THE GEOLOGY OF THE BURLINGTON PENINSULA, NEWFOUNDLAND

by

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The Geology of the Burlington Peninsula, Newfoundland

The results of geological mapping of a large area on the north coast of Newfoundland, and of supplementary laboratory studies, are presented in this report. In addition the problems of correlation of results from this and adjacent areas are given considerable attention.

The history of the coastal region has been found to be considerably more complex than previously assumed.

It has been established clearly for the first time that during the last glaciation the ice moved northward over this region.

Several new rock formations have been named and described and ones previously known have been extended and correlated.

Structural studies have revealed considerable new information, some of which bears an important relation to the control of ore deposition in this region.

Several prospects have been described for the first time and new information has been gathered on some of the older properties.

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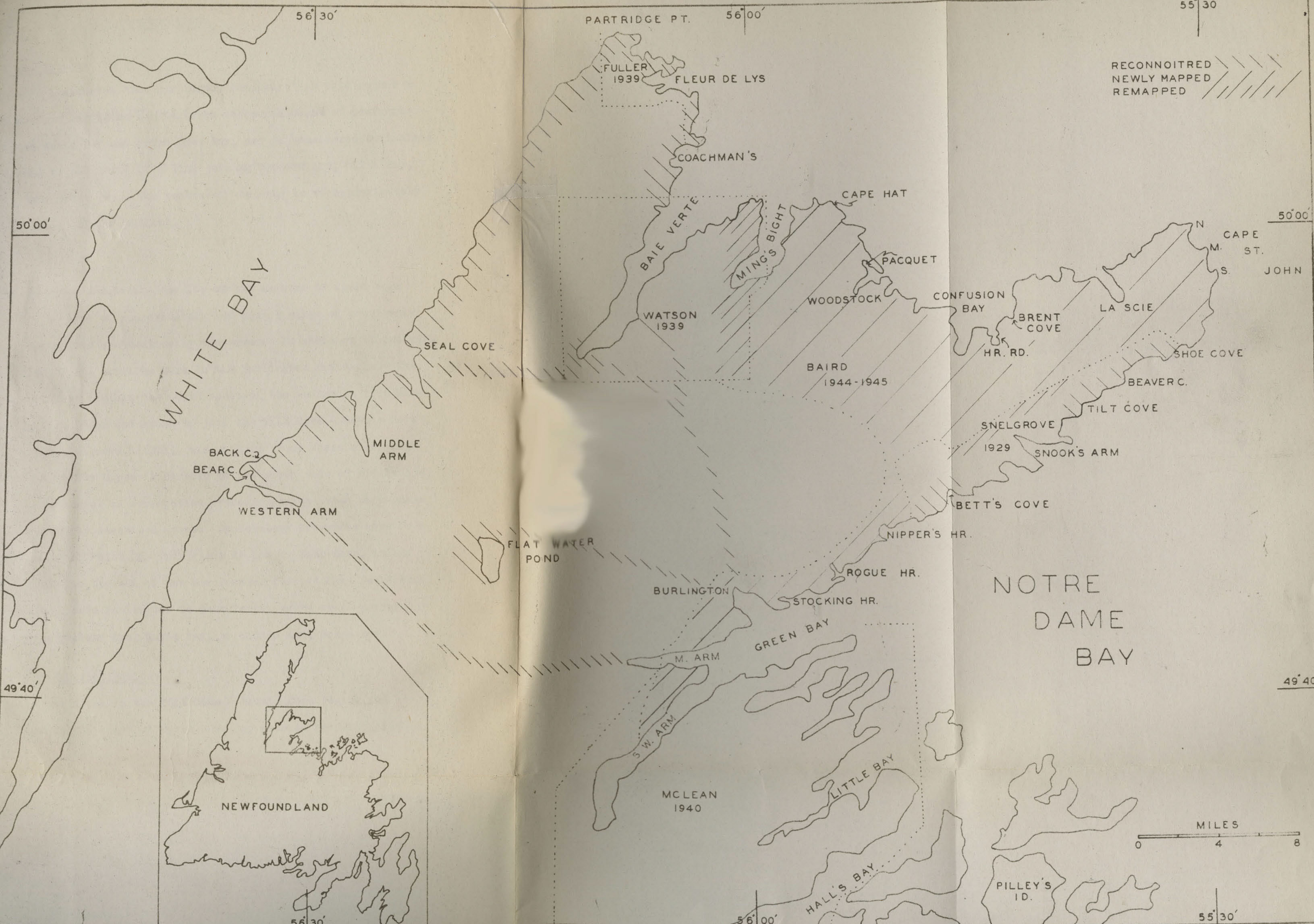


PLATE I

BURLINGTON PENINSULA

INTRODUCTION

Location and Extent:

The area designated "the Burlington Peninsula" in this report is shown in outline in figure 1. It is on the north coast of Newfoundland between White Bay and Notre Dame Bay, and is considered to include all 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 49° 53' N. Lat., 56° 03' W. Long.

Scope:

This report presents the results of two summers of field work during which an area of approximately 140 square miles of previously unmapped country was systematically traversed. In addition it includes a correlation of all previous work in the Burlington Peninsula. The newly mapped areas include the north coast of the peninsula from Ming's Bight to Cape St. John and south to join the Tilt Cove - Bett's Cove area mapped by Snelgrove, (1931), and a strip about three miles wide along the coast from Nipper's Harbour to the south side of Middle Arm, Green Bay. To assist in correlation, reconnaissance trips were taken into the previously described areas. Exploratory traverses were made along the shore of White Bay from Fleur de Lys to Bear Cove, inland from Burlington to the end of the new Bowater road at Flat Water Pond, along the trail from Burlington to Baie Verte, and a trans-peninsular traverse from Western Arm, White Bay, to Middle Arm, Green Bay.

Purpose of the Investigation:

The copper mines in the Tilt Cove - Bett's Cove region and southward along the coast of Notre Dame Bay were in active operation until the close of the nineteenth century. Interest has been high in the possibility of reviving the mining industry in this part of Newfoundland. The Baie Verte region, within which lies the old Terra Nova copper mine, has recently attracted attention as the result of the exploration of the gold-copper-lead-zinc prospects at the "Rambler" (see plate 12 for location). Minor deposits of lead-zinc and molybdenite 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 the Burlington peninsula.

Field Work:

The writer, accompanied by two laborers, spent the summer seasons of 1944 and 1945 in the area. Day to day work was done with aerial photographs, using a stereoscope, which provided a good, three-dimensional picture of the area and a ground control in this unmapped country. Maps on various scales were later drawn by the Geological Survey of Newfoundland from aerial photographs. In the field the geology was plotted directly onto the aerial photographs and later transferred to the maps. Most of the coastline was traversed on foot, but boats were necessary at some places such as the Cape St. John district where the land rises sheer from the sea. There are no roads inland, except near the villages, where short trails provide some access to the interior. The six mile tote road south from Woodstock, and the Woodstock-LaScie-Shoe Cove trail along the telegraph line proved useful.

Accessibility:

Travel in this part of Newfoundland is entirely by water, except in the winter months when some overland travel is possible by dogteam.

For short, sea 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" on the St. John's - Cornerbrook run, calls at ports in the 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 the Geological Survey, is via the Newfoundland Railway to Badger, taxi to South Brook, thence by chartered boat to points north. This is the most dependable route and involves a minimum of delay. At present there are no throughgoing roads in the area. However the Bowater-Lloyd Company is at present building a road southward from Baie Verte to connect with the Humber system in the vicinity of Howley on the Newfoundland Railway. In the late summer of 1945 the road had reached the southern end of Flat Water Pond.

Culture:

The Burlington Peninsula is a sparsely settled part of Newfoundland. A summary of the principal settlements is given below. The population figures have been taken from the census of 1935, and all have been modified somewhat to account for changes in the last ten years.

Settlement	Pop'n	Occupations	Communication	Steamer, mails
Western Arm, WB.	85	Fishing, Woodcutting	Telephone	-----
Bear Cove	70	Fishing	-----	-----
Seal Cove	200	Fishing	Wireless	Twice monthly
Fleur de Lys	300	Fishing	Telephone	Twice monthly
Coachman's Cove	275	Fishing, Woodcutting	Wireless	Twice monthly

Settlement	Pop'n	Occupations	Communication	Steamer, mails
Baie Verte	200	Woods Industries	Wireless	Twice monthly
Ming's Bight	120	Fishing	-----	-----
Pacquet	200	Fishing, Trading	Telephone	Twice monthly
Woodstock	200	Fishing, Woodcutting	Telephone	-----
Harbor Round	120	Fishing	-----	-----
Brent Cove	200	Fishing	Telephone	Weekly mail
La Scie	600	Fishing, Trading	Wireless	Weekly mail, steamer twice monthly
Shoe Cove	175	Fishing	Telephone	Weekly
Nipper's Hr.	400	Fishing, Trading	Wireless	Weekly
Burlington	225	Woods Industries	Telephone	Weekly
Middle Arm	140	Woods Industries	Telephone	-----

Agricultural land is scanty in the district. Coachman's Cove, Baie Verte, La Scie and Burlington each have a few acres. In the other settlements the small gardens 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 the abundant lakes and bogs.

Effects of Resources on Settlement:

In the Burlington Peninsula, as in much of Newfoundland, settlers have turned to the sea for their livelihood because of the barrenness of the interior and the small amount of arable land. Glaciation has left little more than the bare rock on the hills and there is very little drift in the valleys. The sites of early settlements were chosen entirely for the suitability of harbors and their nearness to the fishing grounds. Thus each of the glaciated depressions, now drowned and forming good harbors, was early settled.

Between 1860 and 1880 the rise of copper mining in the district brought settlement to Tilt Cove, Bett's Cove and the Terra Nova district of Baie Verte, and flourishing towns sprang up. With the decline and closing of the mines about 1900 these settlements disappeared almost completely.

The growth of the woods industries in the last twenty-five years has influenced settlement considerably. Burlington early became the scene of a flourishing lumbering industry, but is now declining. Baie Verte is expanding rapidly as the centre of pulp-cutting operations for the Bowater Company.

If the Rambler prospects develop into operating mines, either Burlington or Baie Verte will become the supply centre and shipping port. The district can easily supply the necessary labor and the establishment of a new mining industry might go far to relieve the depressing living conditions in many of the smaller villages in the district.

Forests:

A large part of the 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 Ming's Bight and Pacquet, including most of the outcrop area of the Dunamagon granite and the Ming's Bight gneisses, was swept clean by fires some 45 years ago, according to local residents. Nowhere do the serpentinized, ultrabasic rocks support forest growth for the reasons discussed under "Serpentinized and Steatitized Ultrabasic Rocks". Much of the region underlain by the Cape St. John volcanics and the Cape Brule granite is barren. In the Burlington district forest fires have laid bare large areas of rock. 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 woods grow where glacial drift is thick enough to offer a foothold. Most of the pulpwood and pitprops 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 areas of Newfoundland as poor in agricultural resources as the Burlington peninsula. The incredible barrenness of some of the inhabited places on this coast is illustrated in such villages as Pacquet and Nipper's Harbor, both major settlements, where there is not a single field greater than fifty feet square (See Fig. 1). Burlington, LaScie, Woodstock, Baie Verte and Coachman's Cove have sufficient cultivated ground to supply their basic needs, but other villages must import a large proportion of their staple foods.

There is little hope in the 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 ground will perhaps be found in some of the greenstone areas. The introduction of good agricultural methods and the development of a successful technique for the growing of crops on drained bogland would greatly assist this poor agricultural region.

Historical Resumé:

Attention was first drawn to the geology of this area by the discovery of the Tilt Cove and Bett's Cove copper deposits. The Tilt Cove deposits were discovered in 1857 by Smith MacKay, who was then exploring the coast, and the Bett's Cove mineralization was found shortly thereafter (Murray, 1867, p.116). Since the beginning of active operations at the Tilt Cove properties in 1864 (ibid. p.116) many reports have been made on the copper-bearing rocks of the eastern side of the Burlington 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 the Ming's Bight - Baie Verte region and also to the rocks at Western Arm, White Bay (1864, p.18, etc.). In the report of the Geological Survey for 1867 Murray described in some detail the rocks in and about the Union Mine (Tilt Cove) and mapped an adjoining area of about fourteen square miles. According to Snelgrove (1930, p.5) the maps made at this time including a general map of the rocks along the coast from Nipper's Harbor to La Scie, were destroyed in a fire at the Crown Lands office some years ago. In 1875 Murray made a reexamination of certain parts of the Notre Dame Bay district, including the Bett's Cove Mine, then opening up (1875, 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 (1877) gave a brief description of the topography and rocks encountered on a traverse from 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 (1872), Wadsworth (1884) with Newfoundland's first microscope petrography (Ref. Snelgrove 1929), Garland (1888), and de Launay (1894).

The Princeton expeditions of 1915, 1916 and 1917 contributed much information, as yet unpublished, on the geology of the Burlington Peninsula. In 1923 Sampson discussed the origin of the ferruginous cherts in the volcanic rocks of the Notre Dame Bay region. Eardley-Wilmot discussed the molybdenite and copper deposits of the Fleur de Lys area in 1925. Snelgrove's paper, "The Central Mineral Belt of Newfoundland" was published in 1928. In 1931 the same writer presented a summary of the available information on the Tilt Cove - Bett's Cove region. The first modern detailed work in the Burlington Peninsula, "The Geology and Mineral Deposits of the Tilt Cove - Bett's Cove Region", a study of about 50 square miles along the shore, from Shoe Cove to Nipper's Habor and extending three to five miles inland, was published in 1931 by Snelgrove. Snelgrove's paper of 1935 on the gold deposits of Newfoundland includes descriptions of some of the prospects of the peninsula, in particular the Goldenville Mine, between Ming's Bight and Deer Cove on Baie Verte. In the summer of 1937 Fuller made a study of the rocks of the Fleur de Lys area, the results of which were published in 1941. In 1938 Snelgrove published a resumé of all mineral deposits in Newfoundland and in it described many of the prospects of the Burlington Peninsula. A compilation of all the information on copper prospects in Newfoundland, "The Copper Deposits of 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 described the geology and mineral deposits of the Little Bay area which adjoins the Burlington Peninsula on the south-east. In 1940 Watson completed his report on "The Geology and Mineral

Deposits of the Baie Verte - Ming's Bight Area". Livingstone in 1942 wrote on "The Geology and Vein Mechanics of the Rambler Gold Prospect, Baie Verte". Betz' report on "The Geology and Mineral Deposits of Southern White Bay", to the southwest of this area under discussion appeared in 1941. From 1940 to 1943 Wiseman, MacQuarrie and others contributed some detailed work in the Rambler area. Quinn has given details of the development work there in reports to the Geological Survey (1943). In 1945 Rose completed the detailed geology of an area between Ming's Bight and the Rambler claims, adding to the information on the relations of the various intrusives into the greenstones of the region.

The earliest geological map of Newfoundland, that published by Alexander Murray in 1873 shows the Burlington Peninsula to be made up largely of "Laurentian" rocks, with no further description. Northeast of a line joining Baie Verte and Stocking Harbor the rocks are called "Lauzon", except for a thin strip of "Laurentian" along the north coast from Handy Harbor 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 area to be underlain by "Serpentines, Diorites, Dolerites, etc.", with a long ridge of granite running northeast-southwest just inland from the Notre Dame Bay Coast, with no further differentiation of rocks.

The evolution of the descriptive terminology from the picturesque writing of the first reports of the 1860's to that of the present day and the gradual growth of understanding of the rocks of the Notre Dame Bay coast in particular can be followed in the reports cited above.

PHYSIOGRAPHY

Surface:

The surface of the Burlington Peninsula is an irregular upland, on which the surface features have a general northeast-southwest trend that agrees with the prevailing trend of the rock structure 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 here and there by fiord-like bays such as Ming's 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 are as much as 350 feet high 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 (See Fig. 3). In most places however, the land rises steeply from the cliffline to the general level of the upland surface in a transition zone as much as a quarter 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 seacoast.

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

The distribution of the various rock formations is shown on plate 15 and reference to this will assist in understanding what follows.

The peninsula between Baie Verte and White Bay is a dissected upland, underlain mostly by gneisses and schists of the Fleur de Lys series. The upland surface, at an elevation of about 900 feet, has a relief of about 400 feet near the shore, but less inland. The southern part of the area has been described by Watson as "broad, rolling expanse at an average elevation of 900 to 1000 feet", (1939, p.7), and by Twenhofel and MacClintock as "mature with flat-floored valleys" (1941, p.1707).

Inland, the areas underlain by greenstones of the Baie Verte formation are characterized by a flat, even surface at an elevation of 500 to 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 into the lake country beyond.

Various intrusive rocks stand out boldly above the rest of the country. The outcrop of the Dunamagon granite is marked by a conspicuous range of hills that rise 300 to 500 feet above the rest of the country and reach elevations of as much as 900 feet. South of Confusion Bay, a range of hills underlain by fine grained intrusive rock, rises from the sea to over 900 feet, and stands 300 to 400 feet above the country to the south. Granite, granite porphyry and rhyolitic intrusives underlie a series of prominent hills, which extends in a belt five to ten miles wide in the neighborhood of Middle Arm, (GB), northeastward parallel to the shore of Green Bay to beyond Burlington.

Many of the summits are 1000 to 1100 feet above sealevel, with three at nearly 1200 feet. 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 the part of the peninsula which is underlain by the Cape St. John series ridges of rhyolite and andesite alternate with shallow valleys developed on pyroclastic and sedimentary beds. A similar ridge and valley topography is developed on the Snook's Arm volcanics. In the granite areas, erosion along "lineaments" (see plate 10) has produced long valleys and rolling hills. In the region northwest of Nipper's Harbor the granite country becomes much more bold and rough, presumably the result of local glacial erosion.

At the southwest corner of the Burlington Peninsula a coastal strip, which is lower than the region underlain by the Fleur de Lys gneisses, is developed on rocks of the White Bay series.

As a result of studies of the surface of the whole of Newfoundland, Twenhofel and MacClintock established three erosion surfaces, which they termed the Long Range peneplain, High Valley peneplain, and the Lawrence peneplain (1941, p. 1720, etc.). The uppermost level is present only in the western mountains, but the High Valley peneplain and the Lawrence peneplain are represented in the Burlington Peninsula at levels of 900 to 1000 feet and 500 to 600 feet respectively. Thus the flat, level topography developed on the Baie Verte formation, much of the Cape Brulé granite country, and 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 1000 feet, thus including parts of Middle Arm Ridge, the Burlington Hills, the Confusion Bay Hills and the Dunamagon Highland.

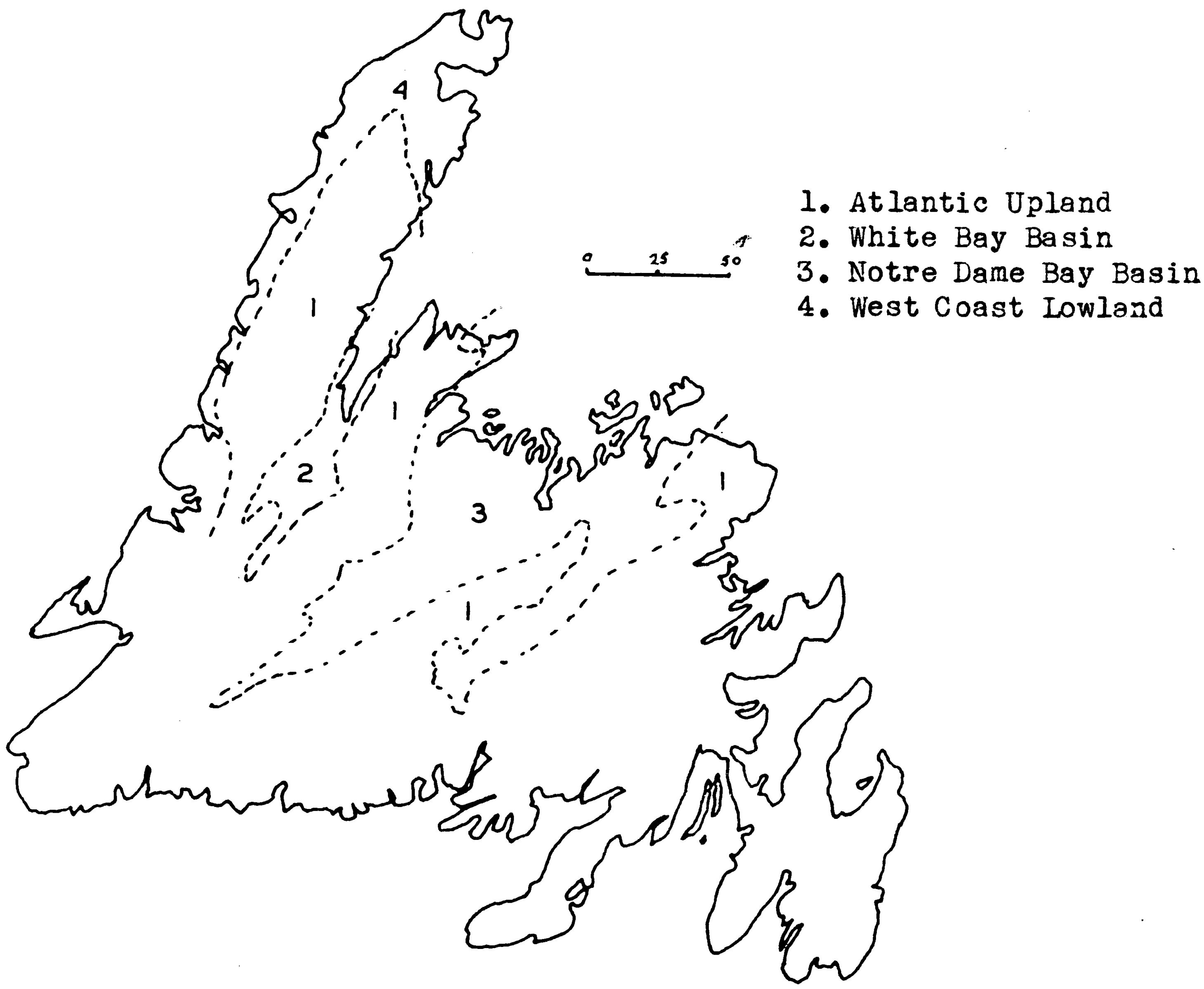


Plate 2.
Physiographic divisions of northern Newfoundland as drawn by Snelgrove, (after Twenhofel and MacClintock, 1940, p. 1670)

According to a map presented by Snelgrove, Newfoundland may be divided into thirteen physiographic regions, three of which extend into the Burlington Peninsula, (See Plate 2; Snelgrove, after Twenhofel and MacClintock, 1941, p. 1670). Most of the peninsula is part of the Atlantic Upland, a complex surface which includes parts of both the Lawrence peneplain and the High Valley peneplain. The White Bay Basin division includes a small part of the southwest corner of the peninsula. Snelgrove includes the Cape St. John district with the Notre Dame Bay Basin. Stratigraphically the Cape St. John peninsula is part of the Notre Dame Bay Basin but physiographically it falls more naturally into the Atlantic Upland Division, with which it is continuous.

