie Verte and White Bay is a dissected upland underlain mostly by gneisses and schists of the Fleur de Lys group. The upland surface, at an elevation of about 900 feet, has a relief of about 400 feet near the shore, and less inland. The southern part of the area has been described by Watson as a "broad, rolling expanse at an average elevation of 900 to 1,000 feet" (100, p. 7), and by Twenhofel and MacClintock as "mature with flat-floored valleys" (94, p. 1707).

Inland, the areas underlain by greenstones of the Baie Verte group are characterized by a flat, even surface at an elevation of between 500 and 600 feet. Minor intrusive masses stand out as low, rounded ridges. Extensive muskegs, bogs, and lakes cover the areas underlain by the greenstones. This type of surface extends southwest along the centre of the peninsula at least as far as

Flat Water Pond, and probably continues several miles farther.

Intrusive masses stand out boldly above the rest of the country. The granite to the west of Pacquet is marked by a range of hills that rise 300 to 500 feet above the general level and have elevations up to 900 feet. South of Confusion Bay, a range of hills underlain by fine-grained intrusive rock rises from the sea to more than 900 feet, and is 300 to 400 feet above the country to the south. Granite, granite porphyry, and rhyolitic intrusions underlie a series of prominent hills, which are 5 to 10 miles wide in the neighbourhood of Middle Arm and extend northeastward parallel with the shore of Green Bay to beyond Burlington. Many of the summits of these hills are 1,000 to 1,100 feet above sea-level, and three are nearly 1,200 feet high; the White Hills of Burlington and the great Middle Arm Ridge are part of this highland.

The Cape St. John peninsula and much of the area underlain by the Cape Brulé granite has a rolling surface at elevations of 400 to 600 feet. In that part of the peninsula underlain by the Cape St. John group, ridges of rhyolite and andesite alternate with shallow valleys developed on softer beds. A similar ridge-and-valley topography is developed on the Snooks Arm volcanic rocks. In the granite areas, erosion along lineaments has produced long valleys and rolling hills. In the region northwest of Nippers Harbour the granite country becomes much more bold and rough, presumably the result of local glacial erosion.

As a result of studies of the surface of Newfoundland, Twenhofel and MacClintock established three erosion surfaces, which they termed the Long Range peneplain, High Valley peneplain, and Lawrence peneplain (1941, p. 1720, etc.). The uppermost level is represented only in the western mountains, but the High Valley peneplain and the Lawrence peneplain are represented in Burlington Peninsula at elevations of 900 to 1,000 feet and 500 to 600 feet respectively. Thus the flat, level surface developed on rocks of the Baie Verte group and much of the flat-topped Cape St. John Peninsula are correlated with the Lawrence peneplain. The High Valley peneplain is represented in the area by the Hilltops at about 1,000 feet, and includes parts of Middle Arm Ridge, the Burlington Hills, the Confusion Bay Hills, and the Dunamagon Highland.

DRAINAGE

Glaciation of Burlington Peninsula has produced the disrupted drainage pattern characteristic of most northern areas of North America. Throughout the area, drift dams, hanging valleys, rock-basin lakes, and poorly integrated stream systems are common features.

STREAMS

The streams of Burlington Peninsula may be divided into three classes: (1) subsequent streams, which follow contacts, fault zones, or soft-rock zones; (2) streams cutting across the rock structure. Many of these have developed on the sides of the main valleys and are, therefore, tributary to them; others follow fault zones; and (3) streams with irregular courses, which are the result of glacial scour and fill.

Many of the major streams follow easily eroded rocks. Trimms Brook at Mings Bight follows the talcose western boundary of a serpentine mass. The lower course of Mings South Brook closely follows the talc schist zone on the eastern margin of the same ultrabasic mass, and in many places in the last mile of this valley it can be seen that massive serpentine has limited lateral erosion by the stream. On the eastern side of the same valley, the massive Mings Bight gneisses have similarly restricted stream erosion. Pacquet Brook flows along the contact of the Mings Bight group and the Dunamagon granite.

The tributaries of the main brooks commonly crosscut the rock structures. Their valleys can be divided into three parts: the flat headwaters, many of which follow irregular courses; middle parts, which are characterized by open, mature valleys; and the lowest parts, with steep, narrow ravines with waterfalls, rapids and steep gradients down to the level of the main streams.

Streams of the third class are common in the headwater region of any of the main streams, and are most common in the region underlain by the rocks of the Baie Verte group. Their irregular courses are the result of the disturbance of the preglacial drainage system, on a surface of little relief, by means of scour and deposition. In the Beaver Pond region and southward, rock-basin lakes and irregular, poorly integrated stream systems, due to irregular damming by glacial debris, prevail. In the Rambler area, extensive swamps and numerous shallow lakes form part of the deranged stream system.

LAKES

The lakes, which are locally called 'ponds' regardless of their size, are largely of glacial origin and may be classified as follows:

(1) Lakes formed by irregular deposition of glacial debris. Lakes of this type are most common. Those along Southwest (Woodstock) Brook from Southwest Pond to the sea are formed as a result of the formation of a series of dams of bouldery drift in the valley bottom. This drift is usually obvious in the outlets of the lakes thus formed.

(2) Lakes in basins formed by the scouring action of glacial ice. Many of the large shallow lakes such as Beaver Pond, Rocky Pond, Big Gull Pond, and Red Cliff Pond are formed in such basins; their outlets are over lips of bedrock, and bedrock is continuously exposed around the shores of some of these lakes.

(3) Bog holes and ponds. Several ponds not more than 100 feet across were observed to be dammed by thick vegetation. Others vary from barren, rocky, plantless ponds to 'quaking bogs' and suggest that some of these ponds are remnants of rock-basin lakes that have been almost completely filled with vegetation.

A different type of lake is illustrated by small water holes not more than 40 feet across that occur in step-like arrangement, one above the other, on gently sloping, boggy areas. They are separated from one another by walls of massive plant growth. The difference in level of adjacent ponds, which are from 3 to 10

feet apart, may be as much as 3 feet. The depth of water is usually not closely measureable, but probably seldom exceeds 10 feet. Their bottoms are obscured by a thick cone of vegetation, and their sides are commonly vertical. The bedrock of such boggy areas was not observed, but from the surrounding country there is little to suggest that the surface is step-like and could so account for such a series of bog-holes. A. E. Porsild (74) explains such ponds as the result of solifluction. Where thick layers of vegetation, lying on smooth, gently sloping rock surfaces, become saturated with water, gradual slipping may result in a buckling of the vegetable cover. This would give rise to a number of low, parallel ridges, with small depressions between. Water would eventually occupy these hollows and give rise to a series of subparallel, oblong, or arcuate ponds, whose long axes would be normal to the direction of slope. Rapid plant growth at the surface of such ponds would soon alter their shapes and could account for their nearly vertical walls.

COAST-LINE AND SEA FLOOR

An abundance of evidence indicates that the north coast of Newfoundland has been deeply submerged. The coast of Notre Dame Bay is very irregular, with long, fiord-like indentations and many islands. River valleys continue below present sea-level in such inlets as Baie Verte, Mings Bight, and Middle Arm. Recent, partial emergence is indicated, however, by the elevated wave-cut benches, uplifted and partly dissected deltas, and terracing at the mouths of some streams.

Each of the indentations along the north coast of Newfoundland that reach as much as 25 miles inland is a drowned river valley that has been modified by glaciation. Baie Verte and Mings Bight do not have shallow thresholds. There can be little doubt that Green Bay has been greately deepened by ice action; from depths as great as 225 fathoms, southeast of Stocking Harbour, it shallows to a threshold of 140 fathoms.

Many uplifted marine features in northern Newfoundland show recent emergence of the coast, and most protected bays show a flight of raised beaches and benches. The major rivers of the district are cutting into old delta deposits that are now exposed, and marine fossils are found in mud and clay deposits as much as 100 feet above the present strand-line.

A wave-cut bench on serpentine rocks occurs at an elevation of 110 feet at the Red Cliffs, Mings Bight. A similar bench occurs at 25 feet in the same locality. East of the mouth of Trimms Brook in Mings Bight, a wave-cut bench at about 110 feet, backed in some places by cliffs, extends for more than 300 yards along the side of the serpentine hills. Other, less prominent benches on bedrock occur at several localities.

Among the uplifted delta deposits are those at Baie Verte, Rattling Brook, and Apsey Cove, which were first described by Watson (1939, p. 10) and were visited by the writer. In these localities, stratified sands and gravel are being exposed and carried off by present stream action. Fossils occur in some of the beds.

Several terraces along the western side of Mings Bight show the characteristics of wave-cut benches. On the eastern side, similar wave-cut benches occur at several levels. Meander scars were noted at the backs of two of the terraces near the mouth of Trimms Brook on the eastern side of Mings Bight. It was, therefore, concluded that some of the lowest terraces in this region are the result of erosion by a stream that became adjusted to different levels of the receding sea. In the last mile of the valley of Mings South Brook, similar terraces were observed, though they are obscured by heavy woods. Trimms Brook, at its mouth, is at present cutting about 6 feet below the top of former flood-plain deposits of stratified sands and fine gravel.

Terraces, at several levels, occur on stratified deposits of boulders, gravel, and sand at the mouth of the brook that flows into Middle Arm of Green Bay just west of the village. Large, wave-washed, beach boulders occur in some layers, and in others boulders and cobbles covered with bryozoa and small gastropods were found. In one clayey layer, abundant, well-preserved remains of pelecypods, barnacles, gastropods, and bryozoa weather out on the rain-washed surface. They have been identified by Professor T. H. Clark of McGill University as follows:

Pelecypoda
- Saxicava arcica Linn
- Macoma calcarea Gmelin

Gastropoda
- Acmaca testudinalis Muller

Crustacea
- Balanus crenatus Bruguière

At Pacquet, Mings Bight, and several places along the shore of Confusion Bay, wave-cut benches as much as 100 feet wide occur at present sea-level.

All observations on uplifted marine features were plotted and compared with what would be expected from the projection into this area of Flint's observations along the west coast (1940). Observations of the writer do not support Flint's hypotheses, and suggest the desirability of reinvestigating the problems of post-Glacial uplift in Newfoundland.

CLIFFS

Cliffs form an outstanding feature of the physiography along much of the shore of Burlington Peninsula and, indeed, along much of the coast of Newfoundland. Yet previous writers have made little mention of them, assuming that they have been produced by wave erosion during the present marine cycle. Several lines of evidence have led the writer to believe that the cliffs of northern Newfoundland are not as simple in their origin as commonly assumed, but that they are the result of a long, complex history.

Some of the cliffs have undoubtedly been cut by recent wave erosion, as evidenced by the beaches and benches at the present strand-line. The cliffs along much of the Cape St. John coast are cut in easily eroded rock, and must have receded considerably during the present cycle of wave erosion. But other cliffs have originated

in other ways. The cliffs that rise abruptly from more than 100 fathoms below sea-level in Green Bay to 700 feet above the sea are due to glacial erosion and steepening of the former valley sides. They have scarcely even been notched by present wave activity. The long line of cliffs along the White Bay shore rises from depths of 160 fathoms to 400 feet above the sea, with no significant breaks in the profile at wave level. Beaches and benches along this shore are virtually lacking. At many places along the Notre Dame Bay shore, in the Handy Harbour area and near Cape Hat, glacial rounding extends to within a few feet of the sea. Between Stocking Harbour and Burlington, glacial gouges and striae occur at water level. On the north side of the entrance to Middle Arm (White Bay), glacial channelling and striae are exposed in the wave-washed zone. The Handy Harbour Islands, Mings Tickle Island, and other islands now exposed to wave attack, show rounded forms that are presumably due to glaciation. The cliffs along the inlets of Mings Bight and Baie Verte in many places extend into deep water without benches or beaches. This evidence suggests that many of the prominent cliffs are not due to wave erosion in the present cycle.

In the New England-Acadian region, D. W. Johnson has shown that wave erosion has been slight since the flooding of the depressed land surface (61, p. 183). He suggests that many of the cliffs, at one time considered as evidence for extensive wave erosion, are actually the result of the submergence of cliffs developed by subaerial processes and but little modified by wave attack.

On the north coast of Newfoundland, soundings on various Admiralty charts indicate that the mature topography of the land surface, developed by subaerial erosion, persists beneath the sea to a depth of at least 150 fathoms. Many of the valleys leading into the long inlets of Notre Dame Bay extend seawards to considerable depths. Without doubt they were carved by rivers at a time when the sea was considerably lower than at present. Halls Bay, for example, continues beneath the sea as a submarine valley beyond the zone of apparent glacial over-deepening to 140 fathoms. Although contouring on the few soundings available is at best inaccurate, there is nothing to suggest that the valley does not continue to 200 fathoms. Its bottom, beyond the range of obvious over deepening, is at about 180 fathoms. This great depression may well be the result of the drowning of a river valley that at one time extended along the eastern side of the northern peninsula.

From soundings along the north coast, there is little evidence of former stands of the sea at which wave erosion cut deeply into the land (Admiralty charts Nos. 280, 285). The bottom of Notre Dame Bay slopes from the present shoreline to a depth of 150 to 175 fathoms within 1 mile or 2 miles. Seaward from there, the bottom is an irregular bench with a relief of 300 to 350 feet. Contours drawn from soundings on the Admiralty charts show that the slope from strand to lowermost bench is fairly regular except for a steepening between 90 and 125 fathoms. The base of the shoreward slope at the margin of the bottom bench may represent a former strand-line. The Horse Islands, about 12 miles northeast of Burlington Peninsula, are joined to it by a flat submarine shelf at a depth of about 70 fathoms. It is possible that this is partly the result of wave planation. One small re-entrant on the northwest side of the shelf may indicate that Baie Verte drainage once joined "White Bay River" as a tributary.

The strand-line of northern Newfoundland must have migrated back and forth many times during the many oscillations of sea-level that have occured in the history of the northeastern coast of North America. The general submerged aspect of the entire eastern seaboard region from the middle Atlantic states northward is well known, but the time and the amount of submergence are not agreed on.

In the opinion of the writer, the present-day shore features are clearly not the result of long-continued wave erosion that has carved great cliffs at the present sea-level and a wide plain beneath the sea in the present cycle of marine erosion. Instead, the slope from the irregular submarine plain at about 150 fathoms to the level of the highest, post glacial, emerged, strand-line features should be looked upon as a zone that has been occupied by several different strand-lines during the oscillations of sea level that have occurred since the great initial drowning of late Tertiary time. Present-day cliffs at sea-level can be regarded as part of a region of complex physiographic history. They are due partly to the submergence of a rugged subaerial topography, partly to glacial steepening, and partly to wave erosion at several different stages, with the present marine cycle in very early youth.

MARINE POTHOLES

On the wave-washed rocks about midway between Little Pacquet Harbour and Teakettle Cove (about 2 miles northeast of Pacquet) one large pothole and several smaller ones are cut into the massive quartz-albite-mica gneisses of the Mings Bight group. Fuller found similar potholes in the shore zone in the Fleur de Lys area (39 p. 4); he thought these were moulins. The return of water to the sea after the breaking of storm waves would provide powerful and turbulent streams of water that would affect the whole shore zone to an elevation of perhaps 40 feet on the exposed parts of the coast. As soon as a small depression in the rocks became large enough to hold a few boulders, the development of potholes would proceed in exactly the same manner as in ordinary streams. Potholes now at elevations above the zone of wave action may have been formed when the sea-level was higher.

GLACIATION

Everywhere in Newfoundland glacial drift is fresh and unweathered, suggesting to numerous writers that the last glaciation was Wisconsin in age. No evidence to the contrary was found in Burlington Peninsula.

The general northeast movement of the ice in the peninsula has been established beyond doubt by the present writer. Diversion of the ice flow, from the flanks of the peninsula into the main flow down White and Green Bays, is evident from striae and ice-scoured rocks along the coasts. Local relief guided ice movements in the last stages at least, as shown by the position of the present-day divides, relative to directions of movement, and the fact that everywhere the striae follow valleys. For example, at the junction of the Middle and Southwest Arms of Green Bay, striae suggest a confluence of ice streams that moved outward from each of these valleys around the peninsula between them.

Numerous crescentic gouges of the type described by Gilbert (41) and Harris (50, p. 245) were observed. These, as well as striae, are common on the rock surfaces that dip to the southwest, and against which the ice must have pushed in coming out of depressions. Roches moutonnées were found to be abundant in some areas. Many of the small lake basins, particularly those just south of Beaver Pond, show plucking on their southwest sides and polishing and rounding on their northeast shores, which is taken to indicate northeast direction of ice movement.

The distribution of erratics suggests that the distance of transportation has not been great, and confirms the general northeastward direction of movement of the ice. This is particularly clear in the district between Mings Bight and Pacquet. No boulders of the Mings Bight group were observed south of its contact with the granite mass to the south, but many granite boulders were found to the north of the contact. On the highest point of the Dunamagon Highland, northeast of Belly Pond, several boulders of Cape Brulé granite, as well as scattered greenstone boulders of the Baie Verte group, were found.

Glacial deposits are nowhere quantitatively important. Erratics are everywhere, but nowhere does the till exceed a few feet in thickness. Glacial deposits and water-sorted glacial debris form the floor of many of the major valleys of the region. Southwest Brook, between Southwest Pond and Lower Pond, flows over large, angular, ice-carried boulders. On the east side of the valley are stratified sands and gravels, which are probably part of local outwash. Boulder dumps are common in many of the granite areas. Between Burlington and Flat Water Pond, heavy forest growth covers coarse boulder drift. Where small streams have swept the surface clean it is evident that nowhere is the cover more than 10 feet thick.

Bowl-like depressions, which must be due in part to glacial erosion, occur at several places along the coast of Burlington Peninsula. Harbour Round and Brent Cove are situated in great semicircular basins that are backed by high, abrupt cliffs. Neither wave action nor stream action seem adequate for the erosion of such depressions, and everywhere ice erosion is evident in rounded land forms, striae, and polished and plucked surfaces. Nippers Harbour, and adjacent coves inside the Nipper Islands, are part of another such basin, now partly submarine, which has a shallow threshold, suggesting that ice action was prominent in its formation. Little Lobster Harbour and an adjacent cove on the coast of White Bay are cirque-like depressions, undoubtedly cut into the tableland of the Fleur de Lys Peninsula by ice. At Tilt Cove, Snelgrove has described the Winser Lake basin as a cirque (1929, p. 28). Whether these various erosion forms have come about through cirque-cutting action of local glaciers in a late stage of the Wisconsin glaciation and, therefore, to be termed cirques, in the strict sense of the word, or have come about through pronounced modification of depressions already there, is open to debate. One thing seems certain, however, and that is they owe their present characters to glacial erosion.

GENERAL GEOLOGY

GENERAL STATEMENT

The rocks of Burlington Peninsula are gneisses and schists overlain by volcanic rocks, with intercalated sedimentary

beds, all of which have been folded and intruded by a complex of igneous rocks. The trend of the fold structures is northeast, parallel with the general trend of structures in Newfoundland, and, indeed, with the trend of the Appalachian belt of which Newfoundland is essentially a part.