Drainage:

Glaciation of the Burlington Peninsula has produced the disrupted drainage pattern which is 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 the area can 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.

(3) Streams with irregular courses, which are the result of glacial scour and fill.

Many of the major streams follow easily eroded rocks. Trimm's Brook at Ming's Bight follows the talcose western boundary of a serpentine mass. The lower course of Ming's South Brook closely follows the talc schist zone on the eastern margin of the same ultrabasic mass. In many places in the last mile of this latter valley it can be seen that the massive serpentine has limited the sideward cutting of the stream. On the eastern side of the same valley the massive Ming's Bight gneisses have restricted the migration and sidecutting. Pacquet Brook flows along the contact of the Ming's Bight formation and the Dunamagon granite.

The large brook which flows from the north into Middle Arm, Green Bay, about a quarter mile west of the village of Middle Arm, follows a fault zone in its upper reaches. The brook that flows into the southwest side of Burlington Harbor follows the Stocking Harbor fault for nearly two miles.

The tributaries of the main brooks form most of the second class. Their valleys can be divided into three parts: the flat headwaters which in many cases belong to class (3); middle portions 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. The rounded surfaces into which the ravines are sharply cut, are drift-covered and show glacial markings. The jagged ravines themselves bear no evidence of glaciation and are therefore considered postglacial. Many of these tributary streams occupy hanging valleys and have begun to cut down their valleys in a new cycle of erosion.

The best example of streams of the second class in the Burlington Peninsula is the tributary to Southwest Brook (Woodstock) at Lower Southwest Pond. Several brooks which flow into Ming's Bight from the west show the same characteristics. Some of the tributeries of Middle Arm Brook belong in this class. Along the seacoast, particularly in the Cape Hat region and along the south side of Cape St. John, small streams flow across the structure and fall over cliffs into the sea. These are hanging valleys produced by the rapid undercutting of the cliffs by wave action locally.

Streams of the third class are common in the headwater regions of any of the main streams, and are most common in the region underlain by the rocks of the Baie Verte formation. 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.

Glaciation has modified the valleys by erosion and irregular deposition, but there can be little doubt that the main drainage follows preglacial lines. Inland from the coast the valleys have a mature aspect and the topography is gently rolling. However the streams which have re-occupied the modified valleys and the new tributaries show some of the characters of youth in the many waterfalls and rapids, narrow gullies and ravines.

Further complication of the development of the streams of the area has been added by the postglacial drowning and subsequent emergence of the land relative to the sea. Many of the outlets of the major rivers were heavily glaciated and now form fiord-like bays. During the period of deeper submergence river deposition took place. Emergence has bared some of these delta deposits and the streams are at present cutting into them. Baie Verte River and Middle Arm Brook are cutting into deposits of their own making, as much as 110 feet above the present sea level.

Lakes:

The lakes locally called 'ponds', regardless of their size, are all of glacial origin. They are classified as follows:

(1) Lakes formed by irregular deposition of glacial debris are the most common. The lakes in the course of Southwest Brook (Woodstock) from Southwest Pond to the sea are formed by deposition of bouldery drift in the valley bottom. Another example is the small pond about three hundred feet above the sea one half mile south of Ming's Tickle, on the eastern shore of Ming's Bight. The dams of drift are usually obvious in the outlets of the lakes thus formed.

(2) The scoured rock-basin type of glacial lake is common. 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 flow over bedrock threshholds and in some bedrock is exposed on all the shores. On several of the small lakes of this type plucking of the shore on the side from which the ice moved into the lake basin and polishing on the other side has produced steep banks and rounded smooth rock surfaces respectively. These are very well shown in the lakes to the south of Beaver Pond.

(3) Bog holes and ponds. A number of ponds of small size not more than a hundred feet across were observed to be held in by massive vegetation. The presence of examples grading from barren, rocky, plantless ponds to 'quaking bogs' suggests that some of these ponds are remnants of rock basin lakes which have been almost completely filled in with vegetation.

A different type is shown in small water holes not more than forty 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 of level of adjacent ponds, which are from three to ten feet apart, may be as much as three feet. The depth of water is usually not closely measurable, but probably seldom exceeds ten feet. Their bottoms are obscured by a thick vegetable ooze, and the sides are commonly vertical. The bedrock of such boggy areas was not observed, but from the surrounding country there is nothing to suggest that it has a step-like surface that could account for the series of bog-holes. A. E. Porsild (Pers. Comm., 1946) explains such ponds as the result of solifluction. When thick layers of vegetation, lying on smooth, rock surfaces of gentle slope, 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 sub-parallel, oblong or arcuate ponds, whose long axes would be at right angles to the direction of the slope. Rapid plant growth at the surface of such ponds would soon alter their shapes and could account for their nearly vertical walls.

Coastline and Seafloor:

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

Each of the indentations along the north coast of Newfoundland, that reach as much as twenty-five miles inland, is a drowned river valley which has been modified by glaciation. Baie Verte and Ming's Bight do not have shallow threshholds. White Bay however which is as much as 270 fathoms deep between Jackson's Arm and Western Arm has a threshhold of only 180 fathoms between Partridge Point and Little Harbor Deep, (Admirality Chart No. 285). Betz (1941, p.10) suggested that White Bay was formed by submergence of a river valley eroded along a major fault in preglacial times and later enlarged and deepened by glaciation. Heyl (1936, p. 3) has suggested that Sop's Arm and Jackson's Arm, on the west side of White Bay, are hanging valleys on the side of the major White Bay channel. Betz suggests that the same relationship probably holds for the other arms of White Bay. However, from the soundings available neither Middle Arm nor Western Arm appear to extend as submarine valleys out to the edge of the principal deepening, so they were probably not deeply eroded by the ice. Middle Arm (WB) is overdeepened with a narrow, shallow outlet (see below). There can be little doubt that Green Bay has been greatly deepened by ice action. From depths as great as 225 fathoms southeast of Stocking Harbor, it shallows to a threshhold of 140 fathoms. The presence of valley glaciers in the late stages of glaciation and their role in the deepening of valleys are discussed in the section on Glaciation.

Many uplifted marine features in northern Newfoundland show recent emergence of the coastline. Almost every protected bay shows a flight of raised beached and benches. The major rivers of the district are cutting into old delta deposits that are now exposed. Marine fossils are found in mud and clay deposits as much as 100 feet above the present strand line.

Wave-cut benches on bedrock are the most reliable indicators of former sea levels. Raised delta deposits show little more than the fact of emergence. However, terraces cut by wave action on delta deposits, such as those at Middle Arm, are considered to show more accurately where the sealevel once stood. Many of the flat-topped deposits of reworked glacial material observed in the small coves along the shores of the Burlington Peninsula are only approximate indicators of the former sea levels since their height would depend on local conditions such as rate of deposition, shore currents, exposure to wave action, and the depth of the water into which the material was being dragged.

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

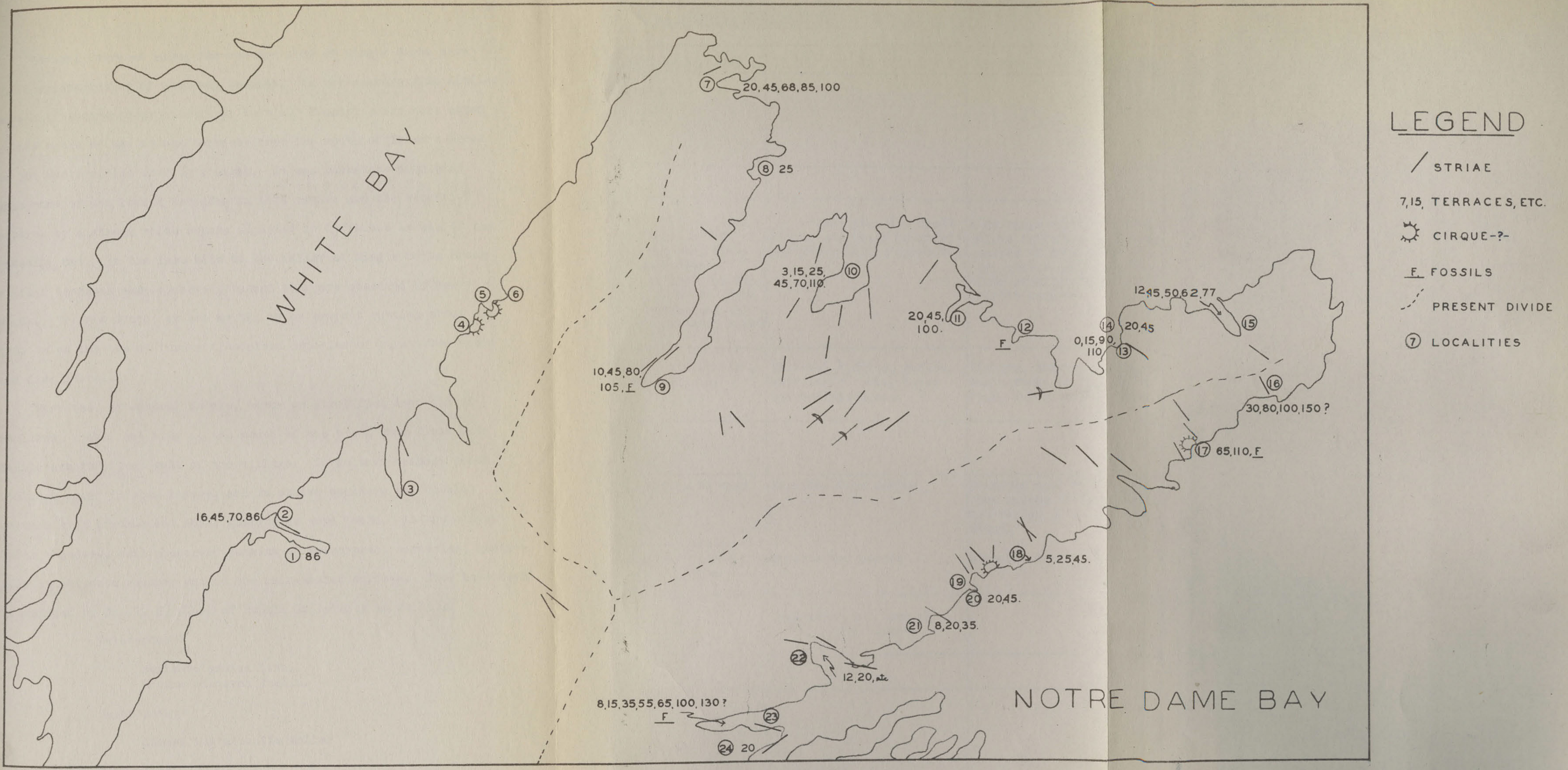


PLATE 3

GLACIAL AND UPLIFTED MARINE FEATURES

Several terraces along the western side of Ming's 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 Trimm's Brook on the eastern side of Ming's Bight. It was therefore concluded that some of the lowest terraces in this region are the result of erosion by a stream which became adjusted to different levels of the receding sea. In the last mile of the valley of Ming's South Brook similar terraces were observed, though they are obscured by heavy woods. Trimm's Brook, at its mouth, is at present cutting about six feet below the top of former floodplain 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 (GB) 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 Dr. T. H. Clark of McGill University as follows:

Pelecypoda:

Saxicava arcica Linn.
Macoma calcarea Gmelin.

Gastropoda:

Acmaea testudinalis Muller

Crustacea:

Balanus crenatus Bruguiere

Fragments of pelecypod shells were found in a clay bank about two hundred yards from the mouth of Gooseberry Cove Brook and about thirty feet above sea level. According to Murray, shells occur in the 60 foot terrace at Tilt Cove (1867). All the fossils that have been found are of modern types and probably could be found in the adjacent marine waters.

At Pacquet, Ming's Bight, and several places along the Confusion Bay shore a wave cut bench of bedrock as much as one hundred feet in width was observed at present sea level (See Fig. 7).

The accompanying map, Plate 3, shows the elevations of emerged marine features and their locations. Observations have been compiled from all known sources and are listed below.

From a study of the emerged, marine features of the west coast of Newfoundland, Flint confirmed Daly's earlier observation that post-glacial uplift in Newfoundland increases to the northwest, (Flint, 1940, p.1777, Daly 1934, p.105). Flint showed that uplift has been interrupted by periods of stability during which wave erosion cut benches on bedrock as much as two hundred feet wide on the west coast of Newfoundland. The highest terraces and benches cannot readily be correlated, with one another. The Bay of Islands surface represents a period of stability, during which wave erosion cut benches and beaches, now correlated as a warped plane, rising to the northwest at a rate of about $2\frac{1}{2}$ feet per mile (Flint, 1940, p.1770). At present sea-level, benches of considerable width indicate a period of stability of duration comparable with that of the Bay of Islands surface.

The wave-cut bench at 110 feet in Ming's Bight, was correlated by Flint with the Bay of Islands surface, and he extended his west coast isobases eastward to the Burlington Peninsula area (See sketch

No.	Locality	Benches and Beaches	Delta Terraces	Fossils	Observed By	Reference
1.	Western Arm, WB	86.5			Betz	1941
2.	Bear Cove, WB	16,45,70,86			Princeton Expeditions	1915, 1916, 1917
3.	Middle Arm, WB	Present but unrecorded			Baird	
4,5.	Lobster Hr. and adjacent Cove	Cirque-like, ice-scour basin			"	
6.	Wild Cove, WB	Not measured but at approximately 30 and 100			"	
7.	Fleur de Lys	20,45,68,85,100			Princeton Ex.	ibid.
8.	Coachman's Cove	25			"	"
9.	Baie Verte	10	45,80,105	Mya, etc. (no sp. given)	Watson	1939
10.	Ming's Bight	45,70			"	1939
	Ming's Bight, Red Cliffs	110			"	1939
	Ming's Bight	15,20,35,50,110	3,25,40		Baird	
	Red Cliffs	25,110			"	
11.	Woodstock	45, 100	20		"	
12.	Gooseberry Cove		35	Saxicava, Balanus, etc.	"	
13.	Brent Cove	15,90,110			"	
14.	West Country Cove	20,45			"	

No.	Locality	Benches and Beaches	Delta Terraces	Fossils	Observed By	Reference
15.	La Scie	45,50,53,62,77			Prin. Exped.	1915, etc.
	La Scie	12,45,50,62,77			Baird	
16.	Shoe Cove	30,80,100,130			"	
17.	Tilt Cove	60		Mya truncata	Murray	1867
	Tilt Cove	65,110			Prin. Exped.	1915,etc.
	Tilt Cove	Cirque-like ice-scour basin			Snelgrove	1931
18.	Burton's Pond	5,25,45			Baird	
19.	Nipper's Hr.	Unmeasured terraces and delta terraces			"	
20.	Walsh's Cove	20,36			Prin. Exped.	1915, etc.
	Walsh's Cove	20,45			Baird	
21.	Rogue's Hr.	8,20,35			"	
22.	Burlington	12,20, and others higher			"	
23.	Middle Arm, GB	10,30,60			Murray	1867
	Middle Arm, GB	50,100			MacLean	1940
	Middle Arm, GB	8,65	15,35,55,100,130	Abundant Saxicava, Macoma, Acmaea, etc.	Baird	
24.	Entrance to Southwest Arm, GB	20			"	

No.	Locality	Benches and Beaches	Delta Terraces	Fossils	Observed By	Reference
Listed but not entered on map						
	Baie Verte	40			Murray	1867
	Apsey Cove		105	Fragmentary	Watson	1939
	Rettis' Cove		20		Baird	
	King's Point	100			McLean	1940

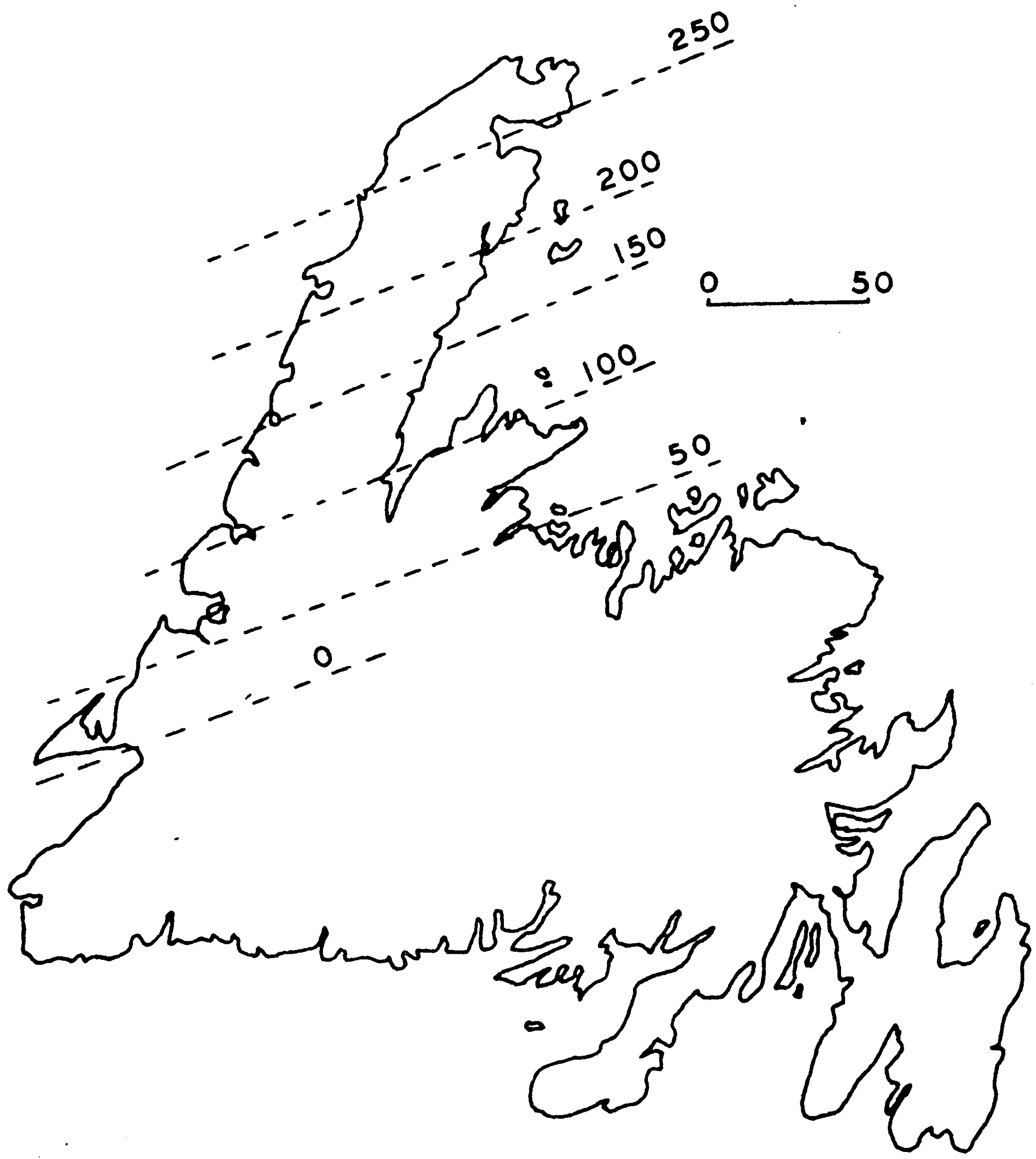


Plate 4.
Isobases as drawn by Flint (1940, p.1772) to represent post-glacial uplift in northern Newfoundland.

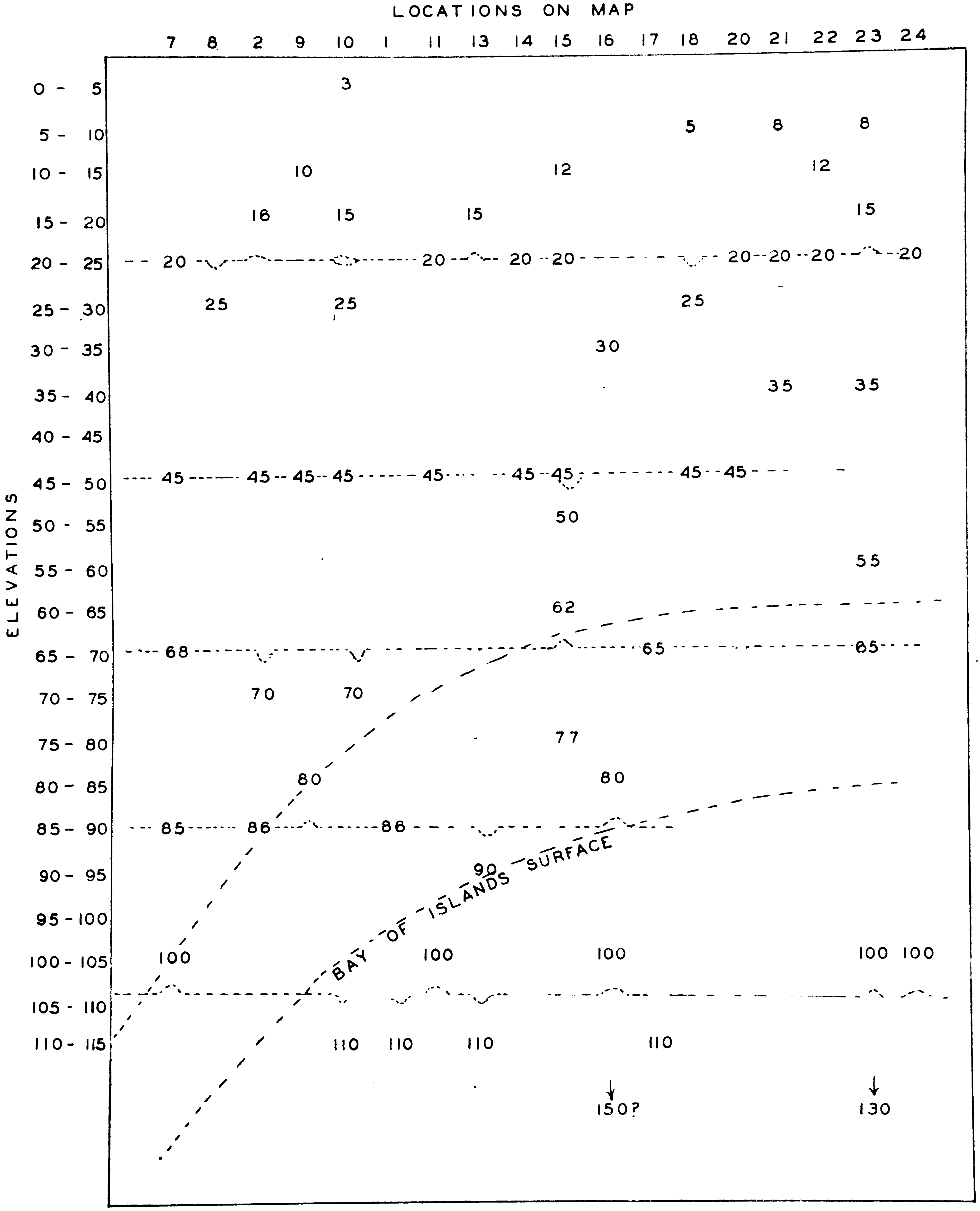


Plate 5. Elevations of wave-cut terraces and benches plotted against locations in a test of the validity of Flint's isobases drawn on the Bay of Islands surface which should extend through the area as shown,(see also plate 4). Another line with better possible correlation is also shown. Location numbers refer to map, plate 3, and table, page 22. (See text,page 25)

map plate 4). In an attempt to correlate the emerged marine features of the Burlington Peninsula, and to find evidence of differential uplift, the elevations and locations of terraces and beaches were plotted in an order which placed the locations that were expected to show the greatest uplift on the left, and those expected to show the least uplift on the right. The sloping curve is the projection of the Bay of Islands surface, which would be consistent with the isobases postulated by Flint on the west coast. The horizontal lines, through the 20, 45 and 105 foot levels mark the most commonly occuring elevations. The bench at present sealevel is not marked on the table.

A notable lack of correspondence exists between observations plotted on this table and what would be expected from projection into this area of the west coast isobases of Flint. It is also noted that certain elevations occur repeatedly over the whole peninsula as if the uplift were uniform.

Several factors may contribute to the non-correspondence of the present observations with those of Flint. It is possible that not enough readings were taken to provide good correlation on any one surface such as the Bay of Islands surface. The limited accuracy of the observations may also contribute. Measurements of elevations were made with chain and Brunton compass, using the tangent method. Some observations were made with an aneroid barometer and a few by estimate. It is not known how the measurements of the Princeton Expeditions, Snelgrove and the others quoted in the table, were made. At any one bench or uplifted beach two sources of error may arise due to irregularities in the top surfaces. They commonly show a slope from back to front, and irregularities in their longitudinal profiles are common. Raised beaches are sometimes higher at their ends and around rock outcrops. At best a margin of error of five feet should be allowed on the observations plotted.

The evidence from this district, however, is strongly suggestive that uplift is not as Flint has shown. In other parts of Newfoundland similar disagreement is found. Widmer, (Pers. Comm. 1946), in the Baie D'Espoir area on the south coast of Newfoundland has found numerous uplifted beaches and wave-cut benches as high as 110 feet above sealevel, where Flint has suggested no uplift at all. Recent work in the Fogo district in northeastern Newfoundland by the writer does not agree with Flint's isobases (1946).

The present discussion shows the desirability of reinvestigation of the whole problem of post-glacial uplift in Newfoundland.

Cliffs:

Cliffs form an outstanding feature of the physiography along much of the shore of the 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 strandline. 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 which rise abruptly from more than one hundred fathoms below sealevel 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 Harbor area and near Cape Hat glacial rounding extends to within a few feet of the sea. Between Stocking Harbor 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 Harbor Islands, Ming's Tickle Island, and other islands now exposed to wave attack, show rounded forms which are presumably due to glaciation. The cliffs along the inlets of Ming's 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 (1925, p.183). Johnson 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, extends under 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. Hall's Bay for example continues under the sea as a submarine valley, beyond the zone of apparent glacial overdeepening, 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. Betz (1941, p.10) has suggested that White Bay is a glacially modified, drowned river valley. Its bottom beyond the range of obvious overdeepening is at about 180 fathoms. This great depression may well be the result of the drowning of a river valley which at one time extended along the eastern side of the northern peninsula. The southern end of such a belt of sediments underlies a lowland at the south end of White Bay and the patches of sediments preserved in the inlets along the eastern shore of White Bay and northward may indicate its former larger extent, (Heyl, 1937). Twenhofel and MacClintock have mentioned the possibility that the great Carboniferous lowland to the south once drained through White Bay (1940, p.1674).

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 one or two miles. Seaward from here 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.

shoreward slope at the margin of the bottom bench may represent a former strandline. The Horse Islands, about twelve miles northeast of the 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 reentrant on the northwest side of the shelf may indicate that Baie Verte drainage once joined the "White Bay River" as a tributary.

The strandline of northern Newfoundland must have migrated back and forth many times during the many oscillations of sealevel 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. Veatch and Smith (1939, p.48) suggest that the submarine canyons on the edge of the continental shelf were carved at a time in the Pleistocene when general sealevel was at least 1200 fathoms lower than at present. This estimate does not seem reasonable in view of the difficulty in accounting for the withdrawal of such an enormous quantity of water. According to D. W. Johnson (1925, p.301) present sealevel is about 1200 feet higher than at the time the Georges Bank area was undergoing subaerial erosion. He also presents evidence to show that the general drowning of the area took place in late Tertiary or even post-Tertiary times. Goldthwait (1924, p.104) in accounting for the submarine canyon of the St. Lawrence River under the Gulf of St. Lawrence and Cabot Strait states that at the time of cutting the sea was 1500 feet lower than at present. Other estimates in the same region include 1200 feet by Alcock (1935), 1100 to 1800 feet by Cooke (1930), 1200 feet by Gill (1945). A submergence of 1200 to 1500 feet does not seem unreasonable in view of the evidence, presented by the mentioned writers, that the Gulf of St. Lawrence area, the Grand Banks area, and the Bay of Fundy - Gulf of Maine area are the results of river erosion at a time of lower sealevel. Movements of the strandline must have taken place earlier in the Tertiary during the uplifts between the formation of each of the three peneplains described by Twenhofel and MacClintock (1940, p.1723). When the sea stood at the low levels mentioned above, the present strandline must have been far removed from the reach of wave erosion and subject to the ordinary processes of subaerial erosion.

Even after the sea assumed its present general level many fluctuations of the strandline have occured. Daly has shown that during the Pleistocene worldwide sealevel changed several times as the result of the withdrawal and return of sea-water during the growth and shrinkage of the continental ice-caps, (1934, p.46 to 50). He estimates that at the time of maximum glaciation sealevel was lowered about 90 meters. Daly has also presented evidence to show that in middle post-glacial times eustatic lowering of sealevel has taken place (1934, p.181). Differential uplift in response to unloading of the earth's crust as the ice-caps receded has changed the level of wave attack in Newfoundland as indicated in the discussion on emerged marine features in an earlier section.

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, strandline features should be looked upon as a zone which has been washed over by several strandlines during the oscillations of sealevel 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 Harbor 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 Ming's Bight series (see Fig. 14). The opening of the largest pothole is about forty feet from the waterline and about eight feet above high-tide level. The orifice is elliptical in plan, measuring about three feet by five feet. The pothole, which is jug-shaped, is about eight feet deep and its bottom is covered with smooth, rounded boulders about six inches in diameter. Smaller, less well-developed potholes occur in the same locality.

Fuller found similar potholes in the shore zone in the Fleur de Lys area (1941, p. 4), at twenty to fifty feet above the present sealevel. He states that, "They are found along the coast where there is no evidence of former stream drainage and are, therefore, believed to have been formed by a glacial stream which formed a moulin in the ice and penetrated to the bedrock." Such an explanation does not seem adequate for potholes in the shore zone. There is no evidence of stream action, glacial or otherwise on the smooth, bedrock slopes, which are backed by cliffs. The return of water to the sea after the breaking of storm waves would provide powerful and turbulent streams of water which would affect the whole shore zone to an elevation of perhaps forty feet on the exposed parts of the coast. As soon as a small depression in the rocks becomes 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 sealevel was higher.

GLACIATION

Since the earliest physiographic studies in Newfoundland there has been discussion as to whether or not the island was covered by ice from a Labrador centre during Wisconsin glaciation. Twenhofel (1912) and others have stated that Wisconsin glaciation was from a Labrador centre and that it covered the whole island. Coleman (1926) recognized two stages of glaciation. The first he placed in an early part of the Pleistocene, the Kansan or Jerseyan, and the second stage in the Wisconsin. The earlier glaciation was more extensive than the later and probably came from a Labrador centre. Wisconsin glaciation, according to Coleman, was of a local nature with an independent centre in Newfoundland itself, and with some areas not covered. The botanical studies of Fernald (1925, 1930, etc.) led him to agree that in the Wisconsin certain areas in the Long Range Mountains remained ice-free, but later papers discredit the theory.

In 1940 Flint, and MacClintock and Twenhofel published papers which clarified the confusion of evidence.

MacClintock and Twenhofel (1940, p. 1730) suggested that there were three stages in the Wisconsin glaciation of Newfoundland which may be summarized as follows:

(1) The maximum episode

(2) The Bay St. George episode

(3) The local and cirque-forming episode

"During the first of these the ice spread as a complete cap from the Long Range Plateau, the Central Plateau and the Avalon Peninsula outward in all directions to beyond the present shore lines of the island ... During the second episode the ice margins receded and fossiliferous marine sediments were deposited ... During the third episode the ice had dwindled to local glaciers excavating cirques at the heads of valleys and building minor moraines ... Evidence from raised and warped strandlines suggests that Newfoundland was completely glaciated by ice spreading from the Labrador centre at the climax of Wisconsin glaciation."

In the Bay St. George region, interbedded glacial deposits and marine beds show that the local ice advanced and receded three separate times. In the Baie Verte River valley glacial till and fossiliferous marine clays are interbedded, and suggest as in the previous case, three separate ice advances separated by periods of withdrawal and limited marine submergence.

The progressive rise to the northwest of uplifted, postglacial, marine features, first observed by Daly (1911) and elaborated upon by Flint (1940), suggest the possibility that the Labrador ice-sheet covered Newfoundland sometime during the Wisconsin, (Flint, 1940, p. 1775). Recent work has shown the doubtful validity of Flint's conclusions, (see above). Even if correct the same effect would be brought about if a large mass of Labrador ice moved off the mainland, crossed the gulf and moved southward parallel to the Long Range without actually crossing it.

For a long time glacial erratics of unknown origin have been used to support the idea of long-distance ice transportation. Anorthosite boulders, supposedly similar to anorthosite known to occur in Labrador, have long been cited as possible evidence for movement of Labrador ice over Newfoundland (Watson, 1939, p. 11, etc.). Such boulders were found by the writer at several places in the Burlington Peninsula, on the western shore of Bear Cove, (White Bay) and at several places in the Fogo district fifty miles to the east. In a region where the geology is as little known as in the northern part of Newfoundland such long-distance correlation of erratics is most speculative.

At Port-au-Port, on the west coast, MacClintock and Twenhofel (1940) found two sets of striae, that indicate a southward movement of ice, followed by a westward movement. That the first set represents movements from a Labrador centre and the other movements from a local centre does not seem as likely as the alternative proposed by the writers themselves that ice, moving off the island, encountered ice in the Gulf (perhaps Labrador ice) and was forced to move southward along the coast, and that later local movement was not so restricted. It seems likely that movement from a local centre in Newfoundland, for which there is such strong evidence, would remove any but the most recent striae, and that striae made by Labrador ice would be erased before the completion of glaciation from a local centre.

MacClintock and Twenhofel sum up the problem of early Newfoundland glaciation thus, "Be these deductions as they may, the known glacial history of Newfoundland begins with an icecap completely covering the island, and radiating outward with its outward limits beyond the present shores." (1940, p. 1750).

That the last glaciation in Newfoundland was from a local centre is shown by several lines of evidence. The great predominance of rocks in the drift are traceable to local sources. Roches moutonnées and striae patterns show that glaciation has been along valleys leading in many directions, but in general leading down to the coast at approximately right angles. MacClintock and Twenhofel (1940, p. 1751) have presented a map which shows all the known striae in Newfoundland. Their direction and distribution show that the ice radiated outward from centres near Grand Lake and Red Indian Lake, in central Newfoundland.

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

The general northeast movement of the ice in the Burlington Peninsula has been established beyond doubt by the writer. Diversion of the ice flow, off the flanks of the peninsula to the main flow down White Bay and Green Bay, is evident from striae and ice-scoured rocks along the coasts. Plate 3 shows all the known striae in the area. 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 Middle Arm and Southwest Arm (GB) striae suggest a confluence of ice streams which moved outward from each of these valleys around the base of Middle Arm Ridge. Much of the apparent local movement may be due to bottom control under the main ice stream.

Numerous crescentic gouges of the type described by Gilbert (1906), and Harris (1943, p. 245) in which the horns of the crescents point in the direction from which the ice came, were observed. These, as well as striae, occur particularly abundantly 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 (see Plate 16) show plucking on the southwest side and polishing and rounding on the northeast shore, indicating a northeast direction of ice movement. This characteristic of the lake basins was used in the search for evidence of the direction of ice movement and many of the striae, indicated on the map (Plate 3) to the south of Ming's Bight, were found by placing traverses along the northeast shores of the lakes.

Preservation of glacial markings was found to vary greatly with the type of bedrock. On the Ming's Bight formation striae were observed in only two places. The Dunamagon granite has weathered to a crumbly surface, removing all small glacial marks. Abundant roches moutonnées, however, were observed on both these formations. The greenstones of the Baie Verte formation show little evidence of glaciation, except a few striae on shore exposures on Side Pont (See Plate 16). The volcanics along Notre Dame Bay show occasional striae but usually only the larger forms such as roches moutonnées remain. The granitic and dioritic intrusive masses, on the other hand, show a great abundance of striae, crescentic fractures, roches moutonnées, and scour forms.

Erratics of local rocks suggest that the distance of transportation has not been great and their distribution confirms the general northeastward direction of movement of the ice. This is particularly clear in the district between Ming's Bight and Pacquet. No boulders of the Ming's Bight series were observed south of the contact with the

Dunamagon granite, but many boulders of the latter were found to the north. On the very 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 series were found. In the region underlain by the Cape Brulé granite, some Baie Verte greenstone boulders were found, but their presence in this apparently anomalous position led invariably to the discovery of small patches of Baie Verte series in the Cape Brulé granite mass, south of the main contact.

As mentioned in an earlier section, numerous inlets representing drowned, glaciated, river valleys occur along the north coast of Newfoundland. Each shows the effect of valley glaciation in steepening of the sides, alteration to a general U-shape, and in some cases apparent overdeepening. White Bay and Green Bay have already been described. Baie Verte and Ming's Bight are fiords although neither are greatly overdeepened compared to inlets along the Notre Dame Bay coast. A partial diversion of the ice off the flanks of the peninsula may account for the difference in overdeepening. (See Plate 3).

An examination of the soundings on Admiralty charts indicates that Pacquet Harbor is little overdeepened. Significant, perhaps is the fact that the submarine outlet of the harbor is only about a third as wide as the basin at the junction of the northeast and southwest arms. It is considered that the northeast arm and the surrounding basin was a local collecting place contributing to the main flow of ice down the southwest arm. The position of the deep southwest arm at the outlet of the large valley, now occupied by Southwest Brook, and its general U-shape suggest its strong glaciation compared to the northeast arm.

At Middle Arm, White Bay, overdeepening seems evident from soundings on Admiralty charts. The bottom of the mouth of Middle Arm, however, is floored with shifting sands and fine gravel, which immediately suggests that some of the apparent overdeepening may be due to drifting of debris by wave action and shore currents across the mouth of the bay. If this is true of Middle Arm, some of the "overdeepening" observed elsewhere, where knowledge of the bottom material is lacking, may be due to similar damming. The land surface near the coasts is nearly bare of glacial till. The ice streams, passing over the land and funnelling into the main valleys, must have dropped their loads of debris somewhere beneath the present sealevel, either at the end of the ice streams if they did not reach the sea, or where melting was taking place, if they did. It is therefore, considered likely that part of the "overdeepening", attributed to ice erosion in the bays along the north coast of Newfoundland, is due to drift dams, and wave-cut and wave-carried debris.

Bowl-like depressions which must be due in part to glacial erosion occur at several places along the coast of the Burlington Peninsula. Harbour Round and Brent Cove (See Fig. 1) are situated in great semi-circular 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, polishing and plucking. Nipper's Harbor, and adjacent coves inside the Nipper Islands, are part of another such basin, now partly submarine, which has a shallow threshhold, suggesting that ice action was prominent in its formation. Little Lobster Harbor (See Plate 3, No. 5) 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.

Glacial deposits are nowhere quantitatively important. Erratics are found everywhere but nowhere does the till cover exceed a few feet in thickness. Glacial deposits and water-sorted glacial debris floor 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 found stratified sands and gravels which are probably part of local outwash. Much of the thick deposit of coarse gravel, sand, and clay found at the mouth of the stream entering Middle Arm, (Green Bay), behind the village, is probably outwash material. Boulder dumps are common in many of the granite areas, as for example along the southwest end of the Dunamagon granite. 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 ten feet thick. About one mile west of Burlington, on the woodroad leading toward Flat Water Pond, small gravel pits reveal coarsely stratified sands and gravel, containing a great variety of mixed, glacial debris, suggesting outwash deposits.