The oldest group of rocks in the area is the Fleur de Lys, a succession of schists and gneisses exposed on the western side of the peninsula, and extending southwest beyond the limit of the map-area. These rocks form an anticline, with minor superimposed synclines. Rock compositions correspond with the garnet zone of metamorphism, except near small intrusive masses where they have been modified by hydrothermal solutions.

Overlying the Fleur de Lys, but beyond the limits of the map-area, are the similar rocks of the White Bay group, which occurs near Western Arm and southward along the eastern shore of White Bay.

The Mings Bight group, comprising gneisses and schists in the biotite and garnet zones of metamorphism, is exposed in the small peninsula between Mings Bight and Pacquet Harbour. The structure is roughly domal, with minor anticlines and synclines. These three groups of rocks are considered to be probably of Precambrian age.

The Snooks Arm group consists of andesitic lava flows with abundant pyroclastic beds and intercalated sedimentary rocks. These rocks occur in a curved anticline, which plunges to the northeast at about 20 degrees. Fossils found at the base of the group indicate that at least part of it is of Ordovician age.

At Tilt Cove, a small exposure of slate and argillite is seen to lie unconformably below the rocks of the Snooks Arm group. These are probably post-Fleur de Lys and Mings Bight in age, and may be as young as early Ordovician. Their area of exposure is not large enough to be included on the map.

The Baie Verte group consists of altered volcanic rocks, and is believed to rest unconformably upon those of the Mings Bight group. On the basis of lithological resemblances and structural relations, the rocks of this group are correlated with those of the Snooks Arm and other altered volcanic rocks in the Notre Dame Bay region that are believed to be of Ordovician age. Most of the rocks of the Baie Verte group were originally lava flows of andesitic composition, with some pyroclastic beds, but include near the top sedimentary rocks that have been altered to marble and slate. They have been folded into northeast trending anticlines and synclines, which in some places lie <u>en échelon.</u>

The Nippers Harbour group occupies a coastal strip that extends southward from Nippers Harbour. The rocks consist of lava flows of andesitic and basaltic composition, with rare sedimentary horizons. The relations of these rocks to those of the other groups are not known.

The youngest strata in the region are those of the Cape St. John group, which consists of reddish brown and green andesites and rhyolites, and fine- to coarse-grained, yellow, orange, and green pyroclastic and sedimentary rocks. They overlie those of the Snooks Arm group on the south and those of the Baie Verte group on the north.

The oldest intrusive rocks of the district are small masses of diorite porphyrite in the Tilt Cove region. These are considered to be the intrusive equivalent of the lavas of the Snooks Arm group, as they intrude those rocks and no others. Some of the thick rhyolites of the Cape St. John group are considered to be intrusive and probably genetically related to the flows of that group.

The other intrusive rocks of the region are younger than the bedded rocks. Of these the oldest are the ultrabasic rocks, which occur at several localities, generally as tabular or sill-like concordant masses. In age they are younger than the Ordovician, Baie Verte group, but probably pre-Devonian. They are commonly serpentinized and partly altered to talc and carbonate.

In the Baie Verte-Mings Bight region, gabbro and diorite are common as small concordant masses, which intrude the volcanic rocks and are clearly younger than the ultrabasic rocks. Quartz diorite, granite, quartz porphyry, and granite porphyry masses occupy large areas in the southeastern part of the peninsula. Numerous dykes, varying greatly in composition, and small stocks of quartz porphyry and granite porphyry, intrude the volcanic rocks. They are known to be post-Ordovician, and are generally regarded as Devonian in age, although no positive dating is possible.

FLEUR DE LYS GROUP

INTRODUCTION

The occurrence of gneisses and schists in the peninsula between White Bay and Baie Verte was noted by Murray (71) and Howley (72). Fuller (39) mapped the type area of the gneisses near Fleur de Lys, and Watson (100) described gneisses in the Baie Verte area, which he named the Rattling Brook group, and which bear a close resemblance to those studied by Fuller in the Fleur de Lys area.

LITHOLOGY

The Fleur de Lys group consists of gneisses, with some interbanded schists, occasional thin bands of crystalline limestone, and, rarely, quartzite.

The gneisses are typically medium- to coarse-grained, light grey rocks, and weather grey or greyish brown. They consist essentially of quartz, albite, and biotite or muscovite, or both. In some facies hornblende occurs. Garnet is commonly present and locally may constitute 20 per cent of the rock. Accessory minerals include chlorite, magnetite, pyrite, graphite, and, rarely, tourmaline. The rocks are commonly banded, and bands that consist chiefly of quartz and feldspar alternate with others in which biotite, hornblende, or chlorite predominate. Augen structure, with albite 'eyes', is also a common feature of these rocks.

Interbanded dark schists form a relatively small proportion of the Fleur de Lys group. They are dark green rocks, and consist chiefly of biotite or hornblende, with minor quartz, feldspar, and a little epidote. The crystalline limestone observed by Fuller (39, p. 7) occurs in narrow lenticular bands and contains much muscovite. The rare quartzite is a white, platy or schistose rock.

A section of the group is exposed in the type locality in the Fleur de Lys area, where it was divided by Fuller into six 'formations', some of which he subdivided into members or zones. The section, as given below, is a modification, by the writer, from Fuller's report (39, pp. 7, 15, etc.). The thicknesses given are true thicknesses. The writer visited the type locality but did not measure the section again.

Fleur de Lys Group

Formation	Description	Thickness Feet
Pardee gneiss	Platy, blue-grey gneiss, in irregular bands, in which thin quartz layers alternate with muscovite-biotite bands; some magnetite, graphite, and pyrite...	1,000
Birchy schist	Uniform, green, chlorite schist, with a few bands of quartz, biotite, and chlorite gneisses; contains dominant chlorite, but minor epidote; quartz and feldspar also present	600
Shoalrocks gneiss	Light, greenish grey, crinkled gneiss, with feldspar augen, quartz, muscovite, and some garnet. The grain size varies from 0.3 to 0.06 mm.	3,000
Logy Formation		
Woody Cove member	Garnet gneiss, schist, and dark brown biotite-garnet gneiss	1,000
Ygol member	Light grey, quartz-muscovite gneiss, with minor garnet, pyrite, and some hornblende-rich layers	1,200
Lue Point member	Dark brown, platy biotite gneiss	350
Lince-a-Jardin member	Light grey garnet gneiss	700
Caplin Cove member	Dark brown, platy, biotite-rich gneiss with graphite. The lowest 20 feet is a bluish grey, pyrite-stained marble, with abundant muscovite	270

Formation	Description	Thickness Feet
Starboard gneiss	Regularly banded, bluish grey gneiss when fresh, weathering to brownish grey; light grey, garnet-bearing gneiss, with darker bands of biotite-bearing gneiss containing graphite, and hornblende gneiss. The lower part contains marble lenses of calcite and muscovite 10 to 40 feet thick; lowermost 2 feet, pure white platy quartzite	5,000
Headland gneiss		
Capta zone	Quartz-feldspar-biotite-garnet gneiss, with whitish grey, fine-grained, muscovite-rich facies and darker, platy, garnet-bearing varieties ..	4,000
Barry zone	Wavy, foliated, pinkish gneiss with many augen of albite, about 2.5 mm. in diameter. Quartz, biotite, muscovite, and magnetite are subsidiary minerals; some chlorite-bearing layers	4,000

STRUCTURE

Where examined by the writer along the western side of Burlington Peninsula, largely beyond the map-area, the Fleur de Lys rocks have a northeasterly strike and dip northwestward at from 40 to 80 degrees. On the east side of the peninsula, in the areas mapped by Fuller and Watson, and between these areas, the same general northeasterly strike prevails, but dips are southeasterly, from 30 to 75 degrees. The structure of the peninsula between Baie Verte and White Bay is thus a broad anticline, whose axis parallels the northeasterly trend of the peninsula. Superimposed on this structure are some minor local synclinal folds, such as that west of Little Bay Head. The possibility that the peninsula is not a single anticlinorium, but a series of close folds, is recognized, but the fact that no other major fold axes have been recognized in the areas mapped favours the more general anticlinal structure.

ORIGIN AND METAMORPHISM

The rocks of the Fleur de Lys group are largely of sedimentary origin. The occurrence of conformable, interbedded crystalline limestone and quartzite strongly suggests this, as does also the presence of graphite in some of the biotitic bands. The fine, persistent banding in layers of different composition is probably an original bedding structure. Less direct, but still fairly conclusive evidence of the sedimentary origin of the gneisses is afforded by the mineral composition. Quartz-mica schists, commonly containing garnets, in some places constituting as much as 20 per cent of the rock, are believed to represent original beds

of impure sandstone and shale.

The origin of some of the darker bands, however, is not as clear. On the southern shore of Middle Arm, White Bay, to the west of the map-area, hornblende-rich layers have the appearance of much metamorphosed dykes or sills. Other layers of the dark schists could possibly represent original dark shales or greywackes.

Opinions differ as to whether the metamorphism of the sediments was chiefly the result of regional processes, or was in large part due to hydrothermal solutions genetically related to granitic and other intrusive bodies that have invaded the rocks of the group.

From their study of the gneisses in the limited areas they mapped, both Watson and Fuller concluded that hydrothermal solutions introduced considerable amounts of quartz and feldspar, and locally some tourmaline. Thus, Fuller found that the gneisses in the Fleur de Lys area contain two kinds of quartz and feldspar: original quartz in small, clear grains included poikiloblastically within feldspar grains or in bands with muscovite and biotite; and secondary, introduced quartz, which shows wavy extinction and includes numerous spherical grains of an unidentified mineral. Similarly, secondary feldspar was recognized surrounding and including original minerals of the rock. Watson concluded, but did not offer definite proof, that the gneisses in the area he studied are richer in soda than are normal sediments, indicating introduction of materials by hydrothermal solutions, but admitted that some of the quartz and feldspar augen and quartz veinlets in the rock might represent recrystallized original quartz and feldspar (100, p.5).

However, because of the general uniformity of these rocks, the writer believes that in general they are the result of normal regional metamorphism, and fall into what Harker has designated the "garnet zone" (48, p. 218). Locally, as in the vicinity of the Partridge Point granite stock and other igneous intrusions, they have doubtless been modified by the introduction of material by hydrothermal solutions.

AGE

The age of the Fleur de Lys group has not been definitely established. Workers in the area from Murray to Watson have considered them to be Precambrian on the basis of lithology.

MINGS BIGHT GROUP

INTRODUCTION

Watson (100) described gneisses and schists that are exposed on the southeast side of Mings Bight for a distance of 1 mile, and termed them the Mings Bight formation. Rose (78) traced these rocks slightly farther, and retained Watson's nomenclature. They are now known to extend from Mings Bight to Pacquet, and to have a somewhat more complex nature than was originally suspected. The writer, therefore, proposes to call these rocks the Mings Bight group.

The Mings Bight group of gneisses and schists occupies about 11 square miles on the peninsula between Mings Bight and Pacquet, and is bounded on the south by the Dunamagon granite. The

structure of the mass is broadly domal, with superimposed folds. A southward plunging anticline parallels the southern shore of Mings Bight, and close isoclinal folds occur in the region of Pacquet Harbour. The writer's estimate of the thickness of the group is about 8,000 feet.

LITHOLOGY

The Mings Bight group consists of gneisses and schists composed essentially of quartz, albite, biotite, muscovite, chlorite, and hornblende, with small amounts of garnet, epidote, magnetite, tourmaline, apatite, calcite, and sphene. They are the result of the metamorphism of a series of quartzose rocks, with minor interbedded shales. The several rock types in this group comprise: (1) distinctly banded gneisses in which the proportions of quartz, albite, biotite, and garnet vary from layer to layer; (2) porphyroblastic augen gneisses; (3) massive, fine-grained, quartz-biotite gneisses; (4) chlorite-rich and hornblende-rich schists and gneisses; (5) graphitic schist and slate; (6) quartzite, (7) garnetiferous quartz-muscovite gneisses; and (8) actinolite schists.

Banded Gneisses

Banded gneisses, which differ from layer to layer only in the proportions of quartz, albite, biotite, chlorite, and garnet, are widespread within this group. They are well exposed along the shore of Mings Bight from South Brook to the Red Cliffs and from Cape St. Martin to Pacquet Point. The individual layers are from ½ inch to 1 foot thick, and persist for distances of 100 feet or more, suggesting the possibility that the layering is of sedimentary origin. Individual layers within the banded gneisses are usually quartz-albite-biotite schists, in places chloritic, and micaceous quartzites.

In thin section, the rocks are seen to be medium grained and foliated, and to have a granoblastic fabric. Quartz, which comprises from 50 to 80 per cent of the rock, occurs as aggregates of interlocking serrate-edged grains that average between 0.1 and 0.5 mm. in diameter in different facies. Biotite occurs in elongated wisps and shreds averaging in fine-grained varieties, 0.5 by 0.05 mm., and in coarse-grained facies as large as 2.5 by 1 mm. It constitutes up to 15 per cent of the rock. Untwinned grains of albite (An_{6-10}) averaging about 0.5 mm. in diameter occur in interlocking aggregates that comprise from 5 to 15 per cent of the rock. Chlorite is a common secondary mineral, and occurs as patches of interlacing sheaves and as an alteration product along cleavage lines and on the edges of biotite crystals. Other accessory minerals include muscovite, magnetite, hematite, ilmenite, leucoxene, zircon, calcite, pyrite, apatite, zoisite, and, rarely, tourmaline.

Porphyroblastic Augen-Gneiss

Light grey gneisses, with albite augen from 1 to 3 mm. in diameter are best exposed about half-way between South Brook and the Red Cliffs on the eastern shore of Mings Bight.

The feldspar augen weather out in relief, and impart a rough, pebbly surface to the rock. In thin section, the augen are seen to consist of lenticular aggregates of cloudy grains of albite (An_6)

with abundant inclusions of epidote, muscovite, and calcite. Augen of mixed albite and quartz also occur.

Massive, Fine-grained, Quartz-Biotite Gneiss

This type of rock occurs at Grand Os Cove, at Cape Hat, and near Little Pacquet. In hand specimens, such rocks are seen to consist of a fine-grained, light grey aggregate of quartz, albite, muscovite, and biotite. The rocks are visibly foliated, but do not show composition banding. They do, however, grade into banded types such as those described above. In thin section, quartz is seen to comprise about 60 per cent of the rock. It occurs as a mosaic of interlocking, serrate grains full of minute inclusions. Anhedral grains of albite (An_9) are scattered through the rock. Brown biotite, in wisps and shreds of irregular outline, comprises 5 to 10 per cent of the rock. Accessory minerals are epidote, chlorite, apatite, calcite, sphene, and, rarely, a greenish muscovite. Some of the massive gneisses, for example that at the Cape Hat exposure, may be sheared granite dykes.

Chlorite-rich and Hornblende-rich Gneisses and Schists

Chlorite schists occur at several places on the eastern shore of Mings Bight, and are best exposed north of the ultrabasic rocks of Red Cliffs. They appear to result from chloritization of Mings Bight schists by solutions related to the ultrabasic mass. Magnetite is a common accessory mineral in the schists, and suggests that much of the chlorite has been derived from the alteration of biotite already present in the schists, and that the introduction of basic material was of secondary importance.

Banded chlorite schists occur on the south side of the mouth of Big Cove Brook and also near the mouth of Pacquet Brook. The chlorite in the schists is very fine grained, averaging less than 0.5 mm. in size. Occasional grains of quartz and albite are scattered through the rock. Magnetite and pyrite occur in octahedra and cubes that commonly transect the foliation of the schists.

Thin zones of hornblende-rich biotite schists occur 200 yards south of Mings Tickle. The rocks consist of a dense aggregate of finely divided biotite, with accessory albite and quartz, in which are set slender prisms of common green hornblende as much as 1 inch long. The parent rock was probably an impure shale.

Graphitic Schists and Slate

Graphite-bearing schists were observed at several localities, notably south of Mings Tickle and in the valley of South Brook about ½ mile from its mouth. In the first mentioned locality, crenulated biotite schist contains minute plates and veinlets of graphite. In the South Brook occurrence, several beds in the gneisses and schists are dark grey or black from contained graphite. In both places, the rock is a dense, exceedingly fine-grained aggregate of sericite, biotite, quartz, and albite, with accessory graphite. Slaty cleavage may be prominent. No trace of organic remains was found in these graphitic rocks.

Quartzite

Thin beds of quartzite occur at several localities between Mings Tickle and L'Anse of Pardi. They grade from pure, chert-like quartzite to quartz-rich mica schist. Several beds of dense, very fine-grained, banded quartzites, which may be as little as 2 inches thick and do not exceed 2 feet, are composed of 90 per cent mylonitized and recrystallized quartz grains, with about 5 per cent albite and 5 per cent biotite. The rock has a conchoidal fracture and a metallic ring. Other quartzites have thin partings of biotite and sericite. One bed, about 2 feet thick, contains scattered, poorly crystallized, red garnets about 1 mm. in diameter. Pyrite in minute cubes was observed in some quartzitic layers.

Garnetiferous Quartz-Muscovite Gneisses

Garnet-bearing quartz-muscovite gneisses occur on the north side of Pacquet Harbour, on the coast northeast of Pacquet, and at other scattered localities. Most specimens consist of lenticular aggregates of elongated serrate quartz grains, which are separated by sheaves of biotite and muscovite. The quartz, which comprises 20 to 35 per cent of the rock, contains numerous tiny, transparent inclusions. Albite and muscovite are present in quantity, and red garnet occurs as euhedral porphyroblasts up to 2 mm. in diameter.

Actinolite Schist

Actinolite schist occurs at one locality in the valley of South Brook at the edge of the serpentinized ultrabasic mass. The actinolite occurs as veins, masses, and irregular replacements in the gneisses and schists of the Mings Bight group. Chromite, magnetite, and calcite are common accessory minerals.

METAMORPHISM

The rocks that gave rise to the gneisses and schists of the Mings Bight group were largely of sedimentary origin, the fine, persistent banding being considered to be more probably an original sedimentary bedding structure than due to metamorphism. Beds of undoubted sedimentary origin, such as quartzites and, probably, the graphitic schists, are widespread but not common. The mineral composition of the gneisses and schists—quartz, albite, biotite, chlorite, and occasionally garnet—is commonly produced by the metamorphism of impure sandstone.

The common mineral assemblage of these rocks indicates that most of the gneisses and schists are high in the biotite zone of regional metamorphism. The occurrence of garnets at several localities, noticeably near the granite contacts, indicates that metamorphism of these parts has been raised to the garnet zone. Garnet crystals are usually microscopic, and are widespread. In general it may be said that these rocks are slightly lower in grade of metamorphism than are the Fleur de Lys gneisses, their possible correlatives.

STRUCTURE

The structure of the Mings Bight gneisses is a broad dome, in the middle of which the dips of the bands range from about 30 degrees to horizontal. On the margins of the dome, the dip is outwards. The rocks, however, are complexly folded in many places.