Appended is a list of all known striae in the Burlington Peninsula. It is included in case local directions of ice movement are required. The value of knowing the direction of glaciation is particularly well illustrated in a report by Quinn (1943, p. 19), which describes a search made for the origin of mineralized boulders found at Gull Pond. Since the direction of glacial movement was not accurately known two separate searches, one to the north and one to the south of the boulders, were necessary.

The effects of glaciation on drainage are discussed under Streams and Lakes and on the shoreline under Shoreline.

Direction	Rock	Observer	Locality
143°	Baie Verte Series (BV)	Livingstone (1942)	Map, northeast corner
172	BV	Quinn (1943)	Claim 1519, Rambler
70	BV	Rose (1945)	Map 3, Section EE, 4000' east of trail to Rambler
8	BV	Rose	Map 3, on NE side of South Brook Pond
9	BV	Rose	7400' along DD (Sheet 2), from Three Corner Pond, and 650' north, on Lake shore
11	Talc	Rose	600' up from mouth of South Brook. Sheet 2
33	BV	Rose	Southeast corner of Gillard Pond

Direction	Rock	Observer	Locality
43^o	CB	Baird	W side of Rocky Pond
45	BV	"	Side Pond, near outlet
50	BV	"	Side Pond, north shore
80, CF	CB	"	Confusion Bay BK. , 200 yds from mouth
125	Cape St. John series (CSJ)	"	Campsite on pond just W of Sisters
140	CSJ	"	ditto but 100 yds to west
100-120	CSJ	"	Just to the NW of northern-most part of Snook's Arm Western Pond
58(302)	CSJ	"	Above last house on Brent Cove - La Scie trail
125	CSJ	"	La Scie - Shoe Cove trail, half way
125	Nipper's Harbor series (NH)	"	N side entrance to Rouge Harbor
135 plus or minus	NH	"	In the Nipper's Harbor cirque
328 (32)	NH	"	Just north of Nipper's Harbor
100	Burlington granite (Burl)	"	Burlington, off the old mill point
135	Burl	"	Burlington, near the church on the shore
100-130	Burl	"	Burlington on the northeast shore, all along it
105, CF	NH	"	Garden Cove, Burlington
95	Burl and NH	"	Stocking Harbor on the south side of entrance

Direction	Rock	Observer	Locality
130°	BV	Baird	Flat Water Pond on the north and northeast sides
130	BV	"	
150	BV	"	
55	Fleur de Lys gneisses	Fuller (1941)	North of F. de Lys
160	Fleur de Lys gneisses	Baird	North side, entrance of Middle Arm
117	Fleur de Lys gneisses	Princ. Exped. (1915)	Western Arm
83	Snook's Arm Series (SA)	Snelgrove (1929)	¼ mile N of Lowlands Pond, Bett's Cove
153	SA	"	200 feet N of the Lowlands Pond
138	SA	"	SE Mine Pond, Bett's Cove
138	SA	"	South of Mine Pond, Bett's Cove
133, 113	SA	"	West of Mine Pond, Bett's Cove
148	SA	"	Mine Pond, Bett's Cove
143	SA	"	South of Main Mine Pond, Bett's Cove
138	SA	"	Bett's Cove Mine Hill
140	SA	"	East Point of Snook's Arm Eastern Pond
143	SA	"	South shore of Red Cliff Pond
123	SA	"	East Mine, Tilt Cove, east edge of open cut
128	SA	"	Dump Pond, west point of North Shore
158	SA	"	Snook's Arm Brook, between Eastern Pond and Steady

Direction	Rock	Observer	Locality
113°	SA	Sampson (1923)	Castle Rock Pond, Tilt Cove
118	SA	" "	Murray Lookout, west side of Tilt Cove
60	BV	Watson (1940)	2500' west of Baie Verte on shore
56	BV	"	2500' east of Baie Verte on shore
70	BV	"	Outlet of lake at head of Upper Duck I. Cove Brook
126 local	BV	"	3000' up Upper Duck I. Cove Brook
11	Talc	"	600' up Ming's South Brook

	SHORE OF WHITE BAY	PARTRIDGE PT. TO MING'S BIGHT	MING'S BIGHT TO C. ST. JOHN	C. ST. JOHN TO NIPPER'S HR.	NIPPER'S HR. TO MIDDLE ARM
Cenozoic – Recent / Pleistocene		← Delta and shore deposits → ← Glacial deposits → ← Prolonged erosion →			
		← Appalachian Revolution →			
Devonian (?), perhaps part of the Acadian revolution	Partridge granite Small granite masses inland from the coast Numerous basic dikes	Partridge granite. Granodiorite, small masses of granite, dikes of various composition. Burlington granite to south. Steatitization and carbonatization of ultrabasic rocks.	Pegmatites and aplites. Dunamagon granite, Cape Brulé granite and offshoots. Dikes of various compositions. Possibly some of the fine felsic intrusives of C. St. John area. Steatitization and carbonitization of ultrabasic rocks.	Cape Brulé granite. Small stocks and plugs of granite and fine, felsic intrusives.	Wide range of dikes. Fine felsic intrusives. Numerous masses of granite porphyry, quartz porphyry. Cape Brulé granite, Burlington granite complex.
Between Ordovician and Devonian	Basic dikes	Diorite, gabbro, ultrabasic intrusives, later serpentinized, etc.	Diorite, gabbro, ultrabasics, later serpentinized, etc.	Diabase, diorite, gabbro, ultrabasic rocks, later serpentinized, etc.	Diabase, diorite, ultrabasic rocks at Flat Water Pond, later serpentinized.
Ordovician or Silurian		← Mountain Building →			
Ordovician		Baie Verte series – Upper / Middle / Lower	Cape St. John series in east. Baie Verte series – Upper / Middle / Lower	Cape St. John series Snook's Arm series	Possibly some of the flow-like masses in the Burlington region and Middle Arm Ridge. Nipper's Harbor series
Ordovician or earlier				Sediments at bottom of Snook's Arm series.	
		← Folding and erosion →			
Precambrian	White Bay series Fleur de Lys series	Fleur de Lys series	Ming's Bight series		

GENERAL STATEMENT

The rocks of the Burlington Peninsula consist of gneisses and schists and later volcanic rocks with intercalated sedimentary formations, all of which have been folded and intruded by a complex of igneous rocks. The trend of the fold structures is northeast-southwest, parallel to the general trend of structures in Newfoundland, and indeed with the trend of the whole Appalachian belt of which this is essentially a part.

The oldest group of rocks in the area is a series of schists and gneisses, the Fleur de Lys series, which is exposed over the whole length of the western side of the peninsula, and extends for an unknown distance southward beyond the limit of mapping. These rocks have been folded into an anticline, with minor superimposed synclines. Rock compositions correspond to the garnet zone of Harker (1932) except where they have been modified by hydrothermal solutions, near small intrusive masses.

Similar in many respects to the Fleur de Lys series is an overlying group of rocks, the White Bay series, which occurs in the vicinity of Western Arm, and southward along the eastern shore of White Bay.

The Ming's Bight series, a group of gneisses and schists which are in the biotite and garnet zones of metamorphism, is exposed in the small peninsula between Ming's Bight and Pacquet Harbour. The structure is generally domal, with minor anticlines and synclines. These three groups of rocks are considered to be most probably

Precambrian in age.

The Baie Verte series consists of altered volcanics with compositions that correspond to the greenschist facies except near intrusive masses where locally the compositions correspond to the amphibolite facies. It is believed to rest upon each of the series mentioned above, and in some places is known to be unconformable. On the basis of lithologic and structural studies, the rocks of the Baie Verte series are correlated with the Snook's Arm series (see below) and other altered volcanic rocks in the Notre Dame Bay region which are of Ordovician age.

Most of the rocks of the Baie Verte series were originally lava flows of andesitic composition, with some pyroclastic beds. Near the top there are sedimentary rocks which have been altered to marble and slate.

The rocks of the Baie Verte series have been folded into northeast-southwest trending anticlines and synclines, which in some places are arranged en echelon. They plunge at angles of 20 to 40 degrees toward the northeast or southwest. Overturned folds were noted along the shore of Confusion Bay and near La Scie.

The Snook's Arm series occupies an irregular strip on the coast of Notre Dame Bay. It consists of andesitic lava flows with abundant pyroclastic beds, and intercalated sedimentary rocks derived from the volcanics. These rocks form a curved anticline, which plunges to the northeast at about 20 degrees. Fossils found in the formations at the base of the Snook's Arm series indicate that at least part of it is Ordovician in age.

The Nipper's Harbor series occupies a coastal strip which extends southward from Nipper's Harbour. It consists of lava flows of andesitic and basaltic composition, with rare sedimentary horizons. Its structure has not been worked out in detail, but the formations in general strike parallel to the shore. The youngest bedded rocks in the region are called the Cape St. John Series. They consist of reddish-brown and green andesites and rhyolites, and fine to coarse-grained, yellow, orange, and green, water-worked, pyroclastic and sedimentary rocks. They occupy the axial portion of a syncline which is overturned to the south and which makes up the Cape St. John peninsula. The Cape St. John series overlies the Snook's Arm series on the south and the Baie Verte series 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 Snook's Arm series, since they intrude the volcanics of that series and no others. Some of the thick rhyolites of the Cape St. John series are considered to be intrusive and probably genetically related to the flows of that series.

All the other intrusive rocks of the region are later than all the bedded rocks. Of these intrusives the oldest are the ultrabasic masses, which occur at nine different localities, generally in the form of tabular or sill-like concordant masses. They cannot be dated more closely than post-Baie Verte (Ordovician) and pre-Devonian. Serpentinization and alteration to talc-carbonate have been widespread in these rocks.

In the Baie Verte - Ming's Bight region gabbro and diorite are common as small concordant masses which intrude the volcanic rocks and which are clearly later than the ultrabasic rocks. Quartz diorite, granite, quartz porphyry and granite porphyry masses occupy a large area in the southeastern part of the peninsula. They are part of a batholith which is thought to extend southward to join the main intrusive masses in central Newfoundland. Numerous dikes of a wide range in composition, and small stocks of quartz porphyry and granite porphyry intrude the volcanic rocks, particularly in the southern and eastern parts of the peninsula. These intrusive rocks are known to be post-Ordovician in age and have generally been regarded as Devonian, although no positive dating is possible.

DESCRIPTION OF FORMATIONS

Fleur de Lys Series

Distribution:

The occurrence of gneisses and schists in the peninsula between White Bay and Baie Verte was noted by Murray (1867) and Howley (1902). Brief descriptions of the gneisses and schists at Seal Cove and Western Arm, on the eastern shore of White Bay, were made by parties from Princeton University in 1915-17. Fuller mapped a small area, around the village of Fleur de Lys, which was largely underlain by gneisses, (1941). Watson, (1940), described similar gneisses, in the Baie Verte area, starting about two miles south of the southern limit of Fuller's mapping and extending for about ten miles southward. There he named the rocks 'Fleur de Lys Gneisses', because of the close resemblance to those in the area studied by Fuller.

Reconnaissance mapping by the writer showed that the gneisses and schists of the Fleur de Lys series form a continuous belt between the Fleur de Lys area and the Baie Verte area. Reconnaissance on the western side of the peninsula showed that these rocks extend from Partridge Point on the north, southward to at least Western Arm, a distance of thirty miles. These rocks occupy the entire width of the peninsula between White Bay and Baie Verte, except for a strip about two miles wide, that extends southward from Coachman's Cove along the west side of Baie Verte. The rocks of the Fleur de Lys series extend southward beyond the limits of the writer's mapping for an unknown distance.

For the rocks of this belt, the name 'Fleur de Lys series' is proposed, in place of 'Fleur de Lys gneisses' since it indicates better the stratigraphic significance of the rock unit and the fact that it includes rocks other than gneisses.

Rock Types:

The Fleur de Lys series consists chiefly 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 which weather grey or greyish brown. They consist essentially of quartz, albite, and biotite or muscovite, or both. In some facies hornblende takes the place of or is present with the mica. Much of the gneiss contains garnet, which locally may make up as much as twenty percent of the rock. Accessory minerals include chlorite, magnetite, pyrite and graphite. Rarely tourmaline is present. Banding is usually well marked. Bands which consist chiefly of quartz and feldspar and which may be quite narrow, alternate with others in which biotite, hornblende or chlorite predominate. Augen structure, with 'eyes' of albite, is also common. No microscope work was done by the present writer on the rocks of this series and for descriptions of a few types from the Baie Verte area and the Fleur de Lys area, the reader is referred to the reports of Watson and Fuller.

The interbanded dark schists form a relatively small proportion of the series. 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 (1941, p. 7) occurs in narrow lenticular bands and contains a considerable amount of muscovite distributed through it. The rare quartzite also described by Fuller, is a white, platy or schistose rock.

Following is a cross-section of the series as exposed in the type locality in the Fleur de Lys area. Fuller subdivided the series into six 'formations', within some of which he distinguished several 'members' or 'zones'. The section, as given below, was modified by the writer from Fuller's report (1941, pp. 7, 15, etc.). The thicknesses given are true thicknesses. The present writer visited the type locality but did not measure the section again.

Fleur de Lys Series

Pardee Gneiss	1000'	Platy, blue-grey gneiss, in irregular bands, in which thin quartz layers alternate with muscovite-biotite bands. Some magnetite, graphite and pyrite are also present.
Birchy Schist	600'	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.
Shoalrocks Gneiss	3000'	Light, greenish-grey, crinkled gneiss, with feldspar augen, quartz, muscovite and some garnet; of grain size varying from 0.3 mm to 0.06 mm.
Logy Formation		
Woody Cove Member	1000'	Garnet gneiss, schist, and dark brown, biotite-garnet gneiss.

Ygol Member	1200'	Light grey, quartz-muscovite gneiss, with minor garnet, pyrite, and some hornblende-rich layers.
Lue Point Member	350'	Dark brown, platy biotite gneiss.
Lince-a-Jardin Member	700'	Light grey garnet gneiss.
Caplin Cove Member	270'	Dark brown, platy, biotite-rich gneiss with graphite. The lowest twenty feet is a bluish-grey, pyrite-stained marble, with abundant muscovite.
Starboard Gneiss	5000'	Regularly banded, bluish-grey gneiss when fresh; weathers to brownish-grey. Light grey garnet-bearing gneiss with darker bands of biotite-bearing gneiss containing graphite, and hornblende gneiss. Lower portion contains marble lenses, made up of calcite and muscovite, ten to forty feet thick. Bottom two feet is a pure white platy quartzite.
Headland Gneiss		
Capta Zone	4000'	Quartz-feldspar-biotite-garnet gneiss, with whitish-grey fine grained, muscovite-rich facies and darker, platy, garnet-bearing varieties.
Barry Zone	4000'	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 present also.

Structure:

Where examined by the writer along the western side of the peninsula from Partridge Point to Back Cove, the rocks of the series have a northeasterly strike, and dip westward at 40° to 80°, except just north of Seal Cove, where some vertical and eastward dips were observed. On the east side of the peninsula in the area mapped by Fuller and Watson, and in the country reconnoitred by the writer between these areas, the same general northeasterly strike prevails, but dips are eastward, at 30° to 75°. 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 locally are some minor synclinal folds, as in the extreme south-east of the Fleur de Lys map area, where a syncline strikes north-easterly across Little Bay Head. Near Partridge Point also a number of east-west strikes and southerly dips were recorded by Fuller, (1941, map). The possibility that the peninsula is not a single anticlinorium, but a series of close folds is recognized. However the fact that no fold axes have been recognized anywhere in the areas mapped in detail or on reconnaissance suggests that the former possibility is more likely than the latter.

Origin and Metamorphism:

Nearly all of the rocks of the series are of sedimentary origin. The occurrence of conformable, interbedded crystalline limestone and quartzite is strongly suggestive of this, as is also the presence of graphite in some of the biotitic bands. The fine, persistent banding of 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, sometimes as much as twenty percent 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 quite so clear. On the southern shore of Middle Arm (WB) some of the hornblende-rich layers have the appearance of much metamorphised dikes, or sills. Some of the dark schists could possibly represent original dark shales or graywackes.

There is some difference of opinion 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 which have invaded the rocks of the series, as for example the Partridge Point granite stock and pegmatite dikes on Pidgeon Island.

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; and similarly "secondary" feldspar which surrounds and includes the original minerals of the rock. He found that the amount of introduced feldspar decreases away from the Partridge Point Stock, (Fuller, 1941, p. 51). 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, (1940, p. 19).

In his study of the Fleur de Lys gneisses through the entire length of the peninsula, the writer was impressed by their general uniformity in mineral composition, and this feature in his opinion indicates that in general they are the result of normal regional metamorphism, falling into what Harker has designated the "garnet zone" (1932, p. 218). Locally, however, as in the vicinity of the Partridge Point granite stock and other igneous intrusions, they have doubtless been subsequently modified by the introduction of material by hydrothermal solutions. The presence of two kinds of quartz and feldspars is not of itself proof of hydrothermal activity, since either of these minerals may well be formed through reconstitution of the material of the sediments which gave rise to the gneisses. This may be true also of the tourmaline as has been shown by Harker, (1932, p. 222) and others, and of the albite "augen" that are present in some facies of the gneiss. It is common for albite that has been formed during regional metamorphism to appear as porphyroblasts, (Harker, 1932, p. 223). Fuller's microscope studies have shown that many of the augen of feldspar contain rows of inclusions that are set at an angle to the general foliation. The orientation of these augen is almost certainly to be explained by the rotation of crystals during growth, examples of which have been reported in augen gneiss from numerous localities. Thus there is no reason to believe that the "augen" of feldspar were not produced by reconstitution of the original material of the sediments.

Age:

The age of the Fleur de Lys series has not been definitely established. Workers in the area from Murray (1864) to Watson (1940) have considered them to be Precambrian on the basis of lithologic studies.

The Fleur de Lys gneisses are apparently not the metamorphosed equivalent of any known Paleozoic series. These are described below. At Sop's Arm on the west coast of White Bay, Heyl (1937) has described fossiliferous, lower Paleozoic sandstones, limestones and shales with some volcanics. Betz (1940) extended the mapping of the rocks described by Heyl into the southern White Bay district. Fossiliferous Cambrian and Ordovician limestones, dolomites, sandstones and shales were studied by Betz (1939) at Canada Bay, forty miles north of Partridge Point. Paleozoic rocks in the rest of the Burlington Peninsula consist of thick Ordovician lavas according to the studies of Watson (1941), Snelgrove (1929) and the present writer (see below). Eastward in Notre Dame Bay MacLean (1940), Espenshade (1937), Heyl (1936), Baird (1946) and others have described fossiliferous middle Ordovician shales and chert with interbedded lavas and graywackes. Zones of conglomeratic red sandstones, and shales, irregular in their distribution, have been assigned to the Silurian by the same writers.

Precambrian sections have been described elsewhere in Newfoundland. Many of the rocks that have been described thus far however have been granite orthogneisses and cannot be correlated with the metamorphosed sediments of the Fleur de Lys series. Buddington (1919, p. 478), Murray and Howley (1868, etc.) state that the Precambrian rocks of the Avalon peninsula were derived from volcanic rocks. Certain biotite schists and quartzose gneisses in the central Long Range which were thought to be Precambrian by Foley (1937, p. 7) correspond in general description to the Fleur de Lys gneisses. Roof pendants of similar gneissic rocks have been observed far to the south in the Long Range in the Bay St. George region by Baird (1943). But in both these places, as elsewhere in the Precambrian of Newfoundland, age determinations are based on lithologic studies, and general negative evidence.

The metamorphic changes in the Fleur de Lys series must have taken place early in the history of the region. The Baie Verte series of supposed Ordovician age is predominantly in the greenschist facies in the western parts of its exposure (see description below). The

Fleur de Lys series, of supposed Precambrian age, is in the garnet zone of progressive metamorphism. No progressive rise in the grade of metamorphism as the boundary of the Fleur de Lys series is approached was noted in the Baie Verte series. It therefore does not seem likely that the Fleur de Lys series and the Baie Verte series can represent different zones of the same regional metamorphism, separated by an isograd. The metamorphism of the Fleur de Lys formations must therefore have taken place during a period of regional deformation predating the Ordovician (?) Baie Verte series and probably in the Precambrian.

Thus, no certain correlation of the Fleur de Lys gneisses is possible at present. However, the absence of fossils, the lack of correspondence with any known Paleozoic section, and the grade of metamorphism above that of any known Paleozoic series suggest that the rocks of the Fleur de Lys series are more probably Precambrian than Paleozoic.

White Bay Series

Distribution:

The White Bay series was named by Betz (1941, p. 24, etc.) from exposures along the eastern shore of White Bay. The rocks extend northward from the south end of White Bay into the southwest corner of the Burlington Peninsula, and occupy a narrow coastal strip in the vicinity of Western Arm. They are not exposed on the eastern side of the peninsula.