Along the southern part of the eastern shore of Mings Bight these rocks strike uniformly north 10 to 15 degrees east, and dip steeply to the west. Farther inland, the dips are to the east and the strike is unchanged. This evidence, together with that from abundant drag-folds, which are well exposed along the shore, indicates an anticline parallel with the shore of Mings Bight and plunging to the south at about 30 degrees.

AGE

The gneisses and schists of the Mings Bight group underlie the volcanic rocks of the Baie Verte group, which are considered to be of Ordovician age. From evidence obtained at Pacquet and southeast of the head of Mings Bight, the contact of the two groups is thought to be an unconformity although such evidence is not conclusive. These rocks, therefore, may be Ordovician, pre-Baie Verte in age, as is suggested by Watson, or they may be pre-Ordovician. The writer tentatively correlates them with the Fleur de Lys group, and ascribes a Precambrian age to the assemblage.

SNOOKS ARM GROUP

INTRODUCTION

The Snooks Arm group is exposed along the coast of Notre Dame Bay from near Nippers Harbour to Beaver Cove. The assemblage lies in a crescent-shaped belt about 3 miles wide at its widest and narrowing toward the northeast and the southwest.

These rocks were first described in the early reports on the copper mines at Tilt Cove and Betts Cove by Murray and others. They were named and systematically mapped by Snelgrove (82, 83), and detailed descriptions of small areas around the mines were published by Douglas (28).

The formations dip steeply, and the general trend is northeasterly. The structure is not entirely clear, but appears to be that of a tightly folded anticline plunging at a low angle to the northeast.

LITHOLOGY

Fine-grained red slates and argillites of uncertain age, associated with minor coarser strata, are exposed at Tilt Cove. Overlying them unconformably is a thick succession of andesite flows, agglomerates, and conglomerates of the Snooks Arm group. The following general types are recognized, and will be described separately: (1) andesitic agglomerates, breccias, and conglomerates; (2) andesite and augite andesite porphyry tuffs; (3) diabase porphyrite; (4) andesite lavas and pillow lavas; and (5) slates and argillites.

Andesitic Agglomerates, Breccias, and Conglomerates

Andesitic agglomerates and breccias are common in the Snooks Arm group, as also are rocks of similar origin that might better be classed as conglomerates. Most of the fragments of such rocks are andesite, similar in all respects to flows above and below the clastic members. The average size of the fragments is about 4 inches, but may be as much as 2 feet. Many are of silicified lavas. The fine-grained groundmass is composed of tuffaceous material and is commonly epidotized. Reddish varieties of the agglomerates and conglomerates commonly owe their colour to a coating of hematite.

In some outcrops, it is evident from the degree of sorting and the conspicuous crossbedding that deposition took place in moving water, and the occurrence of pillow lavas both above and below the agglomerates suggests that deposition was submarine. The lack of red chert fragments and the strongly epidotized groundmass differentiate the water-laid members of the Snooks Arm group from the somewhat similar beds of the Cape St. John group.

Andesite and Augite Andesite Porphyry Tuffs

These tuffs consist of fragments of andesite embedded in a fine-grained tuffaceous matrix. They occur adjacent to both the clastic and the lava-flow members of the Snooks Arm group. Two types were recognized, the first of which comprises aphanitic, andesitic tuffs, which are greenish and in some exposures distinctly stratified. Minute fragments of green chert form a minor constituent, in addition to abundant andesite. These tuffs have been silicified and epidotized, and are strongly chloritized along fault zones.

The second type comprises augite-andesite porphyry tuffs, and was described by Snelgrove but not observed by the writer. It differs from the first type in that it contains fragments of pyroxene and porphyritic augite andesite (82, p. 46).

Diabase Porphyrite

Coarse-grained sills and dykes, and irregular masses of diabase porphyrite in the Tilt Cove area were considered by Snelgrove and Douglas (82, p. 49; 28, p. 107) to be the intrusive equivalents of the andesite lava flows of the region. As such they are included in the Snooks Arm group.

Andesite Lavas and Pillow Lavas

Andesite flows predominate in the Snooks Arm group. The individual flows are thick, persistent, and show little variation areally except to the extent that some are massive, some are pillowed, and some are vesicular.

The most common type is the pillow lava, particularly excellent examples of which are exposed at Betts Cove Head, Beaver Cove, and other points along the coast as well as at many places inland. Some of the individual flows are more than 200 feet thick, and are pillowed throughout. Some of the pillows are bun-shaped, but more commonly they are ellipsoidal or elongated, with local flattening. They are from 8 inches to 5 feet long. In most pillows the cores are much more coarsely crystalline than the margins, which are usually aphanitic and in some places show amygdules and vesicles.

Similar massive pillow lava units have been observed widely in Notre Dame Bay as far east as New World Island. Chert, usually of a greenish or greyish colour, occurs as lenses a few inches thick and also as irregular masses between the pillows. Sampson (79) made a study of the pillow lavas and the cherts of Notre Dame Bay, and concluded that the chert was produced by chemical precipitation during the time of lava extrusion.

Snelgrove (82) showed that the andesites are composed of nearly colourless augite, plagioclase feldspar, and hornblende crystals embedded in a microcrystalline or partly glassy groundmass. Others show a tightly interwoven meshwork of feldspar laths. Flow structure is not ordinarily well developed.

The vesicular varieties are confined to the edges of the pillows and to the top few inches of some of the massive flows. The vesicular lava is commonly somewhat darker than the non-vesicular parts, and may even be black. Quartz, epidote, and calcite are the most common fillings of vesicles.

Slate and Argillite

Black slates, which are associated with the pyroclastic rocks in the lower part of the Snooks Arm group, contain graptolites of early Ordovician age. Fine-grained, red argillites and slates that occur at the base of the group appear to have been deep-water mudstones (83, p. 12).

ALTERATION

Epidotization has affected all members of the Snooks Arm group, but is more marked in the tuffaceous facies. Silicification is a common feature of some zones, notably those near occurrences of copper-bearing minerals. Chlorite is most common in the pillow lava members, where it is most noticeable along the margins of the pillows and in the spaces between them. Copper mineralization, usually confined to shear zones, is almost everywhere accompanied by intense chloritization, which has altered the lavas to chlorite schist.

AGE

The graptolites found by Snelgrove establish beyond reasonable doubt the Ordovician age of the Snooks Arm group. The lavas, pyroclastic rocks, and sedimentary beds follow upward through the series without break. The age of the slates and argillites that underlie the Snooks Arm group at Tilt Cove is doubtful. The unconformity that separates these fine-grained, metamorphosed beds from the overlying lavas, interbedded pyroclastic rocks, and coarse sedimentary strata indicates that they were folded and eroded before the beginning of the volcanism (28, p. 107). These earlier rocks may, therefore, be regarded as possibly pre-Snooks Arm, pre-Ordovician, or Precambrian. It seems improbable that the last is true, as other Precambrian rocks in Newfoundland are of different lithological types, and are more highly metamorphosed. Consequently, the writer believes that the slates and argillites that unconformably underlie the Snooks

Arm group are of Ordovician or earlier age.

BAIE VERTE GROUP

INTRODUCTION

The name Baie Verte was proposed by Watson (100) for a group of volcanic and sedimentary rocks that underlie about 120 square miles of Burlington Peninsula. They consist of andesitic lavas, greywackes, and tuffs, with thin, interbedded slates and marbles. These rocks are in contact on the southeast and south with intrusive rocks and on the west with rocks of the Fleur de Lys group. To the north they lie unconformably on the gneisses and schists of the Mings Bight group, and to the east are overlain by rocks of the Cape St. John group.

The rocks of the Baie Verte group have been folded into a series of anticlines and synclines that trend northeast. Some of these folds are overturned, and most of them plunge northeast.

GENERAL DESCRIPTION

The Baie Verte group consists largely of altered andesitic lavas to which the general term 'greenstone' may be applied. Interbedded with these rocks are fine-grained greywackes, tuff beds, agglomerates, ferruginous chert, slate, altered sandstones, and thin zones of marble.

The lowest part of the assemblage is largely lava flows now altered to rocks grading from pyroxene-bearing lavas to crenulated chlorite schists. A few thin beds of greywackes and tuffs were seen. The rocks are best exposed in the region south of Mings Bight, and in the Baie Verte area to the west.

The middle part of the group is also largely altered lava flows, but interbedded tuffs, agglomerates, greywackes, pillow lavas, and beds of ferruginous chert are more numerous. Amygdaloidal and variolitic lavas and flow breccias are also characteristic. This middle part of the Baie Verte group is the thickest of the three, and has the widest distribution. Sections are exposed along the shores of Baie Verte and the western shore of Mings Bight. The best exposures of the chert beds are near the Goldenville prospect and along the western shore of Mings Bight.

In the uppermost part of the group, greenstone is again the most common rock type. At the extreme top, thin zones of slate, sandstone, marble, tuffs, and greywackes are common.

LITHOLOGY

Most of the lava flows of the Baie Verte group have been so altered that little remains of the original minerals or structures. Pyroxene-bearing lavas were observed by Watson (100, p. 22) and Rose (78) in the Baie Verte map-area, and by the writer at several places in the area to the east. In thin section they are similar to other greenstones of the district except that they contain fragments of recognizable pigeonite ($2V=35^{\circ}$) as cores of larger crystals of hornblende (uralite) in a much altered groundmass.

Amygdaloidal lavas were observed at several localities. The

amygdules commonly consist of calcite, but epidote and quartz are also common. In many of the amygdules a concentric banding was noted, in which quartz formed the outside rim, epidote and calcite the next layer, and calcite the centre. Most of the amygdules are $\frac{1}{8}$ to $\frac{1}{4}$ inch in longest dimension, though much smaller and much larger ones were seen. In some of the more altered zones of the greenstones, elongated and broken clots of calcite, quartz, and epidote were interpreted as deformed amygdules.

Variolitic lavas occur on the western shore of Mings Bight, but were not observed elsewhere by the writer. The variolites form grey or greenish knots about $\frac{1}{8}$ inch in diameter, and are set in a dark green groundmass consisting of chlorite, epidote, and albite. Watson (100, p. 24) found that the variolites themselves now consist of epidote and clinozoisite.

Finely banded, greenish grey tuffs and greywackes are common in the Baie Verte group, but are particularly abundant in the middle part. In many places, such as the excellent exposures about $1\frac{1}{2}$ miles south of Woodstock on a road to Beaver Pond, they are very finely banded, with as many as twenty-five bands to 1 inch. In other occurrences, individual layers may be as much as 8 inches thick. The difference in colour of the various bands is primarily the result of variations in the proportions of hornblende to other and lighter coloured constituents. The light bands are composed almost entirely of quartz, albite, and epidote, with minor amounts of hornblende, chlorite, and magnetite, whereas the dark bands consist largely of altered hornblende needles and fragments of andesite, with smaller amounts of quartz, albite, epidote, and chlorite. In many of the individual bands a progressive decrease upward in the proportion of hornblende to lighter constituents was noted, and with it a decrease in the size of the fragments. Banding in these tuffs is persistent — even the thinnest bands can be traced for distances of 10 feet or more. In most occurrences, banding is much more evident on weathered surfaces than on fresh rock exposures.

At several places in the area, coarse agglomerates, with some finer tuffaceous layers, are interbedded with the lava flows. Good exposures occur on the western shore of Mings Bight and on the road from Woodstock to Beaver Pond. The fine facies are crystal and lithic tuffs, which contain abundant fragments of hornblende (possibly after pyroxene) about $\frac{1}{2}$ inch long, and andesitic rock fragments of about the same size, in a fine-grained groundmass of epidote, chlorite, and calcite. Some fragments of greenish and reddish chert, with darkened margins were also observed in these beds.

The coarse facies consists of angular chunks of altered lava, as much as 1 foot long, in a fine-grained groundmass similar to the fine-grained tuffaceous facies. The lava fragments that appear to be altered andesite consist of albite, chlorite, hornblende, and epidote, and are set in the groundmass with their longest dimensions parallel. Some of the fragments are of porphyritic lava, with much altered phenocrysts of plagioclase or uralitized pyroxene, as much as $\frac{1}{2}$ inch long, in a fine-grained groundmass of hornblende, albite, epidote, chlorite, and calcite. In a few instances, amygdaloidal lavas, with amygdules of calcite, epidote, and quartz, were observed intercalated with the agglomerates.

Slate was observed at four places in the area; the most common type consists of a very fine-grained aggregate of sericite, quartz, chlorite, epidote, altered feldspar, and a disseminated, black, carbonaceous powder. In one locality, magnetite occurs in the slate as discrete octahedra about $\frac{1}{16}$ inch long. In several zones near the southwest end of the Dunamagon granite a slaty rock of the Baie Verte group is composed largely of sericite, with minor amounts of quartz and albite and no dark minerals. About $\frac{3}{4}$ mile south of Woodstock on the road to Beaver Pond, a black slate bed contains a hematite-rich layer about 8 inches thick. The hematite shows slaty cleavage parallel with that of the rest of the rock, and is composed largely of fine scales of hematite with chlorite, sericite, and other accessory minerals.

On the south side of a pond about $3\frac{1}{2}$ miles south of Woodstock, a thin zone of what appears to be dark slate is exposed in a road cut. In the hand specimen, it is seen to consist of a fine-grained groundmass in which are scattered flakes of specularite about 2 mm. in diameter. Thin sections exhibit a groundmass of biotite, chlorite, quartz, and albite grains, which average about 0.05 mm. in diameter, and porphyroblasts of common green hornblende 0.5 to 1 mm. long. The groundmas is strongly foliated and crumpled, and micro-folds, which average about 1.5 mm. from crest to crest, occur throughout the groundmass. Individual flakes of biotite are commonly twisted, bent, and even broken. Quartz, both in the groundmass and as occasional grains as large as 0.5 mm., characteristically contains trains of minute inclusions and strong strain shadows. Albite (An_6) occurs sparingly through the groundmass and also as porphyroblasts up to 0.25 mm. long. Biotite and chlorite occur as wisps and shreds throughout the rock. Accessory minerals are epidote and opaque minerals (mostly magnetite, with some hematite), which occur as discrete grains and as a fine dust throughout the rock.

In Rattling Brook, on the west side of Baie Verte, a lenticular bed of sandstone composed of mylonitized quartz grains in a groundmass of feldspar, chlorite, actinolite, and calcite occurs interbedded with the usual Baie Verte greenstones (100, p. 25).

Grey, green, and cream-coloured marble, as lenses and irregular, non-persistent beds less than 3 feet thick, occurs with some of the altered lava flows, and similar limestones, in places fossiliferous, are common in other parts of the Notre Dame Bay district. They usually occur at the tops of flows or between flows, and are commonly the only sedimentary rocks in thick volcanic sequences. Beds of ferruginous red chert, and lenses and nodules of grey, black, and green chert were observed at several places in the middle part of the Baie Verte group; they reach their maximum thickness and persistence in the exposures at Big Head on the west side of Mings Bight, and westward near the Goldenville prospect. The average thickness of individual layers is 8 inches to 1 foot, although thicknesses of 3 feet are reached locally at Big Head.

Specularite, magnetite, and pyrite are visible in the chert and are concentrated on the margins of the individual beds. Thin, persistent bands, the result of slight differences in the amount of hematite present in the chert, are characteristic in some occurrences. Quartz veins are very common in the chert beds, and apparently fill fissures caused by deformation of the brittle chert beds, which are interbedded with less brittle greenstones.

METAMORPHISM

Greenschist Facies. The lavas and pyroclastic rocks of the Baie Verte group have undergone regional retrograde metamorphism, which has changed them to chlorite schists in extreme cases and to many intermediate types that may be called greenstones.

In thin section, all stages in the degradation of pyroxene through hornblende and actinolite to biotite and chlorite were observed, and in turn the development of hornblende from chlorite and biotite. The ubiquitous presence of chlorite, albite, epidote, and sericite in the greenstones that lie beyond the immediate influence of the intrusive rocks of the region places them in the greenschist facies of Eskola (1920), and approximately in the chlorite zone of Harker (1932). In the region newly mapped by the writer, the principal exposures of the greenschist facies are south of Mings Bight, in the interior of the peninsula around Flat Water Pond, and in the region south of Baie Verte.

Locally along the margins of the granite and diorite bodies of the area, hornblende porphyroblasts are visibly developed at the expense of chlorite and biotite, and thus indicate that the greenstones have reached the amphibolite stage of progressive metamorphism. The amphibolite facies prevails in the long finger of Baie Verte rocks, which lies between the Dunamagon granite and the Cape Brulé granite southwest of Pacquet, in the wedge-shaped area of Baie Verte rocks at Cape Cagnet, and in the small patches along the shore of Confusion Bay.

The chlorite schists of the region are light to dark green and weather to a neutral grey. They are strongly foliated in most exposures and in extreme cases are crenulated and crumpled. The loosely packed pyroclastic members of the series were apparently the most susceptible to alteration, as shown in the exposures along the western shore of Mings Bight south of Big Head, where the andesite members, though chloritized, remain massive whereas the tuffaceous facies have given way to crenulated chlorite schists.

The average chlorite schist contains 30 to 40 per cent chlorite, 20 to 30 per cent epidote, 10 to 20 per cent quartz, and variable amounts of pale blue-green actinolite, brown biotite, calcite, and opaque minerals, mostly magnetite and hematite.

In general, the rocks of the greenschist facies are less intensely altered than the chlorite schists described above. The average mineral assemblage includes chlorite, epidote, calcite, albite, hornblende (uralite), and actinolite.

Partly altered pyroxene-bearing lavas have been referred to above. They consist of crystals of pigeonitic augite, which are almost completely altered to uralite, in a groundmass of chlorite, albite, epidote, biotite, and quartz. In some thin sections, uralitic hornblende constitutes as much as 30 per cent of the rock, but in others it has given way completely to actinolite, chlorite, epidote, and zoisite.

Amphibolite Facies. In the region east of Baie Verte, the rocks of the Baie Verte series have been progressively metamorphosed to the amphibolite facies of Eskola, almost without exception. In hand

specimen, the following types of this facies are recognized:

(a) Massive amphibolitic greenstone
(b) Banded gneissic greenstone
(c) Hornblende-needle schists
(d) Porphyroblastic greenstone

(a) Massive amphibolitic greenstone occurs widely through the area. It results from the metamorphism of massive lava flows, which have resisted deformation to a considerable degree. In thin section it can be seen to be composed of a medium-grained, granoblastic aggregate of hornblende, actinolite, albite, epidote, biotite, chlorite, and accessory minerals. Foliation is usually faint even in thin section. In some places, such as along the shore of Sackerys Cove, in Pacquet Harbour, massive amphibolitic greenstones include abundant irregular knots of albite, calcite, and epidote, which are probably deformed amygdules.

(b) Gneissic amphibolitic greenstones are marked by alternating layers that are, respectively, amphibole-rich and quartz-albite-rich. In some sections, microcrumpling is evident. In the hornblende-rich layers the hornblende occurs as an interlocking meshwork of anhedral crystals that average about 0.5 mm. in greatest dimension. Albite is accessory. In the quartz-albite-rich layers albite (An_8) and some quartz occur in a mosaic of interlocking crystals about 0.25 mm. in diameter, with numerous inclusions of epidote.