The rocks now called the White Bay series were mentioned briefly by Murray in 1865 (Rept. for 1864, p. 18). Howley referred to these rocks in 1902. (Rept. of the Nfld. Geological Survey for 1902, p. 15). Little detailed information was given, however, and the series was described only as, "brilliant mica schists, sometimes characterized by innumerable coarse garnets, --- with micaceous quartzites, and many calcareous layers --- that generally assume the character of impure marbles." It was further stated that the rocks of this series extend, "uninterruptedly from the head of the Bay all along the shore to Middle Arm Point."

The notes of the Princeton expeditions to Newfoundland (1915, 1916, 1917) mention the rocks of the White Bay series. They disagree, however with Howley's description of the northward extent, stating that "the west side of Bear Cove shows the metamorphosed sediments which are not seen anywhere to the north in White Bay." (After Betz, 1941, Appendix p. 3). The rocks are described as "quartzites, mica schists, and crystalline limestone".

On a brief reconnaissance along the eastern shore of White Bay the writer found that the Fleur de Lys gneisses, described above, extend southward along the shore from Partridge Point as far as Back Cove near the mouth of Western Arm (See Fig. 1). Dark schists, gneisses and marbles similar to the rocks at Bear Cove (described below) are exposed along the shore on the western side of Back Cove. The contact of the White Bay series with the Fleur de Lys gneisses appears to lie under the low neck of land, that joins the ridge on the west to the mainland on the east, and to continue southward under Bear Cove (See Plate 1).

Description:

Along the western shore of Bear Cove the White Bay series consists of mica schists, quartz-mica-feldspar gneisses, light cream, and white marble. Small quartz veins were observed at a number of places. Along small faults that cut the marble, calcite crystals, up to six inches long, occur in pockets and lenses. Scattered through the marble are lenses of mica schist six inches to one foot in length.

The strike of the banding of the rocks of the White Bay series is uniformly northnortheast, parallel to the shore of White Bay. Dips are uniformly westward toward the bay at 50° to 70°, except where small faults have caused local irregularities, as for example at Bear Cove. In some places the schists and gneisses are highly crumpled, but do not depart markedly from the general northnortheast trend.

Because of the strike of the formations parallel to the shore and the lack of deep indentations at right angles to the coast, good cross-sections of the White Bay series are not common. At the mouth of Big Chouse Brook the following section, though less than fifty feet thick, is representative of the southward continuation of the series, (Betz, 1941, p. 25)... (Top to bottom)...

Quartz-mica schist
Coarsely crystalline white, grey and pink limestone, with some interbedded schist.
Tourmaline-bearing schist
White and cream colored marble
Quartz-mica schist

Some conglomeratic beds, crystalline limestone with abundant muscovite, rutile and ilmenite-bearing schists were also noted in southern White Bay by Betz.

The presence of abundant muscovite, biotite, and garnet suggests that the rocks of the White Bay series are in the garnet stage of regional metamorphism, according to Harker's classification, (1932, p. 218).

The gneisses and schists of the White Bay series are similar in most respects to those of the Fleur de Lys series. Both series dip westward toward White Bay. The Fleur de Lys series dips under the White Bay series. It is on the basis of this somewhat scanty evidence that the Fleur de Lys series is considered to be older than the White Bay series.

There is no evidence to suggest that the two series are not conformable. Betz divided the metamorphosed rocks of the eastern shore of White Bay into the two series on the basis of lithology, (1941, p. 24). According to the studies of the writer the only significant difference is the presence of abundant recrystallized limestone and marble in the White Bay series. But marble horizons are not altogether lacking in the Fleur de Lys series (See section of Fleur de Lys series, p. 52). The two series may just as well be considered as upper and lower parts of the same series. However, the name exists in the literature and will be allowed to stand until a more detailed study of the complete section, exposed along the eastern shore of White Bay, enables a more authoritative determination of the status of the two units.

Age:

The age of the White Bay series is unknown. No fossils have been found anywhere on the eastern side of White Bay. The marble horizons, the most promising beds of the series, have undergone such a degree of recrystallization that it is unlikely that fossils have been preserved. Age determination at present must therefore be on the basis of lithology, and structural relations. A careful comparison of the rocks of the White Bay series with rocks of known Paleozoic age in Newfoundland shows no lithologic similarities. (Cf. discussion of age of the Fleur de Lys series). This does not necessarily prove that the White Bay series is not a Paleozoic series. However, taken together with absence of fossils and the high degree of metamorphism compared to Paleozoic rocks in adjacent parts of Newfoundland, it seems that the age of the White Bay series is most probably Precambrian.

Ming's Bight Series

Introduction:

The Ming's Bight gneisses and schists occupy about eleven square miles in outcrop in the peninsula between Ming's Bight and Pacquet. The rocks of the series are exposed along the coast from near the mouth of South Brook of Ming's Bight to the south side of Pacquet Harbor, and are bounded on the south by the arcuate contact of the Dunamagon granite (See plate 16). The structure of the mass is broadly domal with superimposed folds. A southward-plunging anticline parallels the southern shore of Ming's Bight, and close isoclinal folding occurs in the region of Pacquet Harbor.

It was not found possible to compile a columnar section of the Ming's Bight series or to arrive at an accurate estimate of the thickness because of structural complications and the absence of a recognizable succession or horizon markers in the monotonous succession of quartz-albite-biotite gneisses. The writer's estimate of the thickness of the series is about 8,000 feet, but it is admittedly little more than a guided guess.

The country which is underlain by the rocks of the Ming's Bight series is a rolling upland, without any distinctive topographic details. Along the coast, in the zone of wave action, massive quartzose members resist erosion and form points whereas chlorite-rich or biotite-rich members commonly underlie the coves. Faults and shear zones are always more easily eroded than the undeformed rocks, and can often be detected by their occurrence along sharply defined inlets.

General Description:

The Ming's Bight series consists of gneisses and schists which are made up 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 intercalated basic sediments.

The rocks of the Ming's Bight series weather to light and dark greys except in the hornblende-rich and the chlorite-rich facies where greens prevail. Several types are recognized within the series:

(1) Distinctly banded gneisses, which contain different proportions in different layers of quartz, albite, biotite and occasionally garnet.

(2) Porphyroblastic augen gneisses.

(3) Massive, fine-grained, quartz-biotite gneisses which may have been derived from granite in some cases.

(4) Chlorite-rich and hornblende-rich schists and gneisses.

(5) Graphitic schist and slate.

(6) Quartzite.

(7) Garnetiferous quartz-muscovite gneisses.

(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 (See Fig. 16). They are well exposed along the shore of Ming's Bight from South Brook to the Red Cliffs and from Cape St. Martin to Pacquet Point. The individual layers are from half an inch to one foot thick. They are persistent over distances of one hundred feet or more, which suggests the possibility that the layering is of sedimentary origin. Individual layers within the banded gneisses are usually quartz-albite-biotite schists, which in places contain abundant chlorite, and micaceous quartzites.

In thin sections the rocks are seen to be medium grained, foliated, and to have a granoblastic fabric. Quartz, which makes up from 50% to 80% of the rock, occurs as aggregates of interlocking serrate-edged grains which average between 1/10 mm and 1/2 mm in diameter in different facies. In almost all the sections the quartz contains abundant minute inclusions and almost always shows prominent Boehm lamellae. Biotite, X-straw, Y-brown (or rarely green), Z-dark brown, almost opaque (dark green), occurs in elongated wisps and shreds which in fine-grained varieties average 1/2 x 1/20 mm and in coarse grained facies as large as $2\frac{1}{2}$ x 1 mm. It constitutes up to 15% of the rock. Haloes are abundant in the biotite around minute crystals of zircon. In some flakes of biotite the haloes are immature and faintly pleochroic, whereas in others they are strongly pleochroic and dense, almost opaque (See Figs. 44 and 45). Untwinned grains of albite (An 6-10) averaging about 1/2 mm in diameter occur in interlocking aggregates which comprise from 5% to 15% of the rock.

Occasional grains show twinning. Chlorite ($N_\gamma - N_\alpha = 0.008$) is a common secondary mineral and occurs as patches of interlacing sheaves and as alteration along cleavage lines and on the edges of biotite crystals. In some slides chlorite makes up 5% of the rock. Muscovite in irregular shreds, and grains of epidote are present in some bands. Other accessory minerals include magnetite, hematite, ilmenite, leucoxene, zircon, calcite, pyrite, apatite, zoisite, and rarely tourmaline. In the banded gneisses and also in the other types introduced quartz occurs as minute veinlets. The quartz shows conspicuous undulatory extinction and rows of inclusions. Calcite is a common accessory mineral.

Porphyroblastic augen gneiss:

Light grey gneisses which contain augen of albite from 1 to 3 mm in diameter are common in the Ming's Bight series. They are best exposed about halfway between South Brook and the Red Cliffs on the eastern shore of Ming's Bight.

The feldspar augen weather out in relief and impart to the exposed gneisses a rough pebbly surface. 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. The groundmass in some of the augen gneisses consists of a mosaic of interlocking quartz grains which make up about 65% of the rock, and average about 1/4 mm in diameter with micas and chlorite aggregating about 10 to 20%

of the rock, whereas others are strongly foliated mica schists in which the quartz makes up only about 20% and the foliation wraps around the eyes of feldspar. In most specimens albite and albite-oligoclase occur as interstitial grains in the groundmass.

Massive, fine-grained, quartz-biotite gneiss:

This type occurs at Grand Os Cove which is just east of the mouth of Ming's Bight, at Cape Hat and near Little Pacquet. In some sections of the coastal exposures the massive gneisses are broadly jointed and break off the cliffs in rectangular blocks as much as ten feet in longest dimension.

In hand specimen 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 commonly grade off into conspicuously banded types such as those described above. In thin section quartz is seen to make up about 60% of the rock. It occurs as a mosaic of interlocking serrate grains which are full of minute inclusions and which show conspicuous Boehm lamellae. Anhedral grains of albite (An. 9) with albite and Carlsbad twins are scattered through the rock. Strongly pleochroic brown biotite in wisps and shreds of irregular outline makes up 5 to 10% 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 dikes.

Chlorite-rich and hornblende-rich gneisses and schists:

Chlorite schists occur at several places on the eastern shore of Ming's Bight. For about 100 yards along the shore of Ming's Bight beyond the contact with the serpentinized ultrabasic rocks the Ming's Bight series consists of highly crumpled chloritic schists. They appear to be the result of chloritization of Ming's Bight schists by solutions which came in along the margins of the ultrabasic mass. Magnetite is an abundant accessory in the schists and suggests that much of the chlorite has been derived from the alteration of biotite which was already in the schists, and that introduction of basic material was secondary in importance.

Banded chlorite schists occur on the south side of the mouth of Big Cove Brook on the eastern side of Ming's Bight, and again near the mouth of Pacquet Brook, at Pacquet Harbor. The chlorite in the schists is very fine-grained, averaging less than 1/2 mm. Occasional grains of quartz and albite are scattered through the rock. Magnetite and pyrite occur in octahedra and cubes which commonly transect the foliation of the schists.

Thin zones of hornblende-rich biotite schists occur on the shore of Ming's Bight 200 yards south of Ming's Tickle (See plate 16). The rock consists of a dense, aggregate of finely divided biotite which averages less than 1/2 mm in diameter with accesory albite and quartz, in which are set slender prisms of common green hornblende as much as one inch long. The parent rock was most likely an impure shaly sediment.

<u>Graphitic schists and slate</u>:

Graphite-bearing schists are prominent at several localities, notably south of Ming's Tickle on the eastern shore of Ming's Bight, and in the valley of South Brook about a half mile from the mouth. In the Ming's Tickle 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 due to graphite. The characteristic rock is a dense, exceedingly fine-grained aggregate of sericite, biotite, quartz and albite, with accessory graphite. Slaty cleavage is sometimes prominent. No trace of organic remains was found in any of the graphitic rocks.

<u>Quartzite</u>:

Thin beds of quartzite occur at several localities between Ming's Tickle and L'Anse of Pardi (See plate 16). There are several types which 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 two inches thick and do not exceed two feet, are composed of 90% mylonitized and recrystallized quartz grains with about 5% albite and about 5% biotite. The rock has a conchoidal fracture and a metallic ring. Other quartzites have thin partings of biotite and sericite. One bed, which is about two feet thick, contains scattered, poorly crystallized, red garnets which are about 1 mm in diameter. Pyrite in minute cubes of less than 1 mm occur in some of the beds.

Between the outcrop of the L'Anse of Pardi granite and the shore thin layers of finely banded, light grey quartzite alternate with dark, biotite-rich layers and apparently are metamorphosed thinly-banded sediments which consisted of quartz sand and mud.

Garnetiferous quartz-muscovite gneisses:

Garnet-bearing quartz-muscovite gneisses occur on the north side of Pacquet Harbor, on the coast northeast of Pacquet, and at scattered localities in the northeast part of the outcrop area of the Ming's Bight gneisses and schists. Most specimens consist of lenticular aggregates of elongated serrate quartz grains which are separated by sheaves of biotite and muscovite. The quartz, which makes up 20% to 35% of the rock has strong undulatory extinction and numerous tiny, transparent inclusions. Albite makes up 10% to 20% of the rock. Muscovite, as much as 25% of the rock, occurs in scattered sheaves and pockets. Accessory minerals include chlorite, epidote, apatite, magnetite, ilmenite and leucoxene, and make up 10% of the total. Tourmaline, variety shorl, was noted in one slide. Strongly pleochroic brown biotite, up to 15% of the rock, commonly contains minute zircons with pleochroic haloes. Common red garnet occurs as euhedral porphyroblasts up to 2 mm in diameter. Theypartly truncate and partly thrust aside the foliated groundmass (See figs. 45, 46 and 47). In many specimens the garnets are clear and transparent, almost of gem quality.

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 Ming's Bight series. The introduction of actinolite into the wallrock is part of the normal sequence of the alteration of ultrabasic masses (See description of ultrabasic rocks). Chromite, magnetite, and calcite are common accessory minerals.

Metamorphism:

The rocks which gave rise to the gneisses and schists of the Ming's Bight series were sedimentary. The fine, persistent banding, which is noted particularly well in the Pacquet district and along the eastern side of Ming's Bight south of Big Cove, is more likely to be sedimentary bedding than banding due to metamorphism. Undoubted sedimentary layers such as the quartzites described above are part of the series. The mineral association of the gneisses and schists - quartz, albite, biotite, chlorite and occasionally garnet - is commonly produced by the metamorphism of impure sandstones, (Harker, 1932).

The usual mineral assemblage of the Ming's Bight series shows that the great bulk of the gneisses and schists are high in the biotite zone of regional metamorphism. The appearance of garnets at several localities especially near the granite contacts show that the rocks have been raised to the garnet zone. Most of the gneisses do not contain visible garnet but thin sections show that small garnets are widespread. In general the rocks of the Ming's Bight series are slightly lower in grade of metamorphism than the Fleur de Lys gneisses, with which they are correlated, (See page 50).

The Ming's Bight schists and gneisses have been affected by emanations from the intrusive rocks of the region. The intrusion of the ultrabasic rocks had little effect. Garnets are abundant in one zone near the contact in the valley of South Brook. Small amounts of actinolite, talc and carbonate have been formed in contact zones of both the Ming's Bight ultrabasic mass and the Red Cliffs mass, but the solutions which introduced these materials may have been derived from the granitic rocks of the area and thus are related to the ultrabasic rocks only in that they used the margins as conduits, (See discussion, page 189).

The rocks of the Ming's Bight series by and large have not received large additions of material from the granitic rocks of the region. Solutions derived from the Dunamagon granite have provided local silicification and minor alteration. Large replacement masses of barren white quartz such as the "White Cow" on the eastern shore of Ming's Bight, preserve the banding of the gneisses even though the original minerals have completely disappeared. At one place east of Pacquet, hydrothermal solutions were active in the production of garnet and muscovite along a narrow shear zone. Microscope studies show that in some of the gneisses the feldspars are sericitized, and that locally albite and quartz have been added, but the minerals in general have come from the reconstitution of sedimentary rocks. No progressive changes in mineral composition, as the distance from the Dunamagon granite increases, were noted, except that garnet is of more common occurrence near the granite.

Structure:

The structure of the gneisses is broadly domal. In the centre of the peninsula the dips of the banding are of the order of 20° to 30°, and in some places are actually horizontal. On the margins of the peninsula the formations dip outward. More detailed work is necessary to determine exactly the structure of these rocks which are complexly folded in many places.

Along the southern margin of the eastern shore of Ming's Bight the gneisses and schists strike uniformly at 10° to 15° and dip steeply to the west. Farther inland the dips are to the east, and the strike is the same. This evidence, together with that from abundant dragfolds which are well exposed along the shore, shows that an anticline with its axis as shown on the map parallels the shore of Ming's Bight and plunges to the south at approximately 30°.

At Ming's Tickle, at the mouth of Ming's Bight, the gneisses and schists which are markedly banded are tightly folded and faulted. North and east of the village of Pacquet, abundant dragfolds and dips which are nearly vertical indicate isoclinal folding. The plunge of the structure is to the southeast at approximately 30°.

Along the seacoast numerous normal faults of small displacement were mapped. One high-angle reverse fault occurs about one half mile west of Cape Hat. Many of the 'lineaments' discussed on page 223 cut the rocks of the Ming's Bight series.

Age:

The gneisses and schists of the Ming's Bight series underlie the volcanic rocks of the Baie Verte series which are considered to be Ordovician. The contact of the two series is thought to be an unconformity as shown at Pacquet and again southeast of the head of Ming's Bight, although at both localities exposures are incomplete and the rocks are greatly mashed. Thus the Ming's Bight series may be Ordovician but older than the Baie Verte series, Cambrian, or Precambrian.

The Ming's Bight series is correlated with the Fleur de Lys series and both are considered to be Precambrian for the reasons given on page 59.

Baie Verte Series

Introduction:

The rocks of the Baie Verte series underlie about 120 square miles of the Burlington Peninsula. They consist of andesitic lava flows, greywackes and tuffs with thin interbedded slates and marbles. The outcrop of the series is terminated toward the southeast by the intrusive rocks of the Burlington complex and the Cape Brulé granite. Toward the northwest they are bounded by the Fleur de Lys gneisses and schists with which they are thought to be in contact along a fault. Toward the north they lie unconformably on the gneisses and schists of the Ming's Bight series. Their southward extent is not known, since the rocks of the group continue beyond the southernmost limit of reconnaissance, (See plates 1 and 15).

The rocks of the Baie Verte series have been folded into a series of anticlines and synclines which trend northeast-southwest. Some are overturned. Most of the folds plunge northeast, although some plunge southwest. South of Ming's Bight folds are arranged en echelon.

General description:

The Baie Verte series consist predominantly of altered andesitic lava flows which are best described by the general term greenstone. Interbedded with the lava flows are fine grained greywackes, tuff beds, agglomerates, ferruginous chert, slate, altered sandstones, and thin marble horizons.

The lowest part of the series consists almost exclusively of altered lava flows which are now in all stages of metamorphism from recognizable pyroxene-bearing lavas to crenulated chlorite schists. A few thin horizons of greywackes and tuffs also occur. The best exposures are in the region south of Ming's Bight, near the southern margin of the Dunamagon granite, and in the Baie Verte area to the west.

The middle portion of the series consists largely of altered lava flows but includes in addition numerous interbedded tuffs, agglomerates, greywackes, pillow lavas, and beds of ferruginous chert. Amygdular and variolitic lavas, and zones which show flow structures, and flow breccias are also characteristic. The middle section of the Baie Verte series is by far the thickest and it is exposed over the widest area. An excellent cross-section is provided in the intermittent outcrops along the tote-road which leads south from Woodstock to Beaver Pond. Other sections are visible along the shores of Baie Verte and the western shore of Ming's Bight. The best exposures of the chert beds are in the Goldenville district and along the western shore of Ming's Bight at Big Head.

In the upper part of the series greenstone, which has come from the alteration of lava flows, is once again the most common rock type. At the very top of the series thin zones of slate, sandstone, marble, tuffs and greywackes are common.

Original Rocks:

Most of the lava flows of the district have been altered so much that little is left of the original minerals or the original structures. In the Baie Verte map area pyroxene-bearing lavas were observed by Watson (1939, p. 22) and Rose (1945), and at several places in the area to the east by the writer. In thin section they are similar to other greenstones of the district except that they contain fragments of recognizable pigeonite ($2V-35^{o}$) 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 one eighth to one quarter of an inch in longest dimension, though much smaller and much larger ones also occur. In some of the more altered zones of the greenstones elongated and broken masses of calcite, quartz, and epidote are interpreted as deformed amygdules.

Variolitic lavas occur on the western shore of Ming's Bight, but were not observed elsewhere by the writer. The variolites occur as grey or greenish knots about an eighth of an inch in diameter, and are set in a dark green groundmass which consists of chlorite, epidote and albite. Watson found that the variolites themselves now consist of epidote and clinozoisite, (1939, p. 24).