(c) Hornblende-needle schists are the most common of the amphibolite facies. Many variations occur along the northeast and southeast shores of Pacquet Harbour, and southwestward to Side Pond. They are all markedly foliated, and in some localities show a strong lineation. Hornblende, which is commonly actinolitic, constitutes 40 to 55 per cent of the rock and occurs as slender prisms and elongated masses up to 3 x 0.5 mm. Albite (An_6), which comprises 35 to 50 per cent of the rock, occurs as a background mosaic of interlocking anhedral grains and as scattered interstitial grains among the hornblende needles. In some sections, lenses composed of a mosaic of albite grains have hornblende needles 'flowing' around them like logs around a boulder. Quartz is an abundant accessory mineral in some slides, and may constitute as much as 10 per cent of the rock. Other accessory minerals include epidote, biotite, zoisite, calcite, and magnetite.

(d) In several amphibolitic areas, a distinctive type of greenstone is found to be composed of slender, euhedral porphyroblasts of green hornblende, or actinolitic hornblende set in a granoblastic groundmass of albite, epidote, biotite, and chlorite, which average approximately 0.25 mm. in length. The porphyroblasts of hornblende, which may be as large as 4 x 0.5 mm. and comprise as much as 40 per cent of the rock, commonly contain poikiloblastic inclusions of epidote and albite.

In some specimens of the amphibolitic facies, the groundmass constituents, particularly well shown by the biotite, are set at an angle to the composition banding, which is visible in both thin section and hand specimen and which probably represents the original bedding. The porphyroblasts are oriented in all directions, regardless of either the composition banding or the orientation of the groundmass crystals. This clearly suggests that the rock underwent at least two periods of metamorphism -- the first, during which the

groundmass minerals developed at an angle to the bedding, was a result of regional dynamic metamorphism; and the second, during which the unoriented porphyroblasts developed, was caused by thermal metamorphism, related to the intrusion of the nearby granite masses.

Another type of porphyroblastic hornblende gneiss occurs at the log-chute on Southwest Pond Brook. In thin section, it is found that the porphyroblasts are uralitized pyroxene phenocrysts from an original pyroxene-bearing lava, which have been added to when changing conditions made the amphibolite facies stable. The large actinolitic hornblende crystals are set in a faintly foliated groundmass of albite (40 per cent), calcite (5 per cent), epidote (3 per cent), and small needles of actinolitic hornblende. In a few crystals, pigeonitic augite is still recognizable at the core, but most of the crystals are uralite. The outer rims consist of irregular series of needle-like projections of darker and more strongly pleochroic hornblende, which cluster about the main masses of the crystals like tacks on a magnet. These large crystals are evidently the result of the uralitization of phenocrysts of pigeonitic augite and the addition of a second generation of hornblende during the thermal metamorphism that raises the greenschist rocks of the region to the amphibolite facies.

Hydrothermal Alteration. In several places, close to the outcrop of the Cape Brulé granite, zones of solicification occur in the Baie Verte group. The introduced quartz occurs as diffuse replacements and as intricate networks of veins that commonly weather out as boxworks on the surface of the greenstones. Sericitization accompanied silicification at some places.

Carbonatization of the greenstones is in some instances very intense, and has produced in some places from the altered volcanic rocks of the series a distinctive rock type that may contain as much as 60 per cent brownish ferrodolomite. Carbonatization and steatitization of the greenstones occur near the contacts of the ultrabasic rocks.

Epidotization is locally important, as for example on the southeast shore of Pacquet Harbour, where it is intimately associated with the quartz veins.

Foliation and Bedding. In many localities in Burlington Peninsula, the principal foliation was found to be parallel with the bedding. Near Big Head, on the western side of Mings Bight, beds of ferruginous chert are visibly parallel with the foliation in the adjacent greenstones of the Baie Verte group. The foliation in the upper part of the group, west of Baie Verte, is parallel with the conspicuous horizon markers, such as marble lenses, slate beds, and greywacke beds. In many places, southwest of Pacquet, in the areas underlain by the rocks of the Baie Verte group, foliation parallels the finely bedded greywackes, the contacts of the slaty members with the volcanic units, and the contacts of the coarse pyroclastic layers with the fine-grained, green lava flows.

Foliation parallel with the bedding is not a local phenomenon, but is characteristic throughout Burlington Peninsula and, indeed, in much of the northern part of Newfoundland. In the Fogo district, the writer has observed thick sections of Ordovician and Silurian slates and quartzites in which slaty cleavage is parallel with the

obvious bedding planes, except in limited areas on the crests of anticlines and the troughs of synclines. Twenhofel (personal communication, 1946) and the writer have found that similar parallelism of foliation and bedding is characteristic of much of the Gander Bay-Fogo district. In the Bay of Exploits region, Heyl (53, p. 16) found considerable isoclinal folding with consequent parallelism of slaty cleavage and bedding. In the rocks of the Baie Verte group, even in the more open folds, cleavage was found to parallel the bedding, which indicates mimetic types of foliation in addition to flow cleavage developed in isoclinal folds.

AGE

No fossils have been found in the rocks of the Baie Verte group in spite of careful search. Any appraisal of the age of rocks of this group must, therefore, be made from lithological and structural evidence. The only fossils yet found in the rocks of Burlington Peninsula are graptolites from the lowest part of the Snooks Arm group on the coast of Notre Dame Bay. They were identified by Ruedemann as Loganograptus logani and Didymograptus gracilis of the second and third Deep Kill zones of the Ordovician, and rocks of the Snooks Arm group are, therefore, considered to belong to this period.

In Notre Dame Bay, from New World Island to Snooks Arm, thick lavas and pyroclastic rocks of intermediate composition, with thin, interbedded, fossiliferous marine strata are characteristic of the Ordovician (Heyl, 53; Espenshade, 33; MacLean, 69; Bair, 7; etc.). They are the result of both fissure and central type eruptions, and were, apparently, partly submarine. The proximity of the Ordovician volcanic rocks of Notre Dame Bay, and their lithological similarities to those of the Baie Verte group would indicate that the rocks of the latter group are also Ordovician in age.

The particular part of the Ordovician system to which the rocks of the Baie Verte group belong is not distinguishable. Metamorphism has altered the lava flows, pyroclastic rocks, and minor sedimentary strata to a monotonous succession of greenstones from which details of the section are difficult to obtain. In addition, wide variations within small geographic limits would be expected in this region of volcanic activity, which was periodically undergoing limited submergence. Thus, detailed comparisons of the Baie Verte section with others in the region are of little value. Both the Baie Verte and Snooks Arm groups immediately underlie the Cape St. John group in different localities. This fact, together with their general lithological similarity, might suggest that the Baie Verte group is the equivalent of the Snooks Arm group.

NIPPERS HARBOUR GROUP

INTRODUCTION

Nippers Harbour is proposed as a name for a group of altered volcanic and sedimentary rocks lying to the southeast of those of the Snooks Arm group, and separated from them by a belt of serpentinized peridotite. Although they are unlike the Snooks Arm rocks in many minor respects, they may, wholly or in part, be

their correlatives. That part of the assemblage lying between Nippers Harbour and the peridotite belt was included by Snelgrove in the Snooks Arm group (83). Outliers to the southwest, at Burlington and Middle Arm, were included by MacLean in his Lushs Bight group (69). As the rocks of this proposed group appear to have many features in common; as they appear to be dissimilar in some respects to those of the Snooks Arm group; and as their relationships to other rock groups are obscure they are grouped separately under the proposed name 'Nippers Harbour'.

LOCATION

The Nippers Harbour group is composed of greenstones, dark volcanic rocks, amphibolites, altered dykes, and sedimentary rocks. They extend along the coast, lying between the interior granite and the sea, as far south as Southwest Arm and nowhere occupy a belt wider than 2 miles. From Stocking Harbour to Southwest Arm of Green Bay, the rocks of this group occur as small outliers, usually cut by granitic dykes.

LITHOLOGY

Nippers Harbour rocks are in many respects unlike those of the Snooks Arm group to the northeast. Most of the latter are representatives of the greenschist facies, whereas those of the Nippers Harbour group more closely resemble rocks of the amphibolite zone of metamorphism. The Snooks Arm group is characterized by numerous, thick pillow-lava members, whereas such structures are rare in rocks of the Nippers Harbour group. Pyroclastic and sedimentary beds are common in the Snooks Arm group, but are almost lacking among Nippers Harbour beds.

The rocks of the Nippers Harbour group have a wide range in composition. The most common types consist of hornblende porphyryoblasts, varying from minute needles to prisms as much as ½ inch in diameter, set in a feldspathic groundmass. The proportions of the plagioclase and the hornblende vary considerably, and many of the rock types of the group differ only in grain size and in the proportions of these two essential constituents.

In thin section, massive amphibolite was found to consist of a porphyroblastic aggregate of hornblende and actinolite (50 per cent), saussuritized plagioclase feldspar (25 per cent), and quartz (15 per cent), together with accessory minerals. The plagioclase feldspar occurs in altered, subhedral crystals of andesine (An_{38}) commonly zoned, with albite margins. The original plagioclase crystal is commonly obscured by an aggregate of albite, epidote, calcite, sericite, and an unidentified scaly alternation product. The quartz occurs as anhedral, interstitial masses as much as 2 mm. in diameter, which, if adjacent to actinolite, are penetrated by slender needles of this mineral. Common green hornblende occurs as irregular subhedral masses. Accessory minerals include magnetite, hematite, epidote, muscovite, albite, and alteration products. In some of the rocks, pale actinolite or tremolite constitute as much as 40 per cent of the rock. The original rocks were probably diorites or thick andesitic lavas.

The chlorite schists and other green schists correspond in general lithology with those of the Baie Verte group previously described. Chlorite constitutes up to 40 per cent of these rocks,

and the remainder is composed of varying amounts of albite, epidote, quartz, and accessory minerals.

Coarse grained conglomerate occurs on the northwest side of Rouge Harbour. It is composed largely of volcanic rock fragments in a red, carbonate-rich cement. The pebbles and boulders are angular to subangular, and average about 5 inches in diameter, with a maximum of about 1 foot. The fragments commonly include vesicular black basalt or andesite, dark, carbonate-rich rock, and massive green lavas (andesite). Some sedimentary rocks occur as lens-shaped masses, and appear to occupy scour channels in the tops of lava flows.

Many dykes of various compositions and forms intrude the rocks of the Nippers Harbour group, and in many places are with difficulty distinguished from them. Pyroxenite and peridotite dykes were observed at several localities, and are commonly serpentinized and weather light brown. Dense, dark grey, diabase dykes, and fine-grained meta-diorite and lamprophyres, which weather to a khaki-brown colour, are commonly intrusive into the rocks of the group near Stocking Harbour. They will be described in detail later.

CAPE ST. JOHN GROUP

INTRODUCTION

The writer proposes the name 'Cape St. John group' to include that sequence of lava flows, with interbedded sedimentary and pyroclastic rocks, that overlies the Snooks Arm group. Snelgrove (83) and Douglas (28, p. 106) used the terms 'Goss Pond volcanics' and 'Red Cliff volcanics' to describe what they thought were lower and upper members. These writers worked in a very restricted area near Tilt Cove, where the lower part of the succession is dominantly tuffaceous and the upper part is largely lava flows. The writer has found, however, in tracing the beds northwest toward Confusion Bay and northeast toward Cape St. John that what was formerly called the 'Goss Pond volcanics' is only the lowermost of a series of tuffaceous sedimentary strata interbedded with a series of thick lava flows. From the excellent exposures along the coast from Shoe Cove to the tip of Cape St. John, it is evident that the entire sequence of rocks represents one period of volcanic activity, and that it can best be considered as one stratigraphic unit.

GENERAL DESCRIPTION

The rocks of the Cape St. John group are rhyolite flows, with small rhyolite intrusions, trachytes, andesites, acidic pyroclastic rocks, and water-laid tuffaceous sediments. They are exposed on the shore of Cape St. John Peninsula from Beaver Cove to Middle Bill, and they extend southward as far as the Sisters Ponds. The steeply dipping, highly coloured beds of the group are conspicuous from seaward in this region. Numerous porphyritic offshoots of the Cape Brulé granite, which underlies large areas to the west of this group, intrude them.

An excellent section, about 8,000 feet thick, is exposed along the coast south of Cape St. John. The lavas are commonly brown, with some purple, green, and yellow-green members. The pyroclastic and water-laid tuffaceous beds are everywhere light coloured, with yellow, light green, and grey tints predominating. A description of the various rock types follows.

Rhyolite Flows

The rhyolite flows of the district are almost exclusively reddish brown, although light red and greenish facies were also observed. On neither fresh nor highly weathered surfaces are flow structures readily seen, but they are strikingly displayed on less weathered exposures.

Hand specimens of the rhyolite consists of numerous phenocrysts of quartz up to 2 mm. in diameter and, less commonly, orthoclase feldspar of about the same size, in a dense aphanitic groundmass. They contain abundant secondary minerals. Minute veins of quartz and calcite are common.

Vesicular rhyolite is rare. A rhyolite section about 40 feet thick underlies massive andesite in the cliffs on the south side of Cape St. John; the uppermost 10 feet of this contains many vesicular and amygdaloidal zones. The amygdules consist of white, cryptocrystalline quartz.

Several zones of spherulitic rhyolite occur in the massive flows near Cape St. John. Spherulites occur as scattered white or greyish knots about 2mm. in diameter in the dense, fine-grained, reddish lava. No phenocrysts of quartz or feldspar were seen.

The rhyolites of this group grade from massive, little altered lavas to crenulated quartz-sericite schists. The thick, red-brown rhyolites in the Cape Cove region show the least alteration. Examples of much altered rhyolites were observed in the shore exposures near Manful Bight, and again farther south in the Red Cliff Pond district.

Sericite is abundant in the altered rhyolites, and may constitute as much as 50 per cent of the rock. Calcite is common as disseminations and as tiny veinlets. Unaltered 'eyes' of quartz and tiny quartz veinlets are characteristic. Locally, orthoclase and quartz show an augen structure, which indicates that crushing took place on a minute scale during the severe folding and faulting of the region. In some instances, notably near faults, the secondary foliation that has developed in the sheared rhyolite is not parallel with the bedding, and is usually visible even after severe alteration.

Trachyte

The absence of quartz phenocrysts and the continued presence of orthoclase phenocrysts in some of the darker facies of the lavas indicate that trachytes occur in the succession. They may be regarded as phases of the rhyolite extrusions.

Andesite

Andesite flows occur throughout the section, but are particularly abundant near Middle Bill of Cape St. John. Individual flows are from 3 to more than 50 feet thick, and one massive bed about 120 feet thick is exposed in the upper part of the cliff at a promontory on the south side of Cape St. John. The andesites of this group, though similar in general appearance to those of the Snooks Arm, are finer in grain and more massive. Lack of pillow structures and shear zones and the greater distance from the intrusive masses are believed to have precluded widespread chloritization of the type that is so characteristic of the Snooks Arm group.

The andesite is light to dark green, or purple. Amygdules and vesicles are found in many flows, but not everywhere. In places where exposures are continuous, it was noted that vesicles are equally plentiful on both the upper and lower margins of the flows, and their occurrence was, therefore, of little value in determining the stratigraphic sequence.

The thick, massive andesite flows exposed in the cliffs at Fishing Point, south of Cape St. John, do not show a proportionately thick layer of vesicles and amygdules, but, indeed, are almost devoid of them, except in the uppermost foot of the flows.

In thin sections, the andesites show felted aggregates of plagioclase (An_{32}) microlites, which have been altered to epidote, calcite, and some sericite. Patches of chlorite and magnetite suggest the former presence of mafic minerals. The abundant magnetite throughout the rock is probably partly original accessory material and partly the result of secondary alteration. Minute veinlets of quartz and calcite cut the andesite.

Amygdules are of calcite, which fills the largest vesicles; epidote, which fills vesicles of intermediate size and is easily distinguishable in hand specimens; and mixtures of calcite, epidote, and quartz.

Coarse Pyroclastic Rocks

A coarse agglomerate is exposed near the north shore of the westernmost of the Sisters Ponds, and occurs widely to the north. Several similar beds were noted in the shore exposures of Cape St. John.

A bed north of the Sisters Ponds is about 100 feet thick, but most others are less than 20 feet thick. Sharp, angular boulders and irregular fragments of a variety of volcanic rocks occur in a fine-grained matrix of angular fragments of quartz, orthoclase, plagioclase, and tuffaceous material. Hematite commonly coats the grains of the matrix, and in some places is altered to limonite. The fragmental rocks include dark purplish amygdaloidal andesite; rhyolite porhyry, with quartz and orthoclase phenocrysts in a reddish aphanitic groundmass; fine-grained, red-brown rhyolite, with good flow structure; fine-grained, grey felsite, with microphenocrysts of feldspar; vesicular andesite; red chert fragments up to 8 inches long; and, rarely, fragments of bright green, highly chloritized, volcanic rock.

These beds apparently represent the subaerial accumulation of explosive volcanic debris. They lack evidence of water transportation, are irregular in their distribution, and consist of heterogeneous angular material.

Fine-grained, Rhyolitic and Other Light-coloured Tuffs

Beds of fine-grained pyroclastic rocks are interbedded with the lavas and sedimentary formations along the shore between Shoe Cove and Beaver Cove, and along the north side of Manful Bight.

The thickness of individual units varies from 1 foot to as much as 200 feet. The colour on fresh surfaces is usually greenish yellow, but in some facies is bright yellow and in others dark green. Weathering produces bright surface colours, which contribute to the beauty of the cliff-lines in the Mother Burke region of Cape St. John.

Within individual units, there is little evidence of bedding beyond an indistinct banding at some places. A secondary foliation is common within the beds; it parallels the bedding and may represent primary incipient parting.

Many of the tuffs are so fine grained that no individual grains are visible to the naked eye. In others, angular fragments of quartz, reddish chert, and fragments of a bright green altered lava are common.

In thin section the tuffs are seen to be composed of faintly bedded, crystal and lithic material. Secondary minerals, such as epidote, zoisite, sericite, calcite, and a fine, unidentified, scaly aggregate, almost completely obscure the original pyroclastic texture. Relict fragments are in some instances outlined by rows of grains of epidote or magnetite, by sericite grouped along the old boundaries, or by differences in texture between the groundmass and the altered fragments. The former presence of rare mafic minerals is suspected from the occurrence of clumps of chlorite and magnetite. Angular to rounded grains of altered albite (An_8) and angular grains and fragments of quartz are scattered through the rock. Extremely fine-grained rock fragments, probably the red, cherty material of hand specimens, occur in irregular masses up to 3 mm. long. Iron oxides are locally abundant.

Water-laid Deposits

Water-laid Ash Beds and Tuffs. In places on Cape St. John, extremely fine-grained ash beds and tuffs, similar to those already described, show stratification and crossbedding, indicating that they were water-laid. The members are usually not more than 10 feet thick. They contain fragments of quartz, bright red chert, rhyolite(?), and andesite, as well as bright green specks thought to be chloritized fragments of lava; and are similar in all respects to the tuffs described above, except that they show sorting and other evidences of water deposition.

Sandstone. In one locality in Seal Island Bight in the Cape St. John region, a thin-bedded quartz sandstone, with muddy parting-planes, shows abundant mud-cracks and ripple-marks. The predominate constituents are quartz, muscovite, and clayey material.

Obscure, trail-like markings found on many of the mud-cracked layers suggest life of some sort, even under the severe conditions of the times. No fossils, however, were found.

Tuffaceous Sandstone. Water-laid tuffaceous sandstones, which are probably the equivalent of some of the fine-grained rhyolite tuffs and ash beds described above, occur throughout the Cape St. John group in the exposures of Cape St. John. The only known exposure inland is on a road about $\frac{3}{4}$ mile north of Shoe Cove. The tuffaceous sandstones are all distinctly bedded, and commonly show crossbedding as well. The great abundance of very fine red chert, the fragments of rhyolite and andesite, and the lack of detrital muscovite, distinguish the tuffaceous sandstones from the sandstones described above, whereas the larger proportion of quartz and the coarser grain distinguish them from the water-laid tuffs.

Moderately Coarse Pyroclastic Rocks and Conglomerates. Conglomerates in which fragments as much as 1 inch long are embedded in a very fine-grained grey-green matrix of quartz fragments and tuffaceous material are of common occurrence in the Cape St. John section. They commonly occur just above and below the tuffaceous sandstone facies described above. The fragments vary from rounded to angular, and include abundant red chert, dense, greenish, chloritized, andesitic and rhyolitic lavas, some minute quartz grains, and a variety of fine, unidentified dark grey particles. Considerable calcite is common in the groundmass, and many specimens effervesce in cold dilute hydrochloric acid. Crossbedding and sorting are common features of these sedimentary rocks.

Coarse Breccias and Conglomerates. Conglomerates with boulders up to 4 feet long were noted at several places in Cape St. John Peninsula. The boulders include rocks of the following types: red rhyolite, with abundant quartz-filled amygdules; red-brown rhyolites similar to those of the thick flows in the Cape Cove region; fine-grained orthoclase porphyry; black, scoriaceous andesite; massive green andesite; fine-grained grey felsite; abundant red chert fragments; mottled purplish lavas, which are in part porphyritic; and considerable tuffaceous and fine sandy material. Much of the groundmass and some of the boulders are coated with a thin layer of hematite, which gives the rock a dark reddish brown colour.

Crossbedding on a large scale is common in these coarse, water-laid deposits. The boulders are commonly well rounded, although some angular fragments were seen. Imbrication was noted in many places.

Scoria Breccia. Breccias, in which the fragments are all of vesicular andesite embedded in a matrix of sandy and tuffaceous material, occur immediately above the tops of some of the andesite flows. In some beds, which may be up to 10 feet thick, the pebbles and cobbles of scoriaceous andesite constitute as much as 50 per cent of the rock. The proportion of scoriaceous material shows a progressive decrease upward in the individual beds.

Slate. In a reconnaissance traverse across the peninsula from Notre Dame Bay to the head of Confusion Bay, Snelgrove noted a thin zone of slate and argillite (82, p. 73). This was not seen by the writer.

Quartz-bearing Conglomerate. Abundant white quartz pebbles occur with the usual assemblage of red chert and volcanic fragments in the conglomerates at Middle Bill, Cape St. John. The quartz pebbles are commonly well rounded, and constitute as much as 30 per cent of the rock.

Chert Beds

Grey and green beds up to 1 foot thick and 100 feet long occur in the Middle Bill region of Cape St. John. The rock is a dense, homogeneous, banded, cryptocrystalline chert, and breaks with a marked conchoidal fracture. The beds are composed of many thin layers, each of which lenses out gradually along its strike. The upper parts of several of the beds were found to be brecciated, and the fragments are recemented with the same cherty material. In some instances, these angular fragments could be fitted into gaps in the layers below, indicating that they did not travel far. The lower parts of the beds are undisturbed. One chert bed grades upward into a conglomerate. Near the boundary between the beds, the pebbles and boulders of the conglomerate are embedded in a cherty groundmass.

The origin of the chert in the volcanic rocks of the Notre Dame Bay region has been discussed in detail by Sampson, who concluded that the abundant lava flows were accompanied by silica-bearing waters from which the chert was precipitated chemically (79, p. 594).

Collins and Quirke (19) described banded silica in the Michipicoten district. It is made up of a succession of thin, non-persistent layers, and in some places shows brecciation of the type described above. These writers believe that the silica was precipitated, probably by evaporation, from pools of magmatic waters that emanated from fissures during the volcanic activity in the area. The chert beds in the Cape St. John group are thought to have originated in much the same way as those in the Michipicoten district. The shallow, crossbedded grits and water-laid tuffs that occur in the group, and the lack of pillow lavas in the flows suggest that the place of deposition was subaerial or possibly marginal marine. The much-disturbed brecciated layers were more probably disturbed by some subaerial agent than by a force operative on the bottom of a submarine basin. The presence of conglomerate boulders and pebbles in the uppermost layers of the chert in one place also suggests that deposition took place in subaerial basins or in shallow marine pools close to shore. The silica-bearing solutions were probably derived by direct emanation from magmatic sources or, perhaps, came from the flows themselves after extrusion.

AGE

The writer considers the rocks of the Cape St. John group to be Ordovician in age. The sedimentary and volcanic rocks of the group are lithologically more similar to the Ordovician rocks of Notre Dame Bay than to any others in northern Newfoundland, and they overlie the Snooks Arm group of known Ordovician age without apparent break.

ENVIRONMENT OF DEPOSITION

It is evident from the occurrence in the Cape St. John group of breccias that contain abundant fragments of scoriaceous andesite derived from the lava flows, and from the occurrence of breccias and conglomerates with fragments of rhyolite and andesite in the same bed, that active erosion was in progress in this region contemporaneously with volcanic activity. The appearance of detrital quartz and muscovite in the sedimentary facies suggests that the streams that fed sediment to this area were eroding crystalline rocks as well as volcanic rocks. The lack of pillow lavas in the andesites of the group suggests that subaerial conditions prevailed during at least part of the time of lava extrusion; and the occurrence of crossbedded and well-stratified, coarse-grained, water-laid deposits indicates that streams were active, and that deposition was taking place in basins at or near the marine shoreline. Ripple-marks and mud-cracks, which were observed in several of the finer grained sedimentary members of the group, show that at some time during their period of deposition the sediments were exposed to the air.

It is evident from the foregoing that the region must have been one of considerable relief, and that the sediments of the Cape St. John group must have been deposited in shallow subaerial basins or in marine basins near shore, near the mouths of streams.

Little is known of the topography of Newfoundland in Ordovician time, and thus there is little to suggest the place of origin of such detrital material as the quartz pebbles. Precambrian highlands have existed in the western part of Newfoundland at least since Carboniferous times, as shown by the pebbles of igneous and metamorphic rocks in the Carboniferous strata of the west coast, but whether or not there were exposures of such crystalline rocks in Ordovician times is not known. It is probable that the metamorphosed sedimentary rocks of the Fleur de Lys and Mings Bight groups were gneisses at this time, but whether or not they were exposed to erosion is uncertain.

In summary, the Ordovician topography of the region probably was one of rugged mountains, with volcanoes of the central vent type in periodic violent eruption, emitting lava flows and abundant pyroclastic material. Large streams carried detrital material from more distant crystalline highlands, and abundant pyroclastic material from this area, depositing their loads at the margins of the sea or in inland basins near the sea.

SERPENTINIZED AND STEATITIZED ULTRABASIC ROCKS

DISTRIBUTION

Serpentinized and steatitized ultrabasic rocks have been observed at several localities in Burlington Peninsula. The individual intrusive masses vary from such as are dykes 20 feet wide and 200 feet long to one mass that is nearly 12 miles long and 200 feet to ½ mile wide. Most of them are tabular bodies, concordant with the rocks that they invade.

GENERAL LITHOLOGY

The ultrabasic rocks of the peninsula were originally peridotite and pyroxenite. In places they are little altered, but generally they are largely or almost completely altered to serpentine, or, less commonly, to talc with associated carbonate.

Where relatively fresh, they are dark green, medium-grained rocks consisting of olivine and pyroxene, with some accessory chromite and magnetite. Olivine predominates in the peridotite. The pyroxenite contains 75 to 90 per cent pyroxene, which may be enstatite alone or may include some monoclinic pyroxene. In the pyroxenites, the olivine is included in the pyroxene and is commonly more or less completely altered to serpentine, whereas the pyroxene is comparatively fresh (cf. Watson, 100, p. 46; Snelgrove, 83, p. 96).

The peridotites show all stages of serpentinization, from rock in which the pyroxene has survived, more or less unaltered, and in which there are remnants of olivine grains, to rock that is more than 90 per cent serpentine. The serpentine occurs as matted aggregates of minute fibres, sheaves, and bundles of larger flakes, and in places as concentrically banded aggregates of radiating fibres. In some partly altered rocks, the olivine remnants appear as isolated islands and rounded aggregates separated by networks of serpentine. Arrangement of the serpentine in bastite structures indicates derivation from pyroxene, and meshworks of secondary magnetite indicate the former presence of olivine. One variety of serpentine, which is especially common in the Red Cliffs occurrence and in the eastern part of the Mings Bight mass, contains abundant, irregular, alined dark patches that in thin section are seen to be clots of finely divided, secondary magnetite.

DESCRIPTION OF OCCURRENCES

The following brief description of occurrences of ultrabasic rocks in Burlington Peninsula is given to point out individual peculiarities.

In the Fleur de Lys area, Fuller (39, p. 15) has described an elongated mass of serpentinized peridotite that intrudes the gneisses of the Fleur de Lys group. Along the margins of the mass, particularly along the foot-wall, and along faults, talc occurs as veins and, together with actinolite, as a general alteration product of the serpentinized rock. Iron-stained magnesite occurs as veins and scattered crystals through the talc facies.

The Duck Island Cove Brook mass is about 2½ miles long and about a mile wide. The Butlers Pond mass is about 1½ miles long and

averages less than ½ mile wide. Both masses are composed of partly serpentinized though recognizable peridotite. Indistinct primary banding or 'pseudostratification' is characteristic of some parts of these masses. Serpentinization has altered about 50 per cent of the olivine and about 20 per cent of the pyroxene crystals (Watson, 100, p. 40).

A mass of much altered ultrabasic rock lies near the north tip of the peninsula between Baie Verte and Mings Bight. Serpentinization is complete. Talc and carbonate facies are common, though no systematic arrangement with relation to the boundaries can be established. At the eastern end of the mass the rock is more than 80 per cent carbonate.

The Mings Bight mass, which extends from the head of Mings Bight southward for about 3 miles to Three Corner Pond, has a maximum width of about 2 miles. Alteration of the original peridotite is nearly complete: the central part of the intrusive body is massive serpentine, but this has been altered to talc-carbonate along the margins and along several fault zones within the mass. The relation of the ultrabasic intrusive rocks to the intruded rocks is well illustrated in the bed of the South Brook of Mings Bight about ½ mile from its mouth. Carbonatization is pronounced in the southeast corner of this intrusive body.

The Red Cliffs mass on the eastern shore of Mings Bight is possibly part of a larger mass beneath the bay. The bulk of the rock is serpentine. Some partly altered peridotite, with remnants of olivine crystals separated by networks of serpentine, was observed at the north end of the exposures, where alteration to talc-carbonate is also prominent. The mass is sheared and faulted.

In the Betts Cove-Tilt Cove area, serpentinized ultrabasic rocks occur in a sweeping arcuate belt about 12 miles long, and from 200 feet to ½ mile wide. In this belt are found peridotite, pyroxenite, and gradations between these rocks and completely serpentinized equivalents. Alteration to talc-carbonate is locally prominent, and primary banding is well displayed in many outcrops.

Along the shore of Notre Dame Bay, southwestward from Nippers Harbour to Stocking Harbour, the altered volcanic rocks of the Nippers Harbour group are intruded by irregular dykes of serpentinized peridotite, which are nowhere more than 20 feet wide. The volcanic rocks themselves show serpentinization in irregular patches from 2 to 100 square feet in outcrop. Occurrences similar to these were also noted in the Snooks Arm group to the northeast. These dykes are not mapped.

SERPENTINIZATION

Local evidence bearing on the process of serpentinization may be summarized as follows:

(1) Serpentinization is confined to the ultrabasic intrusive rocks except in rare cases where tuffs, pillow lavas, and other volcanic rocks have undergone serpentinization, as described previously. This suggests that serpentinization was effected mainly by solutions held within the mass, and not by introduced solutions.

(2) The uniformity of serpentinization throughout any one mass suggests that alteration came from within. Otherwise, localization of the alteration along margins or along faults would be expected. In any serpentinized mass, the relict olivine crystals are uniformly spaced and show approximately the same degree of alteration throughout.

(3) The alteration of the intruded rock is negligible, suggesting a low temperature of intrusion. A 10 to 15 per cent water content in the original magma could account for the low temperature of intrusion and the serpentinization as well (Dresser and Denis, 29, p. 437, et seq.).

Thus, it is concluded that the peridotites were attacked by residual solutions present in the original magma rather than by introduced solutions entering along fissures and channelways. In many other areas similar evidence has led to the same conclusions.

STEATITIZATION AND CARBONATIZATION

Steatitization and carbonatization have affected every ultrabasic mass in Burlington Peninsula except the two that lie west of Baie Verte. Talc and carbonate, the latter of which is usually a ferrodolomite, with varying proportions of iron, calcium, and magnesium, occur as follows: (1) talc schist containing abundant knots of carbonate, hereafter referred to as talc-carbonate rocks; (2) massive talc, and massive carbonate; (3) veins of pure talc or pure carbonate; and (4) carbonatized greenstones, not accompanied by steatitization.

(1) Talc-carbonate rocks that occur along the margins of ultrabasic bodies and in fault zones are usually sheared and slickensided. The talc is white or greenish, and the carbonate occurs embedded in it as brownish crystals 0.3 inch to 3 inches long. Talc-carbonate rocks grade into serpentine rocks. Quartz veins are common in talc-carbonate rocks and are usually rich in carbonate. In thin section, the carbonate appears as irregular masses and partly formed crystals, and the talc in bundles and sheaves of fibrous crystals replacing the carbonate.

(2) Pure talc and pure carbonate rocks may be considered as the end members of a continuously gradational series. In some zones of the marginal talc-carbonate schists, lenses of nearly pure talc occur. They consist of aggregates of nodules of nearly pure, fine-grained, light green talc. The talc in such lenses does not usually show shearing to such an extent as do the schists in which the lenses occur. The Trimms Brook talc prospect, on the eastern side of the Mings Bight mass about a mile southwest of the village of Mings Bight, occurs in a series of such lenses.

Rocks whose composition is 80 to 100 per cent carbonate are found along the eastern border of the Mings Bight ultrabasic mass, in the Devils Cove Pond district, and at various points along the Betts Cove-Tilt Cove serpentine belt. Most easily accessible is the exposure at Red Cliffs. Here, along the shore, the bright reddish brown weathered surface of the carbonate rock is conspicuous against the dull grey-green of the rocks of the Baie Verte group and the meta-diorites. The rock is composed almost entirely of carbonate, with little or no talc. Quartz occurs as small grains, which replace

the carbonate; on weathered surfaces they stand out in relief and produce a sand-paper effect. Quartz also forms conspicuous veins and irregular masses, some of which are vuggy and contain clear quartz crystals with abundant needle-like inclusions of rutile.

(3) Veins of pure carbonate and pure talc are exposed in a few places along the contacts of the altered ultrabasic rocks. In the valley of the South Brook of Mings Bight, about half a mile from its mouth, several veins of talc and carbonate cut the gneiss and slate of the Mings Bight group. The central parts of the veins are pure talc; the margins contain knots and crystals of brownish carbonate, which extend beyond the walls of the veins into the wall-rock. Along small faults and slip zones in the talc-carbonate facies of the altered peridotites, veins, as much as 6 inches thick, of sea-green talc in cleavable masses up to 3 inches in diameter are common. Veins of carbonate penetrate all the rocks of the district except the later intrusions. Masses of actinolite schist 4 to 6 feet long, which are exposed in the bed of the brook, bear an unknown relation to the serpentinization and steatitization in this area, but presumably represent a high temperature facies of alteration.

(4) Carbonatization is characteristic of the metamorphism of the rocks of all types in the region between Baie Verte and Pacquet. Carbonatized parts of the Baie Verte formations are commonly chloritized, and in many places are crumpled and schistose. In such rocks, which weather brown, the carbonate occurs as disseminations and as irregular veinlets. Carbonatization has also affected the meta-diorites, particularly along shear zones. The most strongly carbonatized rocks, however, are the ultrabasic rocks described above. They were thus either more susceptible to alteration, or were closer to the channelways of migration of solutions, which brought about the alteration, or both. The formation of carbonate in the ordinary processes of regional metamorphism is distinct from this flooding of certain areas with carbonate.

RELATION OF THE ULTRABASIC ROCKS TO STRUCTURE

Each of the masses of ultrabasic rock in this region is concordant with the formations it intrudes. In other regions similar concordance is characteristic (Hess, 56, p. 639; Dresser and Denis, 29, p. 415, et al.).

The Fleur de Lys serpentine body is a concordant, sill-like mass that parallels the general strike and dip of the Fleur de Lys group. It is not, apparently, related to any of the major structures of the peninsula, and is offset by the east-west faults of the district.

The two masses of serpentinized peridotite west of Baie Verte are essentially concordant, and occur near the axial part of an irregular syncline in the Baie Verte group. Several small, dyke-like bodies of serpentine near the Terra Nova mine at Baie Verte are near the axis of the same syncline. All the masses are cut by later faults.

The serpentinized and steatitized peridotite on the peninsula between Baie Verte and Mings Bight may possibly be an inclusion in a large meta-diorite sill. The few strikes available in the adjacent greenstone indicate that it is a concordant intrusion.

The eastern and western margins of the Mings Bight mass parallel the general trend of the Baie Verte and Mings Bight rocks. The western end of its southern boundary is a series of interfingering lobes most of which are concordant with the trend of the formations. The eastern part is more complex. Here the mass has been intruded by meta-diorite, and its eastern boundary is apparently a fault. The alinement of clots of magnetite in the serpentine, mentioned above, is parallel with the boundaries of the mass, and further suggests that the intrusion is concordant. This large mass occurs near the axial zone of an irregular syncline in the Baie Verte group. The small Red Cliffs serpentinized peridotite mass is not far from the axial part of an anticline in the Mings Bight group. It may, however, be an apophysis of a larger mass that once occupied Mings Bight and that was continuous with the Mings Bight mass.

The long, arcuate, serpentine belt in the Tilt Cove-Betts Cove region is for the most part a concordant intrusion. The ultrabasic rocks were intruded along the boundary between the tightly folded Snooks Arm group on the south and east, and the Cape St. John group on the north and west. Toward its southern end, however, the serpentine belt swings across the belt of greenstones near the boundary of the Snooks Arm and Nippers Harbour groups, and may follow a major fault.