Finely banded tuffs and greywackes of greenish-grey color occur commonly in the Baie Verte series, but are especially abundant in the middle zone. In many places, such as the excellent exposures about one and one half miles south of Woodstock on the road to Beaver Pond, they are very finely banded with as many as twenty-five bands to one inch. In other occurrences, individual layers may be as much as eight inches thick. The difference in color of the various bands is primarily the result of variations in the proportion of fragments of altered hornblende to the lighter colored constituents. The light bands are made up almost entirely of quartz, albite and epidote, with minor amounts of hornblende, chlorite, and magnetite. 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 occurs, as well as a progressive decrease in the size of the fragments. Banding in these tuffs is persistent -- even the thinnest bands can be traced over distances of ten feet or more. Minute faults cut some of the layers but die out upward, which suggests that they took place during the deposition of the beds. In most occurrences banding is much more evident on the weathered surfaces than on fresh rock exposures.

At several places in the area coarse agglomerates with some finer tuffaceous layers occur interbedded with the lava flows. Good exposures occur on the western shore of Ming's Bight and on the Woodstock-Beaver Pond road. The fine facies are crystal and lithic tuffs, which contain abundant fragments of hornblende (possibly after pyroxene) about half an 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 also occur in these beds.

The coarse facies consists of angular chunks of altered lava, as much as one foot long, in a fine-grained groundmass which corresponds in description to that given above for the fine-grained tuffaceous facies (See Fig. 20). The lava fragments which 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 one half inch long in a fine grained groundmass of hornblende, albite, epidote, chlorite and calcite. In a few instances amygdaloidal lavas were observed in the agglomerates. The amygdules consist of the usual association of calcite, epidote and quartz.

Slate was observed at Duck Pond, at the eastern end of Bridge Pond, (See Plate 16), at the Terra Nova mine, and (by Watson, 1939, p. 25) on the west side of Baie Verte in the valley of Slaughter House Cove Brook. The most common type of slate in the Baie Verte series 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 one sixteenth of an inch long. In several zones near the southwestern end of the Dunamagon granite a slaty rock of the Baie Verte series is made up largely of sericite with minor amounts of quartz and albite, and no dark minerals. About three quarters of a mile south of Woodstock on the Beaver Pond road a black slate bed contains a hematite-rich layer about eight inches thick. The hematite shows slaty cleavage parallel to that of the rest of the rock and is made up largely of fine scales of hematite with chlorite, sericite, and other accessory minerals.

On the south side of Bridge Pond, about three and a half miles south of Woodstock a thin zone of dark slate is exposed in a road cut. In hand specimen it is seen to consist of a fine grained groundmass in which are set scattered flakes of specularite about 2 millimeters in diameter. In thin section it is seen to consist of a groundmass complex of biotite, chlorite, quartz, and albite grains, which average about 1/20th mm in diameter, and minute porphyroblasts of common green hornblende about 1/2 mm to 1 mm in length. The groundmass is strongly foliated and crumpled. Individual flakes of biotite are commonly twisted, bent and even broken. Microfolds which average about 1 1/2 mm from crest to crest occur throughout the groundmass. Quartz, both in the groundmass and as occasional grains as large as 1/2 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 one quarter of a millimeter. Biotite and chlorite occur as wisps and shreds throughout the rock. Accessory minerals are epidote, and opaques (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 made up of mylonitized quartz grains in a groundmass of feldspar, chlorite, actinolite and calcite occurs interbedded with the usual Baie Verte greenstones (Watson, 1939, p. 25).

Grey, green and cream colored marble, as lenses and irregular, non-persistent beds less than three feet thick, occurs with some of the altered lava flows. Similar limestones, which are sometimes 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. There seems little doubt therefore that the original limestone was precipitated as a result of the submarine extrusion of the lavas. The effective solubility of calcium carbonate decreases rapidly with increase in temperature and the heating of the seawater alone may have been sufficient to bring about precipitation. Analyses of the tops of flows and comparisons with analyses of the interior parts to find relative lime, soda, potash and magnesia content would show whether or not reactions between the lavas and the seawater had been a contributing factor.

Beds of ferruginous red chert, and lenses and nodules of grey, black and green chert occur at several places in the middle zone of the Baie Verte series. They reach theirmaximum thickness and persistence in the Big Head exposures on the west side of Ming's

Bight and westward through the Goldenville district. The average thickness of individual layers is eight inches to one foot, although local thicknesses of three feet occur at Big Head.

Specularite, magnetite, and pyrite are visible in the chert and are concentrated on the margins of the individual beds. Thin persistent banding which is the result of slight differences in the amount of hematite present in the chert, is characteristic in some occurrences. Quartz veins are very common in the chert beds and are apparently the result of the filling of fissures in the brittle chert beds which are interbedded with the more easily deformed and less brittle greenstones. The common association of chert with lava flows in Notre Dame Bay has led several writers to believe that the precipitation of the silica on the seafloor was the direct result of volcanic activity (Sampson, 1923; Heyl, 1936; Baird, 1946). Watson found certain colloform structures in some of the Goldenville chert beds which suggested to him that the silica was once in colloidal form, (1939, p. 29). Watson also considers that the presence in the chert of iron oxides, which may have been hydrosols bearing charges opposite to the silica colloids, have been important in the formation of the cherts. While this mutual precipitation of silica and iron oxide colloids may have been a contributing factor in the formation of the iron-rich cherts it could hardly have been important in the formation of the abundant non-ferruginous cherts such as those which occur in the Cape St. John series (see below) and which are abundant throughout the volcanic formations of Notre Dame Bay.

Greenschist facies:

The lavas and pyroclastic rocks of the Baie Verte series have undergone regional retrograde metamorphism which has changed them to chlorite schists in extreme cases and to many intermediate types which 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 which 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 Ming's Bight, in the interior of the peninsula around Flat Water Pond, and in the region south of the Baie Verte map area.

Along the margins of the granite and diorites 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 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 Ming's Bight south of Big Head where the massive 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% chlorite, 20 to 30% albite, 10 to 30% epidote, 10 to 20% quartz and variable amounts of pale blue-green actinolite, brown biotite, calcite, and opaques (mostly magnetite and hematite). The chlorite occurs as irregular sheaves and plates and is commonly developed along the cleavages and edges of biotite flakes. The feldspar is always albite (An 6) which occurs in fine mosaic patches and as irregular disseminated grains which average about 1/4 mm in diameter. The albite is untwinned for the most part, but occasional albite and Carlsbad twinning occur in the larger grains. Quartz occurs in the feldspar mosaic and also as scattered grains as much as 1 mm in diameter. Epidote in scattered grains and in irregular masses may constitute as much as 15% of the rock. Actinolite occurs as small porphyroblasts or as swarms of minute needles.

The average 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 mentioned 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 sections uralitic hornblende constitutes as much as 30% of the rock, but in others it has given way completely to actinolite, chlorite, epidote and zoisite.

Turner has elaborated the views of Eskola, Tilley, Vogt and others on the characteristic mineral assemblages of rocks in the Chlorite Zone, and has proposed further subdivisions of the Zone, in a series of papers on the schists of the Otage district in New Zealand. He has stressed that one must take into account not only variations in temperature and pressure but also "the function of water and CO_2. . .and of the conditions under which the assemblages originate, rather than those under which any assemblage, once formed, may subsequently remain in a state of equilibrium. . ." (1935, p. 419). On this basis he subdivided the Chlorite Zone into:

"(1) A facies corresponding to a relatively high grade of metamorphism, and independent of the presence or absence of CO_2 or of the amount of water available in excess of a minimum requirement. . . .

(2) Several distinct facies, all corresponding to the lowest grade of metamorphism within the Zone of Chlorite, may be recognised . . . ."

These subdivisions may be summarized as:

1. Actinolite-albite-epidote-chlorite schists, where CO_2 is absent, and water is insufficient to allow the chloritization of actinolite.

2. Chlorite-albite-epidote-calcite, where CO_2 is active and water is moderately plentiful.

3. Chlorite-albite-epidote (= Eskola's Greenschist facies), in the absence of CO_2 but with sufficient water to bring about the chloritization of actinolite, a process which demands the progressive removal of lime from the system.

4. Chlorite-albite schist (= Vogt's Chlorite-albite schist facies), in the absence of CO_2 and in the presence of abundant water, when alumina as well as lime is removed from the system.

Watson has discussed the significance of actinolite in chlorite schists, and the characteristic mineral assemblages in the rocks of the Baie Verte series. He has noted the occurrence of the following assemblages:

"(1) Actinolite - (chlorite) - albite - epidote - quartz

(2) Chlorite - (actinolite) - albite - epidote - quartz

(3) Chlorite - calcite - albite - epidote - quartz" (1939, p. 31)

These three assemblages are identical with numbers (1), (3), and (2) respectively of Turner, except that quartz, which is an accessory in nearly all of the rocks of the district has been added in each case, and accessory chlorite and actinolite have been added to numbers (1) and (2) respectively. Watson follows Turner in explaining that the chlorite of the second and third assemblages has come from the alteration of the actinolite, and that there was sufficient water to remove the lime in the second.

The work of the writer bears out the conclusions of Turner and Watson, but in addition suggests that more emphasis should be placed on the concept that the mineral assemblages listed above are but end-members of a continuously gradational series, which represents adjustment in a continuously gradational series of environments. Actinolite and calcite for example were not found to be mutually exclusive although where the one was abundant the other tended to be absent or nearly so.

Amphibolite Facies:

In the region to the east of the Baie Verte map area the rocks of the Baie Verte series have been raised to the amphibolite facies almost without exception. In hand specimen the following types are recognized in the amphibolite facies:

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

Massive Amphibolitic Greenstone:

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 made up 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 Sackery's Cove, in Pacquet Harbor, massive amphibolitic greenstones include abundant irregular knots of albite, calcite, and epidote which are probably deformed amygdules.

Hornblende (X-straw, Y-green, Z-blue green, $Z \wedge c = 19^{\circ}$) occurs as anhedral to subhedral crystals and aggregates up to 2 1/2 mm long and constitutes 35 to 70% of the rock. Some hornblende crystals are full of poikiloblastic inclusions of albite and epidote. Albite (An 6-10) occurs in a groundmass mosaic of interlocking crystals which average 1/4 - 1/2 mm in diameter. It is usually untwinned. In one section much altered crystals of An 40 suggest that the original feldspar of the lavas was andesine. Chlorite occurs as patches of interlocking sheaves in accessory amounts. Epidote in grains less than 1/5 mm may constitute as much as 5% of the rock. Accessory minerals include brown biotite, apatite, zoisite, calcite, quartz, magnetite, and hematite.

Gneissic Amphibolitic Greenstones:

Gneissic amphibolitic greenstones are marked by alternating layers which are respectively amphibole-rich and quartz-albite-rich. (See Fig. 51). In some sections microcrumpling is evident. In the hornblende-rich layers the hornblende (straw - olive-green - blue-green, $Z \wedge c = 19^{\circ}$) occurs as an interlocking meshwork of anhedral crystals which average about 1/2 mm in greatest dimension. Albite is accessory.

In the quartz-albite-rich layers albite (An 8) and some quartz occurs in a mosaic of interlocking crystals about 1/4 mm in diameter with numerous inclusions of epidote. Occasional knots of cloudy feldspar in both the light and dark bands have the foliation wrapping around them. Epidote, which makes up 5% to 15% of the rock occurs as scattered grains and clumps averaging 1/10 mm and as inclusions in altered feldspar grains. Accessory minerals include zoisite, magnetite, biotite, and chlorite.

Hornblende needle schists:

Hornblende needle schists are the most common of the amphibolite facies. Many variations of hornblende needle schists occur along the northeast and southeast shores of Pacquet Harbor, and southwestward to Side Pond (See Plate 16). They are all markedly foliated, and in some localities show a strong lineation. Hornblende, which is commonly actinolitic, constitutes 40 to 55% of the rock and occurs as slender prisms and elongated masses up to 3 mm x 1/2 mm. Albite (An 6) which makes up 35 to 50% 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 which are made up of a mosaic of albite grains have the hornblende needles 'flowing' around them like logs around a boulder. Quartz is an abundant accessory in some slides, and may constitute as much as 10% of the rock. Other accessory minerals include epidote, biotite, zoisite, calcite, and magnetite.

In one section from near a granite contact tourmaline (var. Shorl) makes up 3% of the rock. Occasional knots of chlorite surrounded successively by albite, epidote and then the usual groundmass of the rock possibly represent altered vesicles.

Porphyroblastic Hornblende Gneiss:

In several areas a distinctive type of greenstone is found to be made up of slender euhedral porphyroblasts of green hornblende, or actinolitic hornblende set in a granoblastic groundmass of albite, epidote, biotite, and chlorite which average approximately 1/4 mm in length. The porphyroblasts of hornblende which may be as large as 4 mm x 1/4 mm and make up as much as 40% of the rock commonly contain poikiloblastic inclusions of epidote and albite. In one specimen from the west side of Confusion Bay, in a region of complex overturned folding, slender needle-like porphyroblasts of green hornblende as much as 7 mm long are set in a granoblastic groundmass of quartz (30%), albite (10%), chlorite (10%), biotite (15%), and epidote (15%) of an average diameter of 1/8 mm (See Fig. 54). Accessories include magnetite (up to 5%), hematite, and apatite. The rock represents a reconstituted basic sediment. 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 regional dynamic metamorphism; and the second, during which the unoriented porphyroblasts developed, was 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%), calcite (5%), and epidote (3%), and small needles of actinolitic hornblende. In a few crystals pigeonitic augite is still recognizable at the core. The bulk of the crystals are uralite. The outside 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 which raised the greenschist rocks of the region to the amphibolite facies (See Fig. 55).

<u>Origin of Banding in the Greenstones:</u>

Part of the banding which was observed at many places in the greenstones is without doubt due to original banding in tuffs and greywackes. On the other hand banding, i.e. the alternation of hornblende-rich and quartz-albite-rich layers, in the massive greenstones which were derived from the thick lava flows in the regions of intense metamorphism, such as along the shores of Pacquet Harbor, is thought to be the result of metamorphic differentiation, at least in part. Turner, (1941, pp. 1 to 16), has discussed the processes of differentiation during metamorphism in similar schists of the Otago district of New Zealand and has concluded that they were important in the development of banding. He has emphasized the close interrelationship between chemical and mechanical processes and shows the importance of the selective extraction of the most soluble constituents and their reprecipitation along planes of movement, granulation or fracture. The present writer considers that such a process may have been active in the derivation of the banded amphibolitic greenstones from massive lava flows.

In Pacquet Harbor, not far from the outcrops of the Dunamagon granite and the Cape Brulé granite, numerous poorly-defined masses of quartz and hornblende, in addition to the usual quartz veins, occur in amphibolitic greenstones. In many places pockets of hornblende crystals which are as much as four inches long occur irregularly through the greenstone. They sometimes occur as discrete masses and sometimes as expanded parts of hornblende-rich layers of the gneisses. Such pockets of hornblende are unknown in the adjacent quartzose gneisses and schists of the King's Bight series, although irregular pockets of quartz and felted clots of biotite are common. Though no positive evidence can be adduced it is considered that some of the quartz and some of the hornblende which occurs in the manner described above were concentrated by a process of selective extraction and reprecipitation in the manner first described by Eskola (1932, p. 70) and discussed by Turner (1941, see above).

It is apparent that the practical approach to the problem of distinguishing ordinary vein material, which was introduced from outside the system from vein material which came from the rock itself by selective extraction, is through detailed petrofabric studies and by careful comparison of analyses of the banded and unbanded portions of the same flows.

Alteration:

In several places, close to the outcrop of the Cape Brulé granite, zones of silicification occur in the Baie Verte series. The introduced quartz occurs as diffuse replacements and as intricate networks of veins which commonly weather out as boxworks on the surface of the greenstones. At one locality, about three miles due south of Ming's Bight, and at another about three quarters of one mile north of Side Pond, the introduced quartz constitutes over 60% of the rock. No trace of mineralization was found at either of these places. Silicification on a large scale accompanied the mineralization at the Rambler prospects east of Baie Verte (See Plate 12 for location). Sericitization accompanied silicification at some places. The principal prospect at the Rambler, the 'Gold Pit', occurs in a zone of pronounced silicification and sericitization. In the mass of Baie Verte rocks which lies on the shore of Confusion Bay between Brent Cove and La Scie several zones of silicification accompanied by sericitization and the introduction of small amounts of pyrite occur in the shore exposures. They are without doubt related to the granite porphyry which outcrops nearby.

Carbonatization of the greenstones is sometimes very intense and has produced in some places from the altered volcanic rocks of the series a distinctive rock type which may contain as much as 60% brownish ferrodolomite. Carbonatization and steatitization of the greenstones occurs near the contacts of the ultrabasic rocks.

Epidotization is locally important, as for example on the south-east shore of Pacquet Harbor, where it is intimately associated with the quartz veins.

<u>Age</u>:

Fossils have not been found in the rocks of the Baie Verte series. A careful search in the slates and graphitic schists yielded no trace of recognizable organic remains. On this account, the determination of the age of the series must be on the basis of lithologic and structural evidence. The only fossils ever found in the rocks of the Burlington Peninsula were graptolites which Snelgrove found in the lowest part of the Snook's Arm series 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. They thus identify the Snook's Arm series as Ordovician (Snelgrove, 1931).

In Notre Dame Bay, from New World Island to Snook's Arm thick lava flows and pyroclastics rocks of intermediate composition with thin, interbedded, fossiliferous marine sediments are characteristic of the Ordovician (Heyl, 1936; Espenshade, 1937;MacLean, 1931; Baird, 1946, etc.). They are the result of both fissure and central type eruptions, and were apparently partly submarine.

At no time in the geologic past other than in the Ordovician was such a sequence of volcanic rocks laid down in Newfoundland. The Precambrian rocks of northern Newfoundland are almost entirely granitic gneisses and schists, without volcanic rocks. The Cambrian rocks of the region are entirely sedimentary. The Silurian record consists largely of reddish conglomerates and sandstones, with rare lava flows of acidic composition. Devonian rocks are continental red beds. Carboniferous rocks, known in western Newfoundland, are entirely sedimentary (See discussion of age of Fleur de Lys series). Thus there is little doubt from lithologic comparisons that the rocks of the Baie Verte series are Ordovician.

The particular part of the Ordovician to which the rocks of the Baie Verte series belong is not distinguishable. Metamorphism has altered the lava flows, pyroclastic rocks, and minor sediments 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 use. This difficulty has been experienced previously in attempting to correlate the rocks of different areas in Notre Dame Bay (Unpublished chart of the G.S.N.).

Both the Baie Verte series and the Snook's Arm series immediately underlie the Cape St. John series. Together with a general lithologic similarity this suggests that the two series may be roughly equivalent. But nothing more positive than that the Baie Verte series is most likely Ordovician can be stated with the present evidence.

The Snook's Arm Series

Introduction:

The Snook's Arm series is exposed along the coast of Notre Dame Bay from near Nipper's Harbor to Beaver Cove, which is one half mile northeast of Tilt Cove. The series occupies a crescent-shaped belt which is about three miles wide at its widest part, between Snook's Head and Red Cliff Pond, and tapers toward the northeast and the southwest.

These rocks were first described in the early reports on the copper mines at Tilt Cove and Bett's Cove by Murray and others (See Historical Resume, p. 7). The first systematic mapping and the naming of the series were done by Snelgrove (1929). Detailed descriptions of small areas around the mines have been published by Douglas (1940). The present writer has travelled widely in the area underlain by the Snook's Arm rocks and has done detailed mapping in the Bett's Cove and Nipper's Harbor areas.

The formations dip steeply, and the general trend is northeast-southwest. The structure is not entirely clear, but appears from stratigraphic repetition and the relation of minor folds to the bedding to be a tightly folded anticline which plunges at a low angle to the northeast. A detailed discussion of the structure of the series is deferred to the chapter on Structure.

General Description:

Fine-grained red slates and argillites with some coarse, clastic sediments are exposed at Tilt Cove, (Snelgrove, 1931, p. 12; Douglas, 1940, p. 107). Overlying them unconformably is a thick series of andesite flows, agglomerates and conglomerates which constitute the Snook's Arm series proper. For ease of description the following types are recognized:

(1) Andesitic agglomerates, breccias and conglomerates

(2) Andesite and augite-andesite porphyry tuffs

(3) Diabase porphyrite

(4) Andesite lavas and pillow lavas

(5) Slates and argillites

Andesitic agglomerates, breccias, and conglomerates:

Andesitic agglomerates and breccias are common members of the Snook's Arm series. In addition several members which should properly be classed as conglomerates with well-rounded, water-worn pebbles and cobbles were noted by the writer.

Most of the fragments of the agglomerates, breccias, and conglomerates are andesite, which is similar in all respects to the flows both above and below. The average size of the fragments is about four inches, but some are as long as two feet. Many of the fragments are of silicified lavas and in some cases silica is found as a cement. The fine grained groundmass is made up of tuffaceous material, up to about 3 mm in length, which is commonly epidotized. Reddish varieties of the agglomerates and conglomerates commonly owe their color to a coating of hematite on both the groundmass grains and the large fragments.