AGE

Snelgrove considered that the peridotites and pyroxenites of the serpentine belt of the Betts Cove-Tilt Cove area were part of the same cycle of igneous action as were the other intrusions of the region (83, pp. 10-15). He classified the whole complex as of Acadian age, but adduced no evidence either for the grouping together of the various intrusive rocks or for the assignment of an Acadian age. By analogy with the similar regional geology of the Eastern Townships of Quebec (29) the ultrabasic intrusive rocks might be of Taconic age. The age of the other altered peridotites and pyroxenites in Newfoundland are also not definitely known. On the west coast they are known to be pre-Mississippian, but Cooper (23) suggests that they were intruded at the close of the Ordovician, whereas Ingerson (59) suggests a Devonian age.

The Baie Verte and the Snooks Arm groups, both of which are intruded by the ultrabasic rocks, are probably of Ordovician age. The serpentinized peridotites must, therefore, have been intruded in post-Baie Verte time, which could be late Ordovician or post-Ordovician. If the carbonatization and steatitization of these rocks were accomplished by solutions from the main granitic intrusions of the area, the ultrabasic intrusions are pre-late Devonian in age. The serpentinized masses have been involved in the later mountain building processes, as they are tilted, faulted, and sheared heavily on the margins. It is, therefore, concluded that the serpentinized ultrabasic rocks are post-Baie Verte (Ordovician) and pre-late Devonian in age.

DIORITE, META-DIORITE, AND META-GABBRO

INTRODUCTION

In the northeastern part of Burlington Peninsula, numerous small dykes, sills, and irregular masses of diorite, meta-diorite, and meta-gabbro intrude the rocks of the Baie Verte group. The largest

masses lie west of Baie Verte, between it and Mings Bight, and northeast of La Scie. Several small, irregular masses are exposed south of Mings Bight in the Three Corner Pond district.

Most of the intrusive bodies are concordant, sill-like masses in general outline, although locally their boundaries may cut across the foliation of the intruded greenstones. They range from narrow, transgressing dykes to well-defined, wholly concordant sills.

The sills commonly show well-defined composition banding or pseudostratification. At some places the rocks of this group can be distinguished only with difficulty from the greenstones derived from the alteration of lava flows, but in most exposures the intrusive rocks are more massive and much more coarse grained.

LITHOLOGY

The weathered surfaces of these basic rocks are usually greenish grey. On fresh surfaces, such as those exposed along the sea-cliffs northeast of La Scie, the rock is darker, and the contained feldspars stand out in sharp contrast.

These rocks consist of saussuritized plagioclase feldspar and uralitized pyroxene or hornblende in about equal proportions. The plagioclase, which occurs as subhedral laths as much as 1 inch long, showing albite and Carlsbad twinning, commonly constitutes from 25 to 40 per cent of the rock. Its composition varies between albite and basic andesine; at one place in the sill that lies northeast of La Scie strongly zoned crystals have cores of andesine (An_{38}) and rims of albite-oligoclase (An_{12}). The plagioclase is usually altered to a mass of albite, epidote, zoisite, calcite, and an unidentified scaly aggregate. In most of these rocks no recognizable pyroxene remains. Hornblende, pleochroic in greens or blue-greens, and largely a product of the alteration of pyroxene, comprises 35 to 60 per cent of the rock; some of it is altered to actinolite and chlorite. The amphibole commonly occurs as anhedral masses that occupy the spaces between the feldspar laths, in a roughly sub-ophitic arrangement that is somewhat obscured by later alteration products. Biotite, straw-yellow to dark olive-brown, occurs in twisted lamellae and scattered flakes that constitute as much as 10 per cent of the rock. Accessory minerals include calcite, apatite, epidote, magnetite, and calcite. Introduced quartz, with strong undulatory extinction and rows of inclusions, was observed in one thin section. A zone in which magnetite constitutes about 30 per cent of the rock occurs in the meta-diorite sill just east of Rettis Cove, near La Scie. Pyrite is abundant in some exposures.

Pegmatitic Facies

Pegmatitic facies are common, and may best be observed in the cliff exposures near Rettis Cove, east of La Scie. The coarse-grained facies occur as sharply defined, dyke-like masses or irregular bodies, with gradational contacts, within the finer facies. At several places, particularly near Rettis Cove, crystals of saussuritized feldspar and uralitic hornblende are as much as 2 inches long. In some places in the same region considerable differences in grain size mark the primary bands, so that it is not uncommon to find

layers of medium-grained meta-diorite alternating with layers of pegmatitic meta-diorite. Nor, in the pegmatitic zones, is it uncommon to find that differentiation is more marked than in the ordinary zones, so that light-coloured layers, which consist almost exclusively of saussuritized plagioclase feldspar, alternate with dark layers consisting almost entirely of coarse hornblende crystals. It is probable that the boulders of pyroxenite and hornblendite observed in places in this region are fragments of the dark, massive, hornblende-rich bands of the meta-diorite and meta-gabbro.

ALTERATION

The original pyroxenes of the meta-gabbros are almost everywhere uralitized to actinolitic hornblende. In the meta-diorites, the hornblende may be altered to actinolite and chlorite. The feldspars are invariably saussuritized, and are obscured by a fine-grained mass of albite, zoisite, epidote, and an unidentified, fine, scaly aggregate. In the Baie Verte region, local alteration has produced a zoisite-prehnite rock that has been described by Watson (100, p. 57). Silicification occurs in some areas, and near the ultrabasic masses the meta-diorites and meta-gabbros are locally altered to carbonate and talc.

INTRUSION BRECCIAS

At Rettis Cove, a swarm of dykes, veins, and more massive bodies of irregular outline intrude the coarse-grained dioritic rocks and form what is termed intrusion breccias. Their order of intrusion is: diorite, pegmatitic diorite, diorite 'aplite', diabase, quartz-rich diorite, quartz porphyry, granite, granite aplite, and quartz veins.

The diorite pegmatites and aplites do not form breccias with the intruded diorites. Fine-grained quartz diorite, whether in minute stringers or thick masses, almost invariably penetrates and splits off parts of the wall-rock.

AGE

The basic intrusive rocks are younger than the ultrabasic rocks of the region. This is shown conclusively at several localities by the occurrence of dykes of meta-diorite intruding serpentinized peridotite. At the Red Cliffs on the east side of Mings Bight, a dyke of altered diorite about 130 feet wide cuts the ultrabasic rock. The meta-diorite is veined by carbonate, which suggests that the diorite was intruded before the ultrabasic rock had been carbonatized and steatitized. A zone of aggregates of radiating talc crystals, varying from 1 inch to 1 foot in thickness, commonly lies between the diorite and the unaffected serpentinized ultrabasic rock, and is the result of later alteration along a contact that afforded access to rising solutions.

The common occurrence of dykes and sills of meta-diorite and meta-gabbro with chilled edges in the Baie Verte, Snooks Arm, and Nippers Harbour groups shows that these intrusive rocks post-date the volcanic rocks.

The granitic rocks of the region are younger than the meta-diorites and meta-gabbros. In the Baie Verte region, an offshoot of the Burlington granite complex has altered the meta-diorite within its contact zones. At Seal Island Bight, near the tip of Cape St. John, a small mass of granite porphyry has offshoots that cut meta-diorite. At Rettis Cove, a complete series of granitic satellite rocks intrude the meta-diorite.

BURLINGTON GRANITIC ROCKS

INTRODUCTION

The name 'Burlington' is here proposed for those medium-grained granites and granodiorites that are exposed in the southwest part of Burlington Peninsula and that extend southwestward beyond the map-area. The actual boundary between these rocks and the Cape Brulé granite porphyry is not defined.

LITHOLOGY

The Burlington granite is generally massive, light coloured, and medium-grained, and weathers a light colour. It is commonly stained greenish yellow where exposed on the coast, due to the action of sea water. In other places a green colour is due to epidote.

In hand specimens, the granite is seen to be composed of white and pink feldspar, clear glassy quartz, black or dark green hornblende and biotite, irregular masses of brown sphene, and epidote. Foliation, though uncommon, is faintly developed in places.

In thin sections, the following minerals have been noted: feldspar, 50 to 65 per cent; quartz, 10 to 25 per cent; hornblende, 5 to 15 per cent; biotite, 5 to 10 per cent; and accessory minerals, 5 to 7 per cent.

Etching with hydrofluoric acid and staining with sodium cobaltinitrite indicates that more than 75 per cent of the feldspar is potassic, and largely orthoclase, but some microcline was noted. Plagioclase is albite, An_7 to An_{12}, and is not prominently zoned. Quartz occurs in irregular interstitial masses, and in places shows undulatory extinction. Swarms of needle-like inclusions of rutile(?) occur in the quartz of some specimens. Hornblende occurs through the rocks as subhedral masses as much as 3 mm. long. Biotite occurs in clumps and aggregates up to 2 mm. in length. It is commonly partly altered to chlorite, and in such places contains abundant magnetite in fissures and along the cleavage lines. Inclusions of zircon are commonly surrounded by pleochroic haloes. Abundant, needle-like inclusions (possibly rutile) are arranged along two crystallographic directions in the biotite masses. In places, alteration of the feldspars has produced a scaly aggregate in which some sericite is recognizable.

Various facies of the batholith have different compositions, and granite, biotite granite, hornblende granite, granodiorite, and quartz diorite have been recognized. The great bulk of the mass, however, is granite as described above.

RELATION TO INTRUDED ROCKS

The general trend of the known part of the outlines of the Burlington granite complex indicates that it conforms in shape to the general northeast structural trend in the peninsula, although many small apophyses and offshoots of the main mass cut indiscriminately across the structural trend of the intruded rocks. The small peninsula between Stocking and Burlington Harbours is about half underlain by altered volcanic rocks of the Nippers Harbour group and about half by intrusive rocks, which are largely granite but include many dykes of diabase, aplite, lamprophyre, diorite, fine felsic rocks, and rhyolite. The northwestern boundary of the granite complex conforms to the general trend of the greenstones of the area, though many minor masses of granite occur interfingered with the greenstones. The Burlington granitic complex is, consequently, considered to be mainly concordant, with minor apophyses that may be either concordant or discordant.

INCLUSIONS

Inclusions are uncommon in the main body of Burlington granite. In some of the small offshoots, however, as for example along the shore between Burlington and Stocking Harbours, inclusions may comprise as much as 50 per cent of the rock, and the mass has the appearance of a breccia. The inclusions are mainly of the adjacent, pre-granitic rocks, but in one outcrop east of Garden Cove several inclusions of pink granite-gneiss, of a type common in Precambrian areas and unknown in place on this peninsula, were observed. These may be fragments of the basement complex brought up from depth during intrusion, and thus may indicate the nature of the basement in this district.

STRUCTURE

The foliation in the interior of the Burlington granitic mass is not mapped. Where observed, it appeared to strike northeast, except in the region south of Burlington where the general trend is about north 80 degrees west. The most prominent set of joints in the latter area parallels this foliation, which dips steeply to the north. In the interior of the mass little indication of foliation was observed, but thin sections indicate a slight preferred orientation. In many of the small masses cutting the greenstones, foliation parallels the contacts, though in most outcrops it is only faintly developed.

OTHER ROCK TYPES

Along the coast of Notre Dame Bay from Rouge Harbour southward to the southernmost limit of mapping, at the mouth of the Southwest Arm of Green Bay, a complex of intrusive rocks is associated with those of the Burlington granite complex. The order of intrusion of the dykes and small intrusive masses appears to be as follows, beginning with the oldest: (1) gabbro, pyroxenite, and peridotite; (2) diorite; (3) granodiorite; (4) granite and quartz-rich varieties of granite; (5) rhyolite porphyry series; (6) aplites; (7) pegmatites; (8) diabase; and (9) lamprophyres.

Gabbro, Pyroxene, and Peridotite

Small dykes and masses of these rocks, which are similar to those described elsewhere in this report, are exposed along the shore of Notre Dame Bay, particularly just north of Stocking Harbour. Some of these small masses have been serpentinized.

Diorite

Diorite occurs in sills and small dykes, cutting the rocks of the Nippers Harbour group. It is a greyish green rock composed largely of white plagioclase feldspar (An_{38}) with a small amount of chloritized hornblende. It is similar to the altered diorites of the Mings Bight-Baie Verte district, which were previously described.

Granodiorite, Granite, and Quartz-rich Granite

These are part of the main mass of the complex which has already been described in detail. They occur commonly as dykes and small stocks without chilled margins.

Rhyolite and Rhyolite Porphyry

A variety of reddish or brownish, fine-grained, intrusive rocks occur in dykes and irregular stock-like masses from a few feet wide to half a square mile in area. They cut all the rocks of the region except the minor dykes. The rocks of this class, which are common at, and near, Burlington, are usually conspicuous owing to their bright pink colour.

The fine-grained texture of these rocks indicates emplacement at shallow depths. Some masses contain calcite-filled amygdules. Grain size varies from those with tiny phenocrysts barely visible to the naked eye to others that are entirely cryptocrystalline. Coarser types resemble the porphyries of the Nippers Harbour district in that they show partly resorbed phenocrysts of quartz, orthoclase feldspar, and albite in a fine-grained, reddish groundmass.

North of Burlington and near Middle Arm, some of the rhyolitic rocks have the appearance of flows. Reconnaissance indicates that there is a gradation from porphyries containing abundant phenocrysts and not conspicuously banded to very fine-grained, reddish and brownish rocks with no phenocrysts and showing conspicuous flow bands. The rock commonly splits easily parallel with these bands, and the fact that no intrusive relations between the banded, flow-like rock and the intrusive porphyries were observed suggests the possibility that the former represent flow equivalents of the intrusions. Some of the fine-grained rhyolites in Cape St. John Peninsula possibly represent the intrusive equivalents of the rhyolite masses that are known to be flows in that area. More detailed field work in both these areas will be necessary before definite conclusions regarding the relations of these rocks can be drawn.

Aplites

Very fine-grained, light pink dykes, with visible feldspar crystals, are tentatively termed aplites. Some of them carry small

inclusions of the adjacent intruded rocks. Pyrite is common as small irregular masses and cubes.

Pegmatites

On a small point southwest of Stocking Harbour, several small pegmatite dykes were observed. They are composed of quartz, orthoclase feldspar, albite, muscovite, and clusters of garnets. The average grain size is not more than 2 inches.

Diabase Dykes

Diabase dykes are not common as part of the Burlington granite complex except in a small area along the shore of Notre Dame Bay between Rouge Harbour and Middle Arm, where they are abundant. The dykes, all of which are nearly vertical, show a marked parellelism, and trend north 35 to 60 degrees east throughout the district.

In hand specimens, the diabase is a compact, fine-grained rock of fresh appearance. In thin section, it is seen to consist of plagioclase feldspar and augite, with sub-ophitic texture. The plagioclase feldspar laths are strongly zoned, ranging from basic andesine (An_{44}) in the cores to intermediate oligoclase (An_{18}) on the rims. The pyroxene is pigeonitic augite ($2V=45^{o}$). Alteration has produced abundant fibrous actinolite, chlorite, small amounts of calcite, and a fine-grained, undetermined, scaly aggregate in the feldspars. The accessory minerals include slender rods of apatite, small subhedral grains of magnetite, dark brown biotite, and small grains of epidote.

Lamprophyre Dykes

The youngest intrusive rocks of the Burlington granite complex are lamprophyre dykes, which are especially abundant between Stocking Harbour and the entrance to Burlington Harbour. On weathered surfaces, they are light brown. Feldspar crystals, which are more resistant to weathering than the other constituents of the rock, are etched out on weathered surfaces and appear as a tangled aggregate of grey-brown fibres.

The rocks are composed of euhedral phenocrysts of augite, and some hornblende in a groundmass of lath-like microlites of plagioclase feldspar, with abundant accessory minerals and considerable chlorite. Augite (extinction angle, 51°) occurs in clear, colourless, octagonal prisms up to 9 mm. in length. Most of the augite crystals show strong zoning, and some are twinned. Common hornblende occurs through the rock as euhedral and subhedral grains, usually smaller than the augite, but up to 3 mm. in length. The augite comprises about 40 per cent of the rock and the hornblende about 20 per cent.

Feldspar microlites (An_{38} to An_{40}) constitute most of the groundmass. They display no regular pattern except, in a few places, a faintly developed trachytic flow structure. Accessory minerals include epidote, magnetite in irregular masses, chlorite as an alteration product of the mafic minerals, sericite, calcite, and a fine, scaly alteration product of the feldspars.

CAPE BRULÉ GRANITE

INTRODUCTION

The name 'Cape Brulé granite' is here proposed for a mass of medium-grained porphyritic granite that occupies at least 75 square miles in the northeast part of Burlington Peninsula. Snelgrove proposed the term 'Burtons Pond granite porphyry' for a small part of the mass included in the extreme southwest part of his Betts Cove-Tilt Cove area (83). However, it is felt that the new name is better, as the granite is not exposed at Burtons Pond; the exposures nearest to Burtons Pond are not readily accessible; and rock more typical of the whole is exposed at Cape Brulé and for about 2½ miles along the coast.

The Cape Brulé granite is part of an intrusive complex that extends from the northern part of the peninsula for at least 40 miles to the southwest, and possibly farther to join the granite batholiths of central Newfoundland. The granite body is irregular in outline and is about 10 miles long by 10 miles wide. It is bounded on the north, northeast, east, and southeast by older volcanic and sedimentary rocks and on the southwest by other rocks of the intrusive complex.

LITHOLOGY

The Cape Brulé granite is distinctive, and composed of cloudy grey eyes of quartz and phenocrysts of feldspar, which average 3 mm. in diameter, set in a fine-grained greyish groundmass. It weathers light grey, and the phenocrysts stand out in relief on the surface. Gneissic banding is prominent in some places near the contacts, and has been observed as much as 1 mile from them.

Thin sections show that the phenocrysts of quartz and feldspar are embedded in a fine-grained groundmass of quartz, feldspar, chlorite, epidote, and calcite, and are generally embayed by the minerals of the groundmass. The quartz grains are clear, euhedral crystals, which average about 2 mm. in length and seldom exceed 3.5 mm. Strain shadows are not marked. Occasional trains of minute, unidentified inclusions were observed. Phenocrysts of orthoclase are about the same size as those of quartz. Carlsbad twinning is prominent. Microcline phenocrysts, showing fine grating structure, occur sparingly through the rock. Albite phenocrysts (An_{7-10}) showing good polysynthetic twinning are rare. Embayment of crystals that were formerly euhedral has produced very irregular outlines in some cases. Most of the feldspar phenocrysts are altered to a scaly aggregate containing some recognizable sericite and calcite.

The average grain size in the groundmass is 0.05 to 0.10 mm. in most specimens, but may be 0.25 mm. Chlorite and altered biotite form small wisps and flakes in the groundmass, and vary in amount from a trace to 10 per cent, and sericite and calcite replace the groundmass as well as the phenocrysts. Epidote and calcite are especially abundant in the border facies.

Accessory minerals include magnetite, in well-developed octahedra and irregular patches; some zircon, giving pleochroic haloes to biotite and chlorite; muscovite, in irregular wisps and patches; and apatite and an unidentified brown accessory mineral,

which occurs rarely. This last mineral is one of high relief, with brown to almost opaque pleochroism, absorption greatest where the long axis is parallel with the polarizer, and with a birefringence not greater than low second order; it is uniaxial and negative.

MARGINAL FACIES

A distinctive marginal facies has been noted near the boundaries of the Cape Brulé granite at many localities, and is characterized by 'eyes' of cloudy, grey quartz in a strongly foliated, sericitic groundmass. The texture of this marginal granite is almost completely metamorphic. A mosaic texture is displayed by masses of serrate-edged quartz crystals in the groundmass. The marked foliation, produced by elongated shreds of muscovite and biotite and by lenticular aggregates of quartz with minor albite, 'flows' around the large quartz 'eyes', which probably were originally phenocrysts. It is apparent, from the lack of cataclastic structures and the parallelism between the foliation and the margins of the granite, that shearing took place during the cooling stages of the granite.

In thin section, quartz, which occurs both as grains up to 2 mm. long, and in much smaller grains as part of the groundmass mosaic, comprises about 60 per cent of the rock. Biotite, which is pleochroic in straw-yellow to dark brown colours, occurs as irregular wisps, with dense pleochroic haloes around minute inclusions of zircon. Albite, which rarely shows polysynthetic twinning, occurs in crystals scattered through the rock as part of the groundmass aggregate. Calcite occurs in interstitial masses up to 2 mm. across, and rarely as minute veinlets. Accessory minerals include epidote, apatite, opaques, zircon, and a fine scaly aggregate of alteration products.

RELATION TO INTRUDED ROCKS

Inclusions of intruded rock are common near margins of the Cape Brulé granite. From Pacquet Harbour to the Rambler district the marginal facies zones of the granite carry many inclusions of Baie Verte volcanic rocks. In the Confusion Bay area, inclusions are so plentiful that the rock resembles a volcanic breccia. Some of the inclusions are large and may possibly be roof pendants; the largest noted had an area of about $\frac{3}{4}$ square mile and lay east of Beaver Pond.

The dip of the contact between the granite and the invaded rocks is variable: at Gooseberry Cove, 4 miles southeast of Pacquet, a vertical contact is visible; from the Beaver Pond district westward toward the Rambler mine the contact dips gently toward the north; and in the Cape Brulé region the dip is steep to the west.

The numerous inclusions and roof pendants, the various angles of dip of the contact, the fine-grained facies in certain areas such as south of Confusion Bay, and the many small stocks and bosses of granite porphyry intrusive into the older rocks of the district along the margins of the mass, all suggest that the batholith is not deeply eroded.

Foliation and lineation are marked in the marginal facies of the Brulé granite in most places, and are more prominent on the northern and western sides than on the eastern and southern sides.

The foliation commonly parallels the boundaries of the mass and the trend of the rocks in the adjacent formations, suggesting that the batholith was intruded during the last stages of a period of folding affecting the volcanic and sedimentary rocks of the district.

STOCKS AND BOSSES

Numerous small masses of granite porphyry bearing some resemblance to the main mass, occur throughout the map-area. They may be divided into two classes; those that contain much sericite in the groundmass and in which the foliation is more pronounced than it is in the main mass; and those in which the phenocrysts are larger than in the rock of the main batholith and are set in a dense, fine-grained, reddish groundmass.

Small masses of granite porphyry intruding the rocks of the Cape St. John and Baie Verte groups in the La Scie district are similar to the rocks of the main mass of the Cape Brulé granite, except for a greater degree of sericitization of the groundmass. Phenocrysts of feldspar and cloudy grey quartz are set in the markedly foliated sericite-rich groundmass. Inclusions of the invaded rocks are very common in some places, and are usually elongated in the plane of foliation. Fragments of greenstone are commonly chloritized.

A series of small, concordant masses of medium-grained granite porphyry occur along a line joining Nippers Harbour to Stocking Harbour. Clear, euhedral quartz crystals up to 5 mm. long are corroded on the edges and deeply embayed along cracks and irregular channels. All gradations were observed from euhedral crystals with good boundaries to shapeless, octopus-like masses. Inclusions in the quartz are common. In some of the fluid inclusions, minute bubbles were observed to be in constant motion. Euhedral crystals of orthoclase feldspar up to 12 mm. long and commonly showing Carlsbad twinning, are all altered to a scaly aggregate in which sericite, epidote, and carbonate can be recognized. Albite occurs as altered, polysynthetically twinned crystals, and few large microcline crystals were observed. Late-stage albitization of the potassic feldspars is common. Myrmekite was observed in some thin sections. Quartz phenocrysts in some places show perlitic cracks and a banding due to inversion from beta-quartz to alpha-quartz, which suggests that the temperature of consolidation was above 575°C. The groundmass is fine-grained, and consists of quartz and feldspar, with rare magnetite, chlorite, and epidote. The average grains size is 0.1 to 0.2 mm. Irregular clumps of chlorite, with magnetite and epidote, may indicate the former presence of mafic minerals. A minute veinlet of chlorite, epidote, magnetite, and some muscovite was observed in one thin section.

Several dykes of greyish granite porphyry cut greenstones on the shore between La Scie and Seal Island Bight. Similar dykes intrude rocks of the Cape St. John group between the northwest side of Seal Island Bight and Middle Bill. In hand specimens, equidimensional phenocrysts of white feldspar and grains of clear quartz, averaging about 2 mm. in diameter, visibly make up about 70 per cent of the rock. Pyrite occurs uniformly distributed through it. In thin section, the phenocrysts are seen to be strongly embayed, and the feldspars, which are mostly orthoclase but include some albite (An_8), are, in addition, altered to a very fine-grained aggregate, which is white in reflected light and probably accounts for the milky white colour in hand specimens. The strong odour of the rocks

suggests that the alteration is to kaolin in part. Aggregates of minute reddish unidentified spots (probably hematite) occur in some places. The groundmass of these dykes is finer grained than the average for that of the other types of porphyry, being less than 0.05 mm. Chlorite is common in the groundmass, and its parallel arrangement shows the strong foliation in the rock. Pyrite occurs as masses of irregular outlines, and is usually associated with zones rich in chlorite.

In one reddish quartz-orthoclase porphyry near Red Cliff Pond, clouds of minute specks of hematite occur throughout the rock. The abundant hematite may have originated as a result of resorption of mafic minerals in the manner described by Bain (5, p. 379).

DUNAMAGON GRANITE

INTRODUCTION

The name 'Dunamagon granite' is here proposed for the stock of medium-grained pink granite and its satellitic bodies, which together occupy an area of about 9 square miles, and lie between Pacquet Harbour and the head of Mings Bight. The granite mass stands out above the surrounding country as an irregular highland. The ridges are largely bare rock, and large accumulations of granite boulders occupy many of the depressions.

The rock has a characteristic pink colour and a granitic texture. In many places it is foliated. Usually the colour is unchanged by weathering, except in a few places where the rock is bleached a pure white to a depth of about $\frac{1}{8}$ inch. Weathering has produced a rough granular surface on most outcrops; thus no glacial striae are preserved.

LITHOLOGY

The granite is not uniform in texture or composition. Feldspars may vary from 5 mm. in length to as much as 15 mm.; the groundmass is composed of fine-grained quartz and feldspar, with no mafic minerals, whereas in others biotite may constitute as much as 20 per cent of the rock; and foliation may be marked, or almost lacking.

The following essential minerals are seen to occur in thin sections: microcline and orthoclase, 40 to 60 per cent; quartz, 25 to 40 per cent; biotite, 2 to 20 per cent; and albite, 3 to 10 per cent.

Quartz occurs in aggregates of irregularly interlocking grains, which show conspicuous Boehm lamellae and undulatory extinction. Trains of inclusions, some of them liquid and some of an unidentified dark mineral in dust-like particles, occur commonly in some specimens. The quartz is interstitial to the large feldspar grains.

Microcline crystals as much as $\frac{3}{4}$ inch in length and of irregular outline commonly show characteristic grid twinning on a fine scale. Albite (An_{7-10}) occurs as minor, small crystals. Alteration of the feldspars has produced a scaly aggregate in which sericite and epidote are recognizable. Perthitic intergrowths

are common, and tear-drop intergrowths of myrmekite were observed in some thin sections. Fissures in the large feldspar crystals are commonly filled with secondary albite.

Biotite occurs in clumps and patches, which are attenuated parallel with the foliation, and characteristically shows many pleochroic haloes. Apatite and titanite are common accessory minerals, and are almost always associated with biotite. Much of the biotite is partly altered to chlorite, and the latter also occurs scattered through the rock as irregular wisps and shreds.

Occasional patches of a brownish, gel-like material were observed in thin sections, and probably represent an iron oxide. Magnetite occurs as well-crystallized octahedra, and as abundant irregular masses apparently developed during the alteration of biotite to chlorite.

STRUCTURE

Foliation is prominent at many places in the Dunamagon granite mass, and is faintly developed in others; it bears no relation to the proximity of boundaries, but may be as common in the middle parts of the mass as near its contacts. Nor does it everywhere parallel the contacts of the batholith, some observations on the southern and western boundaries indicating that the foliation is at an angle to the trend of the contacts. Before adequately discussing the general pattern of the foliation a much more detailed study of the mass would be necessary.

Foliation is marked in thin sections of the granite by the parallel arrangement of the mafic minerals, such as biotite and chlorite; by the directions of elongation of the blebs in the intergrowths; and by the directions of the trains of inclusions in the quartz grains.

Jointing in the granite is irregular. One set of prominent joints is nearly parallel with the surface, whereas steep dips and irregular strikes are characteristic of others.

The boundaries of the Dunamagon granite generally parallel the trend of the intruded formations. The north and west contacts of the granite follow closely the bedding of the Mings Bight group; the southeast side follows that of the Baie Verte group; and the southwest end appears to lie in the axis of an anticline that plunges to the southwest at about 40 degrees.

The Dunamagon granite is believed to be a correlative of the Cape Brulé granite. Both granites post-date the main folding of the Baie Verte rocks, and both are largely concordant with the structures of the formations they invade. They are of generally similar mineral compositions, and no other petrographic evidence suggests that they are of widely different ages.

GRANITE NEAR L'ANSE OF PARDI

A small, satellitic body of the Dunamagon granite, about ½ mile wide and a little more than 1 mile long, outcrops in the steep hills on the east side of Mings Bight, north of L'Anse of Pardi. It is similar in all respects to the main mass of the Dunamagon granite described above, except that it is finer in grain. Dykes

of the granite, which show no chilling and no effects on the wall-rocks, are exposed on the shore of Mings Bight about $\frac{1}{4}$ mile north of L'Anse of Pardi.

GRANITE AT PARTRIDGE POINT

Granite occurs at the tip of Partridge Point as a dyke-like mass, about 1 mile long, with numerous dykes and offshoots. Microcline is the most abundant feldspar, with minor amounts of sodic plagioclase. Quartz and muscovite are the other essential minerals, and garnet is the most common accessory mineral. Granitic pegmatites and aplites intrude both the granite and the adjacent older rocks.

PEGMATITE DYKES AND SILLS

Numerous pegmatite dykes and sills occur in a zone $1\frac{1}{2}$ miles wide that extends northwest from Pacquet to Cape Hat. The dykes are as much as 20 feet wide and 3,000 feet long, but generally are much smaller. They are largely concordant with the formations they intrude, but crosscutting dykes are not rare. Only the largest are shown on the map.

These pegmatites are composed largely of feldspar and quartz, with minor muscovite and biotite, and accessory garnet, smoky quartz, and tourmaline. The composition of the dykes varies considerably, and gradations exist from those of nearly pure feldspar to those that could be termed quartz veins. The feldspar is orthoclase, microcline, albite, and perthite, and graphic intergrowths of quartz and orthoclase were observed in some of the smallest dykes of this region. Although commonly distributed uniformly, biotite has been noted in crystals up to 6 inches across and may form as much as 30 per cent of the rock. Greenish muscovite occurs in some dykes as crystals from 1 inch to 3 inches across. Most of the quartz is of the milky variety, but glassy and smoky varieties also occur.

On the southeast side of Handy Harbour, a pegmatite dyke from 8 to 15 feet wide is exposed on a small point. This dyke contains fragments of the intruded rocks in which foliation is parallel with that of the adjacent wall-rock gneisses. This may be taken to indicate that the intrusion of the dykes took place after the principal period of folding of the Mings Bight group.

A mass of pegmatite of irregular outline is exposed on the north side of Handy Harbour, and varies in width from 40 feet near the shore to 10 feet inland, where it splits into several narrow offshoots. In mineral composition it is essentially microcline and perthite with muscovite and some garnet. The feldspars may be as much as 2 feet long. The body cuts indiscriminately across the gneisses and has little visible effect on the wall-rock. It carries fragments of the adjacent gneisses whose foliation is parallel with that of the wall-rock.

An irregular mass of pegmatite outcrops about $\frac{1}{4}$ mile south of Teakettle Cove. The mass is about 1,800 feet long and varies in width from 2 feet at the inland end to about 100 feet near the shore. This body was mentioned by Snelgrove (82) as a possible source of feldspar. It is of further interest inasmuch as a pocket of tourmaline crystals was observed in it near its seaward extremity.

The pegmatite dykes are considered to be related to the Dunamagon granite. Their mineral composition - mostly pink microcline and orthoclase, quartz, and minor albite and micas - is very similar to that of the granite, and their occurrence as near as 500 feet to the granite contact also suggests a genetic relation.

GRANITE DYKES

At several localities north of the Dunamagon granite, fine-grained, light-coloured dykes composed of feldspar, quartz, and accessory dark minerals intrude the rocks of the Mings Bight group. The largest of these with a maximum width of 30 feet, is on the shore about ½ mile southeast of Teakettle Cove, where it intrudes the Mings Bight gneisses irregularly. Another similar body, about 30 feet wide and 1,000 feet long, is exposed about 3,000 feet northwest of Pacquet.

These rocks are pink on fresh surfaces, and weather to a neutral grey. The average grain size is less than 1 mm. In thin section, albite (An_{8-11}) constitutes about 30 per cent of the rock. Carlsbad twins of orthoclase are common. The feldspar crystals are replete with swarms of minute, unidentified, opaque inclusions, which are commonly irregular and rarely rod-shaped. Bent lamellae were observed on one albite crystal. Quartz, which constitutes about 20 per cent of the rock, occurs as interstitial masses of irregular outline, without strain shadows or Boehm lamellae, and with irregular inclusions. Calcite forms 15 to 20 per cent of the rock, and occurs as irregular interstitial patches and as small veinlets cutting it. Magnetite and apatite are abundant accessory minerals. Minute shreds and flakes of chlorite and some epidote were observed.

RELATIONS OF THE GRANITIC INTRUSIONS

Though no positive proof can be offered, it is suggested that the various granitic intrusions on Burlington Peninsula are the result of progressive differentiation from a single igneous source. The Cape Brulé granite porphyry, with its abundant orthoclase phenocrysts and sericitic groundmass, represents a stage beyond that of the main mass of Burlington granite that extends far south of the limits of mapping to join the main batholiths of central Newfoundland. The Dunamagon granite and the Partridge granite, rich in potassic feldspar and poor in mafic minerals, are the results of still further differentiation, and the pegmatites and aplites of the northern parts of the peninsula are the end products of the process. The general distribution of these rocks, with progressive differentiation towards the northeast, suggests that intrusion was from the southwest.

QUARTZ VEINS AND SILICIFICATION

Quartz veins are common in the rocks of the Burlington Peninsula. The following types are recognized:

(1) Quartz-sericite-magnetite veins, usually related to apophyses of the Cape Brulé granite.

(2) Quartz-pyrite-chalcopyrite veins, which are common in some areas

close to the main granite mass or near small stocks. The sulphides are usually more abundant near the walls of the veins. These veins are the only ones in the district that carry minerals of economic importance, both copper and gold being present.

(3) Quartz-fuchsite veins were found (78, p. 23) in some of the carbonatized greenstones near the ultrabasic bodies in the Three Corner Pond area. Fuchsite occurs both in the quartz veins and in the adjacent wall-rock. These veins were noted only in the region south of Mings Bight, where abundant ultrabasic rocks occur. It is suggested that the chromium in the fuchsite may have been derived from the chromite that occurs as an accessory mineral in the ultrabasic intrusive rocks.

(4) Quartz-carbonate veins, usually without sulphides, are very common in the greenstones of the area. Epidote commonly accompanies them. They are also found in the ultrabasic rocks.

(5) Large, barren replacements, such as one on the eastern side of Mings Bight, consist of massive quartz grading outward into the adjacent gneisses and schists.

(6) Clear, glassy quartz veins occur commonly in the granites.

Most of the quartz veins of the district are undoubtedly related to the intrusion of the granite masses. Not only are they more abundant near the contacts of these masses, but they commonly occur within them. Markedly silicified zones almost invariably occur within a few hundred feet of the contact of the main granite masses or of apophyses from them, but certain irregular masses and clots of quartz, particularly common in the older gneisses and in the Baie Verte group near Pacquet, may be the result of metamorphic differentiation.

ECONOMIC GEOLOGY

INTRODUCTION

Burlington Peninsula has long been known as a mineralized area favourable for prospecting. In the period between 1870 and 1910, four successful mines flourished, and although they represented small operations by modern standards, they contributed largely to making Newfoundland an important copper producing country of the time. The active mines and the periods of their operation were: the Tilt Cove West mines, 1864 to 1912; the Tilt Cove East mine, 1888 to 1912; the Betts Cove mine, 1875 to 1883; and the Terra Nova mine at Baie Verte, to the west of the map-area, 1862 to 1907. In addition to these copper mining operations, a gold mine was operated unsuccessfully west of Mings Bight, between 1902 and 1906. Large sums have been spent in the past 5 years (prior to 1947) on the Rambler prospect east of Baie Verte. Surface work has been done and shallow shafts sunk on most of the prospects shown on the map accompanying this report.

Each of the mines ceased operations when the high-grade ore had been mined. Methods of extraction and transportation employed at the time necessitated selective mining and hand-picking the ore,

and the productivity of each of the mines would have been greatly increased if modern flotation methods of ore separation had been available. At the Tilt Cove West mine, about 100,000 tons of 2 per cent copper ore lies on the dumps, and 250,000 tons of similar ore is untouched in the old workings above sea-level (Williams, 102, p. 117).

GENERAL DESCRIPTION

The copper deposits of the region are mesothermal, replacement deposits in greenstones derived from the alteration of lava flows of Ordovician age. Mineralization is commonly in evidence along shear zones where chlorite schist is developed. Pyrite, with chalcopyrite and lesser amounts of other sulphides, forms veins, irregular replacement lenses, and disseminations in the sheared greenstones, and quartz and carbonates are usually present in small quantities as gangue minerals. Chloritization and silicification commonly attended the formation of the copper deposits.