In some examples it is evident from the degree of sorting and the conspicuous cross-bedding that deposition took place in a swift current of water. The occurrence of pillow lava units both above and below the agglomerates suggests that deposition was submarine. The absence of red chert fragments and the strongly epidotized groundmass differentiate the water-laid units of the Snook's Arm series from the somewhat similar beds of the Cape St. John series.

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 water-laid and the lava flow members of the series. There are two types:

(a) Aphanitic, andesitic tuffs, which are greenish and which are sometimes distinctly stratified. Minute fragments of green chert in minor quantity are sometimes present in addition to the abundant andesite. These tuffs have been silicified, epidotized and, along fault zones, strongly chloritized.

(b) Augite-andesite porphyry tuffs were described by Snelgrove in the series though they were not observed by the writer. They differ from the general type above in that they contain fragments of pyroxene and porphyritic augite-andesine (Snelgrove, 1929, p. 46).

Diabase porphyrite:

Coarse-grained sills and dikes, and irregular masses of diabase porphyrite in the Tilt Cove area were considered by Snelgrove and Douglas to be the intrusive equivalents of the andesite lava flows of the region. (Snelgrove, 1929, p. 49; Douglas, 1940, p. 107). In other parts of Notre Dame Bay a similar relation has been postulated (Heyl, 1936).

Andesite lavas and pillow lavas:

Andesite flows make up the major part of the Snook's Arm series. The individual flows are thick and persistent. They show little variation from outcrop to outcrop except that some are massive, some are pillowed and some are vesicular.

The most common are the pillow lavas, which are particularly well exposed in Bett's Cove Head, Beaver Cove and other points along the coast as well as in several cliff exposures inland (See Fig. 22). Some of the flows are over two hundred feet thick, and are pillowed throughout. The pillows themselves are sometimes bun-shaped, but more often are ellipsoidal or elongated, and are locally flattened. They are from eight inches to five feet long. In most cases the centres are much more coarsely crystalline than the edges which are aphanitic and in some places show amygdules and vesicles. Similar massive pillow lava units occur widely in Notre Dame Bay as far east as the middle of New World Island (Heyl, 1936; MacLean, 1940; Baird, 1946, etc.). Chert, usually of a greenish or greyish color is present in important amounts as lenses a few inches thick and as irregular masses between the pillows. Sampson 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, (1923, see also Cape St. John series below).

Snelgrove's (1931) microscope studies showed that the andesites are made up of nearly colorless augite, plagioclase feldspar and hornblende crystals which are 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 portions and is sometimes even black. Quartz, epidote and calcite are the most common fillings of vesicles.

Slates and argillites:

Black slates which are associated with the pyroclastics in the lower part of the series contain graptolites of early Ordovician age. Fine-grained red argillites and slates which occur at the base of the series appear to have been deep-water mudstones, (Snelgrove, 1931, p. 12).

Alteration:

Alteration in the series is widespread. Epidotization affects all the members of the series strongly but particularly the tuffaceous facies. Silicification is common in some zones, notably near the copper mineralization. Chloritization is most common in the pillow lavas of the series, where it is most intense along the margins of the pillows and in the spaces between them. Copper mineralization, which is usually confined to shear zones, is almost always accompanied by intense chloritization which has altered the lavas to chlorite schist. The heterogeneity of the pillow lavas and the numerous fault zones in the series have made them especially susceptible to chloritization by affording channelways for the migration of solutions from the nearby granite masses, (Cf. Cape St. John series).

Bishop's Rock:

In addition to reconnaissance on the mainland the writer visited Bishop's Rock, which is an island of about one acre that rises about 30 feet above the sea, some 1.7 miles southeast of Manful Head in the Cape St. John area (See Plate 16). The rocks are conglomerates, tuffs, and dark green, fine-grained sediments and pyroclastics. Most of the fragments in the pyroclastic layers and the boulders in the water-laid deposits resemble closely the andesites of the Snook's Arm series. In some layers rounded and angular boulders as much as one foot in diameter are contained in a fine-grained, greenish-yellow, tuffaceous matrix. Silicification and epidotization of both the boulders and the groundmass are common. The rocks of this exposure are in every way suggestive of the Snook's Arm series and are correlated with them, although the nearest exposure is at Beaver Cove about 7.1 miles distant.

Age:

The graptolites which were found by Snelgrove establish beyond reasonable doubt the Ordovician age of the Snook's Arm series. The lavas, pyroclastic rocks and sediments follow upward through the series without break. The position of the slates and argillites which occur at the base of the Snook's Arm series is doubtful. The unconformity which separates these fine-grained, metamorphosed sediments from the overlying lavas, and interbedded pyroclastic rocks and coarse sediments shows that the earlier sediments were folded and eroded before the beginning of the volcanism, (Douglas, 1940, p. 107). The age is regarded therefore as possibly:

(1) Pre-Snook's Arm, but Ordovician and part of a separate series.

(2) Pre-Ordovician.

(3) Precambrian. This does not seem likely in view of the fact that other Precambrian rocks in Newfoundland are of different lithologic types, and are more highly metamorphosed, (See Fleur de

Lys series, Age).

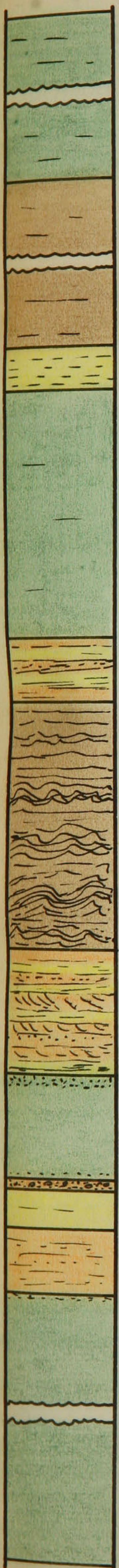
The writer therefore has classified the red slates and argillites which unconformably underlie the Snook's Arm series as Ordovician or older.

The Cape St. John Series

Introduction:

The writer here proposes the name Cape St. John Series to include the whole sequence of lava flows, interbedded sediments and pyroclastics which lie above the Snook's Arm series. Snelgrove (1931) and Douglas (1940, 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 series is actually dominantly tuffaceous and the upper part of the series is composed largely of lava flows. The writer has found however in the extension of the series to the northwest toward Confusion Bay and the northeast toward Cape St. John that what was formerly called the Goss Pond volcanics is but the lowermost of a series of tuffaceous sediments which are 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 whole sequence of rocks represents one phase of volcanic activity and that it can best be considered as one stratigraphic unit.

Section of Cape St. John series from Cape Cove to Manful Bight



Section continues in lavas, pyroclastics and sediments.

400' Massive green lavas, red rhyolite exposed across the head of Cape Cove. Much fractured and broken up by joints and minor slips.

200' Massive red to brown rhyolite, which forms much of the southeast side of Cape Cove.

10' Fine grained, greenish-yellow, bedded pyroclastics. Some fragments of cherty material one half an inch long occur scattered through it.

60' Massive fine-grained, green andesite. Not vesicular on either edge. Some fine-grained black inclusions as much as one inch long. No trace of flow lines, amygdules, etc.

15' Greenish-yellow sediments consisting of fine pyroclastics and some bedded conglomerate horizons. Mudcracks and surface markings prominant on certain shaly beds. Thin bands of scoria breccia, with angular fragments of amygdular and vesicular, dark lavas.

60' Red rhyolite. On weathered surfaces intricate flow banding well shown. Breaks into small blocks, less than six inches on a side, due to innumerable, irregular joints. Bright orange color at soil line.

30' Sediments and fine ash beds. Some indistinct cross-bedding. Variety of facies..from finest ash beds to conglomerate and breccia.

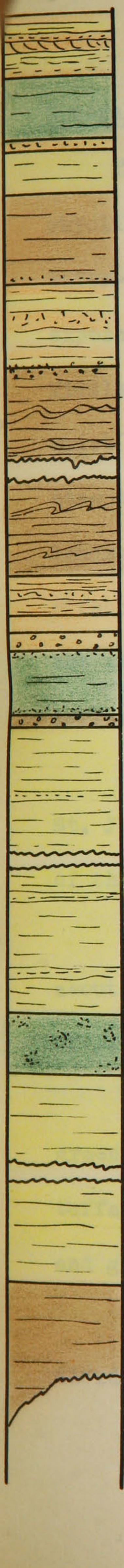
25' Massive green lava flow. About 18 inches of scoriaceous, dark lava on upper margin and about six inches on the bottom. Both boundaries are regular. Amygdules rare, but where present are calcite-filled.

2' Conglomerate.

10' Fine-grained, yellow tuffaceous pyroclastics, little trace of bedding

15' Sandstone, conglomerate, and water-laid pyroclastic series.

100' Massive green andesite. No structures of any kind in the interior and not conspicuously vesicular on the edges, except for the outermost six inches which bears calcite amygdules.



15' Sediments and pyroclastics, commonly containing reddish chert fragments in a fine yellow groundmass. Cherty bands up to six inches thick. Coarse conglomerate layers contain fragments of red rhyolite, and other rocks of this series. Some scoria boulders.

15' Dense grey lava; minute feldspar phenocrysts and epidote stringers.

3' Fine siliceous sediment with calcite stringers.

10' Fine yellow pyroclastics; rhyolite fragments in flinty matrix.

20' Red rholite, broken into innumerable small blocks by closely spaced joints and fractures. Bottom 2 feet contains some flattened vesicles.

20' Bright yellow-green sediment, containing mostly fine pyroclastic material. Some conglomerate made up of flat, angular pieces of rhyolite in white groundmass. Rounded masses of chert like those described below occur in bottom two feet.

175' Massive red and brown rhyolite. No individual flows observable within the mass. On weathered surfaces crumpled and crenulated flow lines of great complexity are visible. Contact with overlying sediments always marked by great numbers of concentrically banded, round masses of cherty material up to two inches in diameter.

10' Sediment, containing rhyolite fragments and assorted debris in fine grained, white-weathering groundmass. Fragments are not rounded.

10' Sediments and thin scoriaceous breccia.

15' Massive green andesite, vesicular zone on top and bottom.

3' Reddish rhyolite breccia.

150' Fine grained grey, green, and maroon colored pyroclastics, with thin, persistent laminations less than three inches thick. A few fragments of rhyolite, greyish volcanics, and black specks are visible in the fine grained groundmass. Fragments are angular and sharp, imparting a gritty feeling to some layers.

15' Andesite, with irregular vesicular zones within, not related to edges. Wedges out visibly in 300 yards.

100' Fine tuff beds. Persistent thin laminae. Minute fragments of rhyolite, grey lavas, etc. in fine grained groundmass. Secondary platy parting parallel to the original banding.

Section continues in dense, dark red rhyolite.

General Description:

The Cape St. John series consists of rhyolite flows with small rhyolite intrusives, trachytes, andesites, acidic pyroclastics and water-laid tuffaceous sediments. The rocks of the series 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, which are south of the head of Confusion Bay (See Fig. 16). The steeply dipping, highly-colored beds of the series are conspicuous landmarks in the Cape St. John region. Numerous porphyritic offshoots of the Cape Brulé granite, which underlies large areas to the west of Cape St. John, intrude the rocks of the Cape St. John series.

An excellent cross-section is exposed along the coast of Cape St. John, where the section is approximately 8,000 feet thick. Part of the measured section is given on pages 107 and 108.

Similar rocks which are exposed in the Middle Arm (GB) area about twenty miles to the south may represent part of the same period of igneous activity.

The lavas are commonly of a red-brown color, with some purple, green, and yellow-green members. The pyroclastic and water-laid tuffaceous beds are always light colored, with yellow, light green and grey predominating.

For ease of description the rocks of this series have been divided as follows:

(1) Rhyolite flows: (a) Massive
(b) Porphyritic
(c) Spherulitic
(d) Sericitized and altered

(2) Trachyte

(3) Andesite: (a) Massive
(b) Vesicular and amygdaloidal

(4) Coarse pyroclastics: (a) Rhyolitic
(b) Mixed

(5) Fine-grained pyroclastics: (a) Rhyolitic
(b) Very fine-grained tuffs

(6) Water-laid deposits: (a) Water-laid ash beds and tuffs
(b) Sandstones
(c) Tuffaceous sandstones
(d) Medium-grained pyroclastics and conglomerates
(e) Coarse breccias and conglomerates
(f) Scoria breccias
(g) Slate
(h) Quartz-bearing conglomerates

(7) Chert beds

Rhyolite Flows:

The rhyolite flows of the district are almost always reddish-brown, although light red, and greenish facies also occur. On fresh surfaces and on highly weathered ones flow structure is not usually visible. Where weathering has progressed to an intermediate stage however, flow structures are strikingly shown. The best examples occur in the cliffs behind "Mother Burke", on the tip of Cape St. John.

In hand specimens the rhyolite is seen to consist of numerous phenocrysts of quartz as much as 2 mm in diameter and less commonly orthoclase feldspar of about the same size, which are set in a dense aphanitic groundmass. The lavas which are invariably altered contain abundant secondary minerals. Minute veins of quartz and calcite are common. In some places the alteration of the rhyolite has resulted in the formation of enough calcite to give a good acid test.

In thin sections the rhyolite is found to consist of a fine-grained microcrystalline groundmass of much altered orthoclase, albite and quartz. Alteration products mask most of the minerals. Quartz and orthoclase occur as phenocrysts as much as 2 mm long. The quartz phenocrysts occasionally show corrosion on the margins.

Vesicular rhyolite is rare. A rhyolite bed about forty feet thick underlies the massive andesite beds in the cliffs at Mad Rock on the south side of Cape St. John. The uppermost ten feet of the rhyolite contains numerous vesicular and amygdaloidal zones. White cryptocrystalline quartz fills the amygdules. At one locality about one mile southeast of Harbor Round Pond, a thin zone of similar vesicular rhyolite occurs at the top of a thick series of massive and porphyritic rhyolite.

Several zones of spherulitic rhyolite occur in the massive flows of the Cape region, and also in the White Hills of Burlington (see below). Spherulites occur as scattered white or greyish knots about two millimeters in diameter in the dense, fine-grained reddish lava. Phenocrysts of quartz and feldspar are absent.

The rhyolites of the Cape St. John series 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 occur 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% of the rock. Calcite as disseminations and as tiny veinlets is common. 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 which has developed in the schisted rhyolites is not parallel to the bedding, which 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 suggests that some trachytes occur in the series. Notable examples are in the "Mother Burke" section and in the Red Cliff Pond region. Snelgrove proved the presence of such trachytic facies in the region southeast of Red Cliff Pond with an analysis, (1929, p. 72).

Andesite:

Andesite flows occur throughout the section but are particularly abundant near Middle Bill of Cape St. John. Individual flows are from three feet to over fifty feet thick, although one especially massive bed about 120 feet thick is exposed in the upper part of the cliff at Fishing Point on the south side of Cape St. John. The andesites of the Cape St. John series, though similar in general appearance to those of the Snook's Arm series, are finer in grain and more massive. Absence of pillow structures and shear zones, and greater distance from the intrusive masses are believed to have precluded widespread chloritization of the type which is so characteristic of the Snook's Arm series.

The andesite is light to dark green, or purple. Amygdules and vesicles are found in many flows, although not all flows have vesicular edges. In many places along the shore sections where exposures are complete it was found that vesicles are equally developed on both margins of the flows. They were thus of little use in the determination of tops and bottoms.

The massive andesites which are 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 one foot of the flows.

In thin sections the andesites show felted aggregates of microlites of plagioclase (An 32) which have been altered to epidote, calcite, and some sericite. Patches of chlorite and magnetite suggest the former presence of mafic minerals. 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 four types: (1) Calcite is the most common and fills the largest vesicles.

(2) Epidote fills vesicles of intermediate size and is easily distinguishable in hand specimens.

(3) Quartz

(4) Mixtures of calcite, epidote and quartz are common.

Coarse pyroclastics:

A coarse agglomerate is exposed in the cliffs which parallel the north shore of the westernmost of the Sisters Ponds, and occurs widely in the area to the north. Several similar horizons were noted in the shore exposures along Cape St. John.

The bed at the Sisters locality is about one hundred feet thick, but others in the area are usually less than twenty feet thick. Sharp angular boulders and irregular fragments of a variety of volcanic rocks occur in a fine-grained groundmass of angular fragments of quartz, orthoclase and plagioclase feldspar and tuffaceous material. Hematite commonly coats the groundmass grains and in some places it is altered to limonite. The boulders and pebbles consist of the following:

(1) Amygdaloidal andesite of dark purplish color

(2) Rhyolite porphyry, with quartz and orthoclase phenocrysts in a

reddish aphanitic groundmass

(3) Fine grained red-brown rhyolite with good flow structure

(4) Fine-grained, grey felsite with microphenocrysts of feldspar

(5) Highly vesicular andesite

(6) Red chert in fragments as much as eight inches long

(7) Very rarely seen in the agglomerates are fragments of bright green, highly chloritized, volcanic rock, which are sometimes conspicuous in the finer-grained facies.

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

Fine-grained rhyolitic and light colored tuffs:

Beds of fine-grained pyroclastics and ash 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 (See Fig. 24).

The thickness of individual units varies from one foot to as much as two hundred feet. The color of fresh surfaces is usually greenish yellow, but some facies are bright yellow, and others dark green. Weathering produces bright surface colors and the resulting orange-colored tuff formations which alternate with the green andesites, the reddish-brown rhyolites, and the grey-green,water-laid beds provide the picturesque cliffline 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 is parallel to the boundaries of the beds and may represent an initial bedding bias.

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 made 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. Relic outlines of altered fragments are sometimes made visible by rows of grains of epidote or magnetite, sericite grouped along the old boundaries or by differences in texture between the groundmass and the altered fragments. The former presence of occasional mafic minerals is suspected from clumps of chlorite and magnetite. Angular to rounded grains of albite (An. 8) which are covered with alteration products, and quartz in angular grains and fragments showing Boehm lamellae are scattered through the rock. Extremely fine-grained rock fragments, which are probably the fine-grained, 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 some places at the end of Cape St. John extremely fine grained ash beds and tuffs, similar to those described above, show stratification and cross-bedding, which indicate that they were water-laid. The units are usually not more than ten feet thick. They contain fragments of quartz, bright red chert, rhyolite (?), and andesite, as well as bright green specks which are thought to be chloritized fragments of lava. They are similar in all respects to the tuffs described above except that they show sorting and other evidences of water-deposition.

Sandstones:

In one locality in Seal Island Bight (See Fig. 16) in the Cape St. John region, a thin-bedded quartz sandstone with muddy partings shows abundant mudcracks and ripple marks. The predominant constituents are quartz, muscovite and clayey material. Obscure trail-like markings which are found on many of the mudcracked layers suggest that life was present even under the severe conditions of the times. Fossils were searched for in this horizon but without success.

The source of the detrital quartz and muscovite in these dominantly volcanic rocks is discussed under 'Environment'.

Tuffaceous sandstones:

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 series in the Cape St. John exposures. The only known inland exposure is on the road about three quarters of one mile from Shoe Cove toward La Scie. The tuffaceous sandstones are always distinctly bedded and commonly show cross-bedding as well. The great abundance of very fine red chert, fragments of rhyolite and andesite, and the lack of detrital muscovite distinguishes the tuffaceous sandstones from the sandstones described above, whereas the large proportion of quartz and the coarser grain distinguishes them from the water-laid tuffs.

Medium-grained pyroclastics and conglomerates:

Medium-grained conglomerates in which fragments as much as one inch long are embedded in a very fine-grained, grey-green matrix of quartz fragments and tuffaceous material are of common occurrence in the section. Beds of this type commonly occur just above and just below the tuffaceous sandstone facies described above. The fragments vary from rounded to angular and include abundant red chert, dense greenish chloritized lavas (andesite ?), rhyolite and andesite, 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. Cross-bedding and sorting are characteristic.

Coarse breccias and conglomerates:

Coarse conglomerates with boulders as much as four feet long occur in several places in the Cape St. John peninsula. Notable localities are on the north side of the westernmost of the Sisters Ponds and in two places in the Cape exposures.

The boulders consist of the following: 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 sometimes porphyritic; and in addition considerable tuffaceous and fine sandy material. Most of the groundmass particles and some of the boulders are coated with a thin layer of hematite which gives the rock a dark reddish-brown color.

Cross-bedding on a large scale is common in these coarse water-laid deposits. In one locality an angular discordance of layers of nearly ninety degrees within a single thick bed of conglomerate apparently resulted from the slumping of unconsolidated material. The boulders are commonly well rounded, although some angular fragments also occur. Imbrication is marked in many places.

Scoria breccia:

Beds, which consist of an abundance of rounded to angular fragments of highly 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 as much as ten feet thick, the pebbles and cobbles of scoriaceous andesite constitute as much as fifty percent of the rock. The proportion of scoriaceous material shows a progressive decrease upward in the individual beds. It is evident from the composition of these scoria breccias that erosion of the tops of lava flows, extrusion of tuffaceous material, and sedimentary deposition were going on in the area simultaneously.

Slate:

In a reconnaissance traverse across the peninsula from Notre Dame Bay to the head of Confusion Bay Snelgrove noted the occurrence of a thin zone of slate and argillite, (1929, p. 73). This was not seen by the present writer.

Quartz-bearing conglomerates:

An abundance of white quartz pebbles occurs with the usual assemblage of red chert and volcanic fragments in the conglomerates which occur at Middle Bill, Cape St. John. The quartz pebbles are commonly well rounded and constitute as much as thirty percent of the rock. The significance of coarse detrital quartz in this series is discussed in 'Environment' below.

Chert beds:

Grey and green chert beds as much as one foot thick and one hundred feet long occur in the Middle Bill region of Cape St. John.

The rock is a dense,homogeneous, banded chert which is cryptocrystalline and which breaks with marked conchoidal fracture. The beds are made up of many thin layers, each one of which lenses out gradually along its strike. The upper parts of several of the beds were found to be brecciated, and the fragments recemented with the same cherty material. In many instances the angular fragments could be fitted into gaps in the layers below, which shows that they did not travel far. The lower parts of the beds are always undisturbed. One of the chert beds grades upward into a conglomerate. Near the boundary between the beds the pebbles and boulders of the conglomerate are embedded in a cherty groundmass. No systematic relation to the tops of flows or to particular stratigraphic units could be established.

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, (1923, p. 594). Collins and Quirke (1926) have 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. The writers believe that the silica was precipitated, probably by evaporation, from pools of magmatic waters which emanated from fissures during the volcanic activity in the area.

The chert beds in the Cape St. John series are thought to have originated in much the same way as those in the Michipicoten district. The shallow, cross-bedded grits and water-laid tuffs which occur in the same series, and the absence of pillow lavas in the flows suggests 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 which were 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:

There can be little doubt that the Cape St. John series is Ordovician in age. The sedimentary and volcanic rocks of the series are lithologically more similar to the Ordovician rocks of Notre Dame than to any others in northern Newfoundland, and, in addition, they overlie the Snook's Arm series of known Ordovician age without apparent break.

Environment of deposition:

It is evident from the occurrence in the Cape St. John series of breccias which contain abundant fragments of scoriaceous andesite derived from the lava flows, and from the occurrence of breccias and conglomerates which contain fragments of rhyolite and andesite from the same series, that active erosion was going on in this region contemporaneous with volcanic activity. The appearance of detrital quartz and muscovite and well-rounded pebbles in the sedimentary facies suggests that the streams that passed through this area were eroding crystalline rocks as well as volcanic rocks. The absence of pillow lavas in the andesites of the series suggests that subaerial conditions prevailed during at least part of the time of lava extrusion. The cross-bedded and well-stratified, coarse-grained, water-laid deposits show 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 series show that at some periods during their 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 series must have been deposited in shallow subaerial basins or in marine basins near shore, near the mouths of streams.

Little is known about 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 igneous and metamorphic rocks in the pebbles of the Carboniferous sediments of the west coast, but whether or not exposures of such crystalline rocks were present in Ordovician times is not proven. It is likely that the metamorphosed sediments of the Fleur de Lys series and the Ming's Bight series were gneisses at this time, but whether or not they were exposed to erosion is not known.

In summary, the Ordovician topography of the region must have been one of rugged mountains with volcanoes of the central type in periodic violent eruption, emitting lava flows and abundant pyroclastic material. Large streams which carried detrital material from distant highlands, which were underlain by crystalline rocks, and abundant pyroclastics and lava fragments from this area debouched in the volcanic region and deposited their loads at the margins of the sea or in inland basins near the sea.

Nipper's Harbor Series

Location:

Near the outlet of Burton's Pond, just northeast of Nipper's Harbor, a temporary boundary is drawn to separate the Snook's Arm series from a series of greenstones, dark volcanic rocks, amphibolites, altered dike rocks and sediments which is here called the Nipper's Harbor series. The series occupies an intermittent strip which extends along the coast, between the interior granite and the sea, as far south as Southwest Arm, Green Bay (See Plate 18). The width of the belt is nowhere greater than two miles. The margin of the granite lies within 2000 feet of the head of Nipper's Harbor. Both to the north and the south of Nipper's Harbor the contact swings inland. Southward the margin of the granite approximately parallels the coast until at the northern end of Stocking Harbor tongues of granite which cut the Nipper's Harbor series are exposed at the shoreline. From Stocking Harbor to Southwest Arm of Green Bay the rocks of the Nipper's Harbor series occur as small remnants, which are usually much cut up by granitic dikes, on the edge of the main granite, (See Plates 15 and 18).

The rocks of the Nipper's Harbor series differ from those of the Snook's Arm series to the northeast. Most of the Snook's Arm rocks are in the greenschist facies whereas the Nipper's Harbor series is predominantly in the amphibolite zone of metamorphism. In a few localities in the Nipper's Harbor series doubtful pillow structures were observed, as for example at Shiner's Prospect (See Plate 12) and on a point between Stocking Harbor and the entrance to Burlington Harbor. But nowhere are pillow lavas widely developed. This contrasts markedly with the Snook's Arm series which is characterized by numerous thick pillow lava units which form such prominent features as Bett's Cove Head. Pyroclastic and sedimentary beds are almost absent in the Nipper's Harbor series whereas they are of common occurrence in the Snook's Arm series.

Description:

The rocks of the Nipper's Harbor series present a wide range in composition. The most common types consist of hornblende porphyryoblasts from minute needles to prisms as much as half an inch in diameter set in a feldspathic groundmass. The proportions of the plagioclase and the hornblende vary considerably and many of the different rock types of the series are the result of variations 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%), saussuritized plagioclase feldspar (25%), quartz (15%) and accessory minerals. The plagioclase feldspar occurs as much altered subhedral crystals which are of a composition An 38 in the cores but are commonly strongly zoned and rimmed with albite. They are almost completely obscured in most examples by an aggregate of albite, epidote, calcite, sericite and an unidentified scaly alteration mineral. The quartz occurs as anhedral, interstitial masses as much as 2 mm in diameter, which do not show Boehm lamellae or speck inclusions. Where the quartz lies adjacent to actinolite, which occurs throughout the rock as fibrous aggregates and irregular crystals, swarms of slender needles of actinolite penetrate the quartz grains. Common green hornblende ($Z \wedge c$ 26°, X-straw, Y-olive, Z-green) occurs as irregular subhedral masses. Accessory minerals include magnetite, hematite, epidote, muscovite, albite and alteration minerals. In some of the rocks pale actinolite or tremolite make up as much as 40% of the rock. The original rocks were most likely diorites or thick andesitic lava flows.

The chlorite schists and greenschists correspond in general description to those of the Baie Verte series given above. Chlorite constitutes as much as 40% of the rock and the rest is made up of varying amounts of albite, epidote, quartz, and accessory minerals.

Coarse grained conglomerate occurs on the northwest side of Rogue's Harbor. It is made up principally of fragments of volcanic rocks in a red, carbonate-rich cement. The pebbles and boulders are angular to sub-rounded and average about 5 inches in diameter, the largest being about one foot. Vesicular black basalt or andesite, fragments of dark, carbonate-rich rock and chunks of massive green lavas (andesite) predominate. The sediments which occur as bulging, lens-shaped masses appear to occupy scour channels in the tops of lava flows.

Numerous dikes of a wide range of composition and form intrude the rocks of the Hipper's Harbor series and in many places are scarcely distinguishable from it. Pyroxenite and peridotite dikes occur at several localities, as for example on the point which juts out into the northeastern end of Stocking Harbor. These are almost invariably serpentinized and commonly weather to light brown. Dense, dark grey, diabase dikes, fine-grained metadiorite and lamprophyres which weather to a peculiar khaki-brown color are commonly intrusive into the rocks of the series near Stocking Harbor. They are described in detail under "Burlington Granite Complex".

INTRUSIVE ROCKS

Dunamagon Granite

Introduction:

The name Dunamagon Granite is here proposed for the stock of medium-grained pink granite which occupies about nine square miles in outcrop between Pacquet Harbor and the head of Ming's Bight. The rock is everywhere well exposed except on the southwestern end of the mass near Last Camp Pond (See Plate 16), where it is covered with glacial drift and dense forest. The granite mass stands out above the surrounding country as an irregular highland. The ridges are completely bare, and large accumulations of ice-carried boulders of the granite itself occupy the bottoms of many of the depressions.

The rock characteristically has a pink color and a general granitic texture. In many places it is well foliated. Most of the rock maintains its color when it weathers. However, on the high ridge north of Belly Pond (See Plate 16) a type which is bleached to pure white to a depth of about one eighth of an inch is common. Weathering has produced small accumulations of arkosic sands in small rock basins all along the ridges. All the glacially smoothed surfaces have been attacked by weathering which has left a rough granular surface on nearly all outcrops, with the result that no striae are preserved on outcrops of the Dunamagon granite.

Description:

The granite is not uniform throughout. Crystals of pink microline and orthoclase in some specimens average 5 mm in length, and in others may average as much as 15 mm. The groundmass in which they are set is, in some places, fine-grained quartz and feldspar with no mafic minerals and in other occurrences biotite may constitute as much as twenty percent of the rock. The granite is markedly gneissic in many places, but in others banding is faint.

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

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 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 three quarters of an inch in length and of irregular outline commonly show the characteristic grid twinning on a fine scale. Orthoclase crystals show good Carlsbad twinning. Albite, of composition An 7 to 10, is present as small crystals in small amount. Alteration of the feldspars has produced a scaly aggregate in which sericite and epidote are recognizable.

Throughout the rock perthitic intergrowths are common. Teardrop intergrowths of myrmekite occur in some slides. Throughout the rock a secondary filling of fissures in the large feldspar crystals by albite is common. The opposite sides of the secondary "veins" correspond as if the feldspar crystal had been torn apart and the fissure between them filled. These intergrowths are injection perthites as described by Colony, (1923), and together with the myrmekite are believed to represent late stage deuteric activity in the crystallizing melt (See Figs. 62, 64 and 66).

Biotite occurs in clumps and patches which are strung out parallel to the foliation. Its pleochroism is as follows: X-yellow, Y-greenish brown, Z-dark khaki-brown, almost opaque. The biotite of the Dunamagon granite characteristically contains an abundance of pleochroic haloes which are dark to their edges, and which have small grains of zircon at their centres. Apatite and titanite are common accessories and are almost always associated with biotite. Much of the biotite shows partial alteration to chlorite (straight extinction, slate-blue interference colors) which also occurs scattered through the rock as irregular wisps and shreds.

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

Effect on the Country Rock:

No marked changes in the immediately adjacent country-rock have been effected by the Dunamagon granite. A certain amount of material was introduced into the wallrocks as is indicated by the occurrence of zones rich in garnet, and by local silicification. However the usual assemblage of biotite, quartz, albite and scattered garnets found in the Ming's Bight series occurs right up to the contact. If the mineral assemblage of the gneisses of the Ming's Bight series was already in a stage of metamorphism about at the biotite zone-garnet zone boundary then the lack of pronounced effects at the margins of the granite could be attributed to the fact that the assemblage was already stable at the temperature and pressure conditions prevailing at the time of the granite intrusion, necessitating no further adjustment. If the granite was intruded during the last stages of the regional alteration, the possibility of which is suggested by the fact that there is little alteration on the edges of the granite and the fact that the pegmatite dikes associated with the granite contain inclusions of country-rock already metamorphosed and foliated, then contributions from the cooling granite could assist in the production of garnet in local zones.

An interfingering of granite and the gneisses of the Ming's Bight series occurs on some of the margins, as for example along the northern boundary about a mile and three quarters west of Pacquet where the contact is exposed in the bed of the brook which enters

Pacquet Brook from the south. No marked change from the quartz-albite-biotite assemblage occurs. Hazy boundaries with the country rock suggest that some intermingling of the material of the gneisses and the granite has taken place. On the southern end of the satellitic L'Anse of Pardi granite plug (described below) a rock consisting of large masses of cloudy orthoclase feldspar in a fine-grained groundmass of quartz, feldspar, biotite, and chlorite occurs along the margins of the granite and has been interpreted as an original gneiss that has been soaked and modified by material from the granite. Although the actual contact was observed in very few places, it is probable that nowhere does the zone of intimate injection and magmatic soaking exceed thirty feet in width.

Inclusions are not common in the Dunamagon granite. However several tabular masses of dark altered rock, now composed mostly of coarse biotite, with their greatest dimensions parallel to the foliation of the granite occur along the northwestern shore of Woodstock Harbor. Along the edges of these masses, which seldom exceed six feet in width and forty feet in length, gradational boundaries suggest a partial assimilation.

Structures within the mass:

Foliation is marked in many places in the granite mass, but faintly developed in others. The degree of foliation bears no visible relation to the present boundaries, since well-banded masses occur just as commonly in the interior of the mass as along the edges. Foliation of the Dunamagon granite was not mapped with the object of determining the patterns of the banding. The observations available however suggest that the foliation is somewhat irregular in its relation to the boundaries. On the northern edge of the granite mass several outcrops show marked gneissic banding parallel to the structure of the adjacent Ming's Bight gneisses. In the interior of the mass irregular swirls and flow patterns were indicated on reconnaissance traverses. Some observations on the southern and western boundaries show that the foliation is at an angle to the trend of the boundaries. Before any conclusions can be reached as to the general pattern of the foliation of the Dunamagon granite and its relation to the boundaries, a much more detailed study of the mass would be necessary. This small body of granite, which is nearly everywhere well exposed, would provide an excellent place to apply some of the new techniques of granite tectonics.

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 the directions of the trains of inclusions in the quartz grains.

Jointing in the granite is somewhat irregular. One set of prominent joints is nearly parallel to the surface, and is the familiar sheety jointing observed in many granite masses. Steep dips and irregular strikes are characteristic of the other joints. The most prominent sets trend east-west, and northeast-southwest, parallel to the regional set, and are therefore probably not related to the cooling of the granite, but to regional stresses (See section on Structure and Plates 10 and 11).

Relation to Regional Structure:

The boundaries of the Dunamagon Granite are everywhere parallel to the strikes of the boundary formations. The north and west contacts of the granite follow closely the changes in strike of the Ming's Bight series. The southeast side follows the trend of the Baie Verte series. The southwest end appears to occupy the nose of an anticline, in the Baie Verte series which plunges to the southwest at about 40 degrees (See Structure and Plate 16). On the basis of this evidence the Dunamagon granite mass is considered to be dominantly concordant with the rocks which it intrudes.

After such a granite mass had been intruded into a series of bedded rocks, it seems likely that later periods of deformation would tend to accent the parallelism of the structures of the country-rock and the margins of the granite. The large faults and "lineaments" (see elsewhere) of the district cut across the granite showing that there has been post-intrusion deformation, and that this effect may be present in the area. That the granite was originally concordant, however, is proved conclusively by the occurrence on the north side of the mass, about one mile west of Pacquet, of interfingering granite and Ming's Bight gneisses with the foliation in the granite parallel to the wallrock structure.

The Dunamagon granite is believed to be part of the main intrusive mass of the Cape Brulé granite (See Plate 16). Both masses are later than the main folding of the Baie Verte series, and both are largely concordant with the structures of the formations they invade. They are of generally similar compositions and no other petrographic evidence suggests that they are of widely different ages.

Though part of the same general intrusion, the Dunamagon granite may be slightly later than the Cape Brulé mass. The following evidence is in no way conclusive but is advanced as being suggestive.

(1) A swarm of pegmatite dikes, that intrude the Ming's Bight series north of Pacquet, is apparently related to the Dunamagon granite (see below). Pegmatites commonly occur with the later differentiates of magmas. This association suggests that the Dunamagon granite is later than the main mass.

(2) The larger proportion of potassic feldspar and the smaller proportion of mafics suggest that this granite is itself a later differentiate of the larger mass.

(3) Along the coast of Notre Dame Bay in the Nipper's Harbor region several small masses of granite porphyry are visibly later

than the main granite mass. If the satellite masses in this district are later than the main body of granite then it is not unreasonable to assume that the same relation holds for the Dunamagon granite.

L'Anse of Pardi Granite:

A small satellite body of the Dunamagon granite, about half a mile wide and a little over one mile long, occurs in the steep hills on the east side of Ming's 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 slightly more fine-grained.

Dikes of the granite, that show no chilling and no effects on the wallrocks, are exposed on the shore of Ming's Bight about a quarter mile north of L'Anse of Pardi. On the southern end of this small mass of granite an intimately injected and soaked composite rock (mentioned above) that was originally a gneiss of the Ming's Bight series, is exposed in the lower end of L'Anse of Pardi Brook. Apart from this one locality there is little effect on the wallrocks.

Pegmatite Dikes and Sills:

Introduction:

Numerous pegmatite dikes and sills occur in a zone, one and one half miles wide, which runs northwest from Pacquet to Cape Hat. The dikes are as much as twenty feet wide and 3000 feet long, but are usually much smaller. They are mostly concordant with the formations they intrude, though many cross-cutting dikes occur. The largest masses are shown on Plate 16.

The pegmatites are composed predominantly of feldspar and quartz, with minor muscovite and biotite, and accessory garnet, smoky quartz, and tourmaline. The composition varies considerably and a complete series from nearly pure feldspar with a few accessories to ordinary quartz veins occur. The feldspar is orthoclase, microcline, albite and perthite. Graphic intergrowths of quartz and orthoclase were observed in some of the small dikes of the region. Though ordinarily scattered through the rock, biotite in crystals as much as six inches across cleavage faces sometimes forms as much as thirty percent of the rock. Muscovite of a greenish tinge occurs in some dikes in crystals from one to three inches across cleavage faces. Quartz is usually the milky variety but glassy and smoky varieties also occur.

Handy Harbor Pegmatites:

On the southeast side of Handy Harbor a pegmatite dike, from eight to fifteen feet wide, cuts across a small point and disappears beneath the sea at both ends. The dip of the contact of the dike with the wallrock is irregular and changes abruptly within a few feet. This dike contains fragments of the country rock in which the foliation is parallel to that of the adjacent wallrock gneisses, which indicates that the intrusion of the dikes took place after the principal folding of the Ming's Bight series.

This pegmatite is composed largely of pink microcline and perthite in crystals from a quarter of one inch to eight inches in length. Books of muscovite one inch or less in diameter occur scattered through the rock. Clusters of minute red garnets occur throughout the mass but are more concentrated along the margins.

Later quartz veins cut both the pegmatite and the wallrock. Offshoots of the main pegmatite dike penetrate the wallrocks for as much as two or three feet beyond the contact. Some of these dikelets are fine-grained whereas others have coarse crystals along their walls and finer-grained material within. The only visible effect of the pegmatite on the wallrock is the reorganization of the material of the gneiss which results in a felted mass of biotite about one inch thick, immediately adjacent to the contact.

A large mass of pegmatite of irregular outline occurs on the north side of Handy Harbor. At the seaward end it is nearly forty feet wide but 600 feet inland it is only ten feet wide and splits into a number of narrow offshoots. In mineral composition it is a repetition of the dike described above except that the crystals of feldspar may reach as much as two feet in length. It cuts indiscriminately across the gneisses and has little visible effect on the wallrock. It includes fragments of the adjacent gneisses with foliation parallel to that of the wallrock.

Because of the rapid pinching out landward from the main bulge at the seaward end, and the fact that the pegmatite can be seen "lying" on the rocks of Ming's Bight formation with very shallow dip, it is considered that this mass has very little depth and is not as large as it appears.

Grey Point Pegmatite:

A considerable mass of pegmatite occurs about 1500 feet southward along the shore from Teakettle Cove which is about one mile south of Handy Harbor. Eighteen hundred feet inland from the shore exposure it is two to five feet wide. It gradually widensin outcrop seaward until fifty feet from the waveline it is 100 feet wide in outcrop, then terminates abruptly just above the water. Its rapid wedging out, the irregular dips of the contact with the wallrock, and the fact that it is terminated within a few feet of its greatest outcrop width suggest that it has limited depth.

The minerals present are as follows:

(1) Microcline in crystals one to four feet in length, make up most of the rock.

(2) Albite in white, striated crystals as much as one foot long.

(3) Quartz in several varieties .. white, glassy, smoky.

(4) Biotite in crystals as much as six inches across cleavage faces.

(5) White muscovite with a greenish cast occurs in numerous small books.

(6) Dodecahedra of red garnet occur in clusters throughout the mass, but are nearly always included in quartz.

(7) Tourmaline crystals were observed in one pocket on the seaward side of the cliff exposure at the eastern end.

(8) Ilmenite occurs in irregular masses up to three inches in length with poorly developed crystal faces.

Snelgrove (1939, p. 107) drew attention to this areaas a possible prospecting ground for commercial feldspar. None of the known deposits, of which the most important have been described above, appear to be large enough or of sufficient purity to warrant development. It seems unlikely in this well-travelled, well