Snelgrove has stressed the importance of dioritic intrusive rocks in the mineral deposits of the Betts Cove-Tilt Cove area. In a classification of these deposits he has grouped them under two headings, those associated with the dioritic rocks and those associated with the granitic rocks. He suggests that the relationship is "spatial and inferentially genetic", and that "the role of these intrusive rocks is conceived ... as that of a conduit for the solutions which deposited the ore rather than as the parent rock of the ore solutions themselves" (83, pp. 36-39). In a later publication (86, p. 53) Snelgrove states that "a genetic relationship between the diorites and the ore bodies is ... indicated". The present writer suggests that the copper minerals have been derived from emanations from the abundant granitic rocks of the region.

Copper minerals were observed in one place near Burlington in the granite itself. The granites and granodiorites of the area occur within a surface distance of three-quarters of a mile or less from every known copper deposit. Dioritic rocks and gabbroic rocks on the other hand occur near only two mines, those at Betts Cove and Tilt Cove.

The structural setting of the copper deposits of the Notre Dame Bay coast of Burlington Peninsula has been clarified by the discovery that every prospect from Burlington to Snooks Arm lies on the Stocking Harbour fault or a subsidiary shear zone.

WALL-ROCK ALTERATION

The most common type of wall-rock alteration is chloritization. Every copper prospect on Burlington Peninsula and, indeed, in much of Notre Dame Bay, consists of lenses, veins, and irregular replacements in such chloritized shear zones.

Snelgrove, from a study restricted to the Betts Cove-Tilt Cove region where dioritic rocks are common, stresses the importance of these rocks in their relation to both chloritization and mineralization. However, because chlorite has formed at many places where diorites are lacking, and because granite bodies occur throughout the district, it appears more probable to the writer that

chloritization was accomplished by emanations from granitic magmas.

Silicification has affected the wall-rocks at many places. At the 'Gold Pit' of the Rambler prospect, introduced quartz comprises more than 75 per cent of the rock; the principal ore mineral is pyrite, and values are in gold. Other silicified, pyrite-bearing zones occur along the shores of Confusion Bay.

Mild sericitization of the wall-rock has affected the lead-zinc deposits at Betts Cove and Walsh Cove, and sericitization is marked at several places on the Rambler property. The specularite-bearing quartz-vein deposits at the north end of Snooks Arm Western Pond are partly silicified and sericitized.

GANGUE MINERALS

Gangue minerals are prominent at very few of the copper prospects of the district. At the Rouges Harbour prospect, at Rouge Harbour, the chalcopyrite is associated with a quartz vein from 10 to 30 feet wide. At Burtons Pond, small quartz veins, most of which contain some calcite, occur with the mineral deposits. In the massive sulphide replacement deposits, such as Tilt Cove, Betts Cove, and the Terra Nova mine at Baie Verte, late-stage quartz veins, with accessory carbonate, are common, but are rarely more than 1 inch wide.

In the lead-zinc deposits at Betts Cove and Walsh Cove, quartz, calcite, and talc are the gangue minerals. Calcite, which is not commonly abundant in the ore deposits of the region, comprises more than half the vein material at Betts Cove. Fluorite was observed at one place at the Rambler prospect.

In this report, detailed descriptions of prospects are given only for those for which the writer has new information. For detailed descriptions of the others the reader is directed to the references shown in the bibliography.

STOCKING HARBOUR FAULT

The Stocking Harbour fault is believed to have a direct bearing on most of the mineral occurrences on the southeast side of Burlington Peninsula, and as reference will frequently be made to it, a brief description of it will be given here.

The Stocking Harbour fault is the most prominent fault along the coast of Notre Dame Bay. It is marked along its entire length by a sharply delineated depression, which is most conspicuous in the Stocking Harbour-Rouge Harbour district. It has been traced from a point just north of the head of Middle Arm of Green Bay northeastward to a point northeast of Betts Cove, a distance of more than 20 miles.

In the region south of the White Hills of Burlington, a gulch along this fault is followed for several miles by the stream that enters Burlington Harbour from the southwest. The gulch is steep walled and narrow, and the rocks in the walls show fracturing and shearing but little other direct evidence of the fault. The fault follows the two arms of Burlington Harbour, the elongated arms of Stocking Harbour, and the southwest arm of Rouge Harbour. Sheared

and slickensided volcanic rocks were observed in the fault zone near the copper prospect at Rouge Harbour. At the head of a small cove, three-quarters of a mile southwest of Walsh Cove, the fault is exposed in a cliff and displays a vertical sheared and mashed zone about 30 feet wide, but from which the direction of movement cannot be determined. The fault trace passes northeastward under the isthmus at Walsh Cove and across the mouth of Nippers Harbour, along Burtons Pond, and then follows a depression to where it disappears north of Betts Cove.

Evidence from the field and from air photographs suggests that a branch of this fault continues along the band of serpentinized ultrabasic rocks southwest of Betts Cove. The serpentinized rocks are everywhere sheared and in many places schisted. The topographic breaks that mark the position of the fault to the south continue into both the Betts Cove mine area and into the belt underlain by the ultrabasic rocks.

Several copper prospects lie along the Stocking Harbour fault and its subsidiary shear zones. The Garden Cove prospect lies only a few hundred feet from the fault in complementary shear zones. The Shiners Prospect at Stocking Harbour lies on subsidiary shear zones visibly related to the main fault. The prospect at Rouge Harbour lies within a few hundred feet of the fault, and part of it is along the fault zone itself. The Betts Cove mineralized area, which supported mining operations for more than 10 years, lies within 1,000 feet of the main fault, at the intersection of two shear zones, one of which is parallel with the main fault. Another strong topographic depression, which probably marks another major fault, parallels the Stocking Harbour fault about a mile northwest of it, between Stocking and Nippers Harbours.

DESCRIPTIONS OF OCCURRENCES

ROGUES HARBOUR PROSPECT

The Rogues Harbour prospect, so-called from the local pronunciation of Rouge Harbour, where the prospect is located, was first opened in 1899. The writer visited the property in 1945.

The deposit is a mineralized quartz vein, which ranges from 10 to 30 feet in thickness and has been traced for about 2,700 feet, cutting amphibolites and altered volcanic rocks of the Nippers Harbour group. It trends southwest from the head of the western arm of Rouge Harbour for approximately 1,000 feet, then swings southward for about 1,700 feet. It dips at a high angle to the eastward. Diamond drilling indicated that the deposit is not persistent in depth. The ore minerals are chalcopyrite, pyrite, pyrrhotite, and a little galena. Assays by Douglas (28, p. 97) showed traces of gold and up to 1.24 per cent of copper.

The amphibolitic rocks in the vicinity of the deposit are intruded by small plugs of quartz porphyry, and silicified zones were observed at several places. Near the veins these rocks show slickensides and shearing. The Stocking Harbour fault is close to, or coincident with, the vein at its northeastern end. Some of the movement along this fault occurred after the intrusion of the granite porphyry, as the small masses immediately adjacent to the fault have been sheared. In the deposit itself the sulphide minerals are offset by tiny faults.

BETTS COVE MINE

This abandoned mine was visited by the writer in the summer of 1945, and again in 1946. The latest and most authoritative descriptions of the mine are those of Snelgrove (83, p. 39) and Douglas (28, p. 22).

The rocks in the vicinity are pillow lavas, massive andesites, and pyroclastic rocks of the Snooks Arm group. These trend north-northeast, dip steeply, and are intruded by small bosses of diorite and quartz diorite. One small mass of olivine gabbro outcrops about 2,800 feet south of the mine, and 2,000 feet to the northwest is a mass of serpentinized ultrabasic intrusive rocks. Dykes of lamprophyre, olivine diabase, and pyroxenite occur within ½ mile of the mine, and the main Cape Brulé granite mass is exposed 1 mile to the northwest.

The ore shoots occur in chloritized shear zones in the pillow lavas. Pyrite, chalcopyrite, and sphalerite, which were introduced in that order, replace the chlorite schist. The mineralization has, heretofore, been thought to be genetically related to adjacent masses of diorite, which are slightly mineralized in places, but the writer believes that the ore-bearing solutions probably came from the granite.

The Stocking Harbour fault passes through a small pond within 1,500 feet of the old Betts Cove mine. The small inset sketch appearing on the accompanying geological map shows the main lineaments of the area as viewed from air photographs, and, in addition, the known faults and shear zones. In one system the lineaments cross the district from east to west; in another they trend generally parallel with the northeasterly extension of the Stocking Harbour fault. Both systems are prominently exhibited in the immediate neighbourhood of the mine, and the trends of the known shear zones of the region coincide with one or the other of the lineaments of the two systems, establishing beyond reasonable doubt that these lineaments are structural breaks in the rocks of the region.

There is little direct evidence near the Betts Cove mine itself of the major Stocking Harbour fault, except the great topographic lineament that continues to the southwest for some 20 miles. However, at the north side of the head of Betts Cove a considerable shear zone coincides with the lineament, which is assumed to be the trace of the fault.

That most of the breaks of the region are steeply dipping is indicated by the fact that they show little deviation in direction in spite of a topographic relief of more than 400 feet. This is particularly well seen in the trace of the main Stocking Harbour fault, which rises from sea-level at Betts Cove to the adjacent hills without changing direction appreciably.

It seems apparent that the easterly trending shear zones are related to the main Stocking Harbour fault, and that the mineral deposits are situated at the junction of fractures of this system with those of another system that parallel the main fault.

MOUNT MISERY

On the northeastern side of Betts Cove, several parallel shear zones in chloritized pillow lavas lie close to the assumed

position of the Stocking Harbour fault. The schistosity in the lavas trends about northeast and dips steeply to the southeast. Little bedrock is now exposed in the mineralized zones, but in the dumps, nodules and irregular lenses of pyrite and chalcopyrite, with some pyrrhotite, indicate that the mineral deposits have the form of irregular replacements of the chlorite schists in the shear zones. A geophysical survey carried out by Douglas indicated that there is little likelihood of finding a large body of ore in this prospect (28, p. 64).

The mineral deposit lies in the Stocking Harbour fault zone, and is probably related to this major fault system. Similar mineralized shear zones occur at the Lowlands, about a mile south of Betts Cove mine.

BETTS COVE LEAD-ZINC PROSPECT

A mineralized zone outcrops on a hillside west of a small swamp about 6,500 feet due west of the head of Betts Cove. The deposit occurs in a lobe of altered volcanic rocks of the Snooks Arm group, which is bounded on the west by a tongue of the Cape Brulé granite and on the east by altered ultrabasic rocks. The volcanic rocks were originally of andesitic composition, but have been partly altered to chlorite, serpentine, and talc.

Development work has consisted of about 300 feet of trenching and stripping, and sinking a shaft about 35 feet deep. The rocks exposed at the shaft and trenches are sheared and broken along a vertical zone that trends easterly. Slickensides, and crumpled chlorite and serpentine schists are common. A fissure-type vein, 4 to 6 inches wide, lies in the shear zone, and is approximately parallel with the foliation of the schists. Pyrite and chalcopyrite occur in the central part of the vein, and sphalerite and galena are more abundant near the walls. Quartz and calcite are gangue minerals, and may comprise up to 50 per cent of the vein material. Polished sections indicate that pyrite, chalcopyrite, sphalerite, and galena were deposited in about that order. A similar vein, about 3 inches wide and dipping to the northeast at about 40 degrees, is exposed near the level of water in the shaft. Scattered pyrite stringers cut the volcanic rocks in the northeastern wall of the trench that trends southeastward from the shaft. There is no indication of other mineralization in the surrounding region.

Little wall-rock alteration accompanied mineral deposition. Sericitization is prominent near some parts of the vein, but it has not affected the wall-rocks beyond a few inches from the vein.

On the dumps, there is nothing to indicate that larger veins or more abundant ore minerals were encountered during development. The prospect does indicate, however, that deposits carrying copper, lead, and zinc are represented in the district.

BURTONS POND PROSPECT

This prospect lies about 100 yards northeast of the outlet of Burtons Pond, which is between Nippers Harbour and Betts Cove. Work on the property has included the sinking of four shallow shafts and considerable trenching and stripping.

The mineral deposit is in altered volcanic rocks of the Nippers Harbour group, with serpentinized ultrabasic rocks about 300 feet to the west. The volcanic rocks have been cut by a fault that strikes about north 30 degrees east and dips steeply to the northwest.

The prospect consists of disseminated pyrite, with some chalcopyrite and sphalerito, in irregular veins and as replacements of the chloritized greenstones, and associated with veins of quartz and carbonate that are rarely greater than 1 inch thick. The lenses of sulphides are as much as 3 inches thick and 1 foot long. A grab sample taken by Rove (28, p. 33) contained some gold, silver, and arsenic as well as copper.

The prospect is located on a shear zone subsidiary to the Stocking Harbour fault, which lies about 500 feet to the west.

SHINERS PROSPECT

This prospect is on the northwest side of Stocking Harbour. Development work includes a half dozen shafts, up to 40 feet deep, and a considerable amount of stripping and trenching.

The deposit occurs in rocks of the Nippers Harbour group, which have been intimately intruded by several small, irregular granite dykes. Mineralization occurs along an irregular set of shear zones that trend about northwest and lie within a fault block between the Stocking Harbour fault and a parallel fault a little less than a mile to the northwest. The mineral-bearing shear zones are apparently complementary to the major faults.

The wall-rocks are not notably altered, but are partly chloritized and silicified in places. The mineral deposits consist of irregular veins and lenses of pyrite, chalcopyrite, and pyrrhotite, with small quantities of sphalerite and galena in the chloritized schist. A little quartz and calcite comprise the only gangue minerals.

GARDEN COVE (Jennings) PROSPECT

This small prospect, near the east entrance to Burlington, was trenched and a shaft sunk about 40 years ago, according to local residents.

The rocks are sheared and amphibolitized volcanic members of the Nippers Harbour group, intruded nearby by abundant granitic dykes and offshoots of the Burlington granite. The shaft is not more than 20 feet deep and is now inaccessible. Rock on the dump is slickensided and sheared, chloritized and partly silicified greenstone, mineralized mainly by pyrite, but containing small veins of later chalcopyrite and accessory pyrrhotite. It is not a promising prospect.

PACQUET COPPER PROSPECTS

Copper prospects occur at several places at Pacquet Harbour. The most important is located at high-tide level on the east side of the harbour, near the southernmost houses of the village.

At the back of a natural recess in the cliffs, an inclined shaft was driven about 30 feet deep, some 40 years ago. The shaft is now completely filled with wave-washed shore debris. Pyrite, chalcopyrite, and magnetite occur in pockets and lenses as much as 1 inch thick and 6 inches long in an irregular zone about 25 feet long and 6 feet wide.

The mineralized rock is chlorite and hornblende schist of the Baie Verte group, and is not far from the contact of the Mings Bight group. Locally, the rocks strike about north and dip at low angles to the east. The schists have been invaded by aplite dykes and are cut by quartz and calcite veins. The aplite occurs as irregular sills and dykes up to 8 feet thick, which are foliated parallel with their walls. They consist of very fine-grained aggregates of orthoclase and quartz, and contain numerous flecks of pyrite and chalcopyrite. The quartz veins, which are as much as 6 inches thick, carry chalcopyrite and cut the aplite intrusions. The calcite stringers are up to $\frac{1}{8}$ inch thick, and are the youngest veins.

On the south side of the harbour, a brecciated fault zone in hornblende-chlorite-garnet schists is cut by numerous barren quartz veins, which contain abundant chloritized fragments of the schists. This locality is locally referred to as "the mine". Nearby, in the low cliffs, several quartz veins carry small amounts of pyrite and chalcopyrite. Adjacent aplite dykes, which are strongly foliated parallel with their walls, carry numerous flecks of pyrite and chalcopyrite. The constant association of the sulphide-bearing aplites with the copper deposits in Pacquet Harbour suggests that they are related in origin. The Dunamagon granite, which is exposed along the northwest shore of the harbour, is cut by numerous fine-grained aplite dykes that were presumably derived from the main granite mass, whereas the Cape Brulé granite, which is exposed about 1,000 feet to the south of the mineralized zones, has no aplites associated with it. The aplites are thus believed to have been derived from the Dunamagon granite.

These small, mineralized zones are important only in that they show that some copper mineralization accompanied the intrusion of the nearby granite masses.

NIPPERS HARBOUR PROSPECT

The Nippers Harbour prospect is situated in the hills about one-quarter mile north of Nippers Harbour. It is a mineralized zone in dark, chloritized lava of the Nippers Harbour group, and follows a well-defined depression, that, from the abundance of slickensided chlorite schist along it, probably marks the course of a shear zone. Mineralization has resulted in the replacement of the chloritized lavas by pyrite, chalcopyrite, and some pyrrhotite. Small quartz veins constitute the only gangue. Development consists of one shaft about 20 feet deep and some trenching. No commercial quantities of ore are in sight.

WALSH COVE

At Walsh Cove, just south of Nippers Harbour, pyrite, chalcopyrite, and galena occur in greenstones of the Nippers Harbour group. The mineralized area is now completely covered with beach debris. A flooded and caved shaft of unknown depth was sunk

just above high-water mark near the east end of the beach.

Several dykes of quartz-orthoclase porphyry, which are related to the main mass of rhyolite porphyry about 200 feet to the north, intrude the greenstones, and may be responsible for the mineralization. Material from the dump indicates that the sulphide minerals occur in quartz veins less than an inch wide, as thin lenses replacing the chlorite schist, and as disseminations in the wall-rock. Nowhere were indications of a large deposit seen.

WOODSTOCK BROOK

Small quartz veins intersect Baie Verte greenstones just west of Woodstock in the bed of a small brook. They carry pyrite and traces of chalcopyrite, but at no place is the concentration of sulphide minerals sufficient to warrant development work.

MINGS TICKLE

Several veins and irregular masses of quartz, averaging about 18 inches in total thickness and about 50 feet in length, outcrop in the Mings Bight group just north of the fishing shacks at Mings Tickle. Pyrite and chalcopyrite occur on the margins of the quartz veins and in the adjacent wall-rock. The prospect is not considered to be of economic importance.

SNOOKS ARM PONDS

Specularite occurs at several places in the Snooks Arm Pond-Red Cliff Pond district. In each place quartz veins intersect altered lavas or pyroclastic rocks of the Snooks Arm group, except near the northern end of Snooks Arm Western Pond where they occur in rocks of the Cape St. John group. Pyrite, chalcopyrite, and small pockets of galena commonly accompany the specularite.

TILT COVE

The writer visited Tilt Cove in the summer of 1945 and has only to report that since the latest recorded visit, that of Douglas in 1940, this once active mining town has almost completely disappeared. The ramp leading down to the wharves from the East mine, all the mine buildings, and the town that once flourished on the shore of Windsor Lake, have been demolished.

TERRA NOVA

Watson (100) has described in detail the copper-bearing pyrite ores of the Terra Nova mine at Baie Verte and to the west of this area. The stockpile of ore, estimated as 20,000 tons by Rove (28, p. 18) and commonly considered an asset to future mining in the region, caught on fire in the autumn of 1945, and despite repeated efforts to put it out has continued to smoulder. When the writer visited the site in the late summer of 1946 the ore pile was nearly unapproachable due to the great heat and the sulphurous fumes.

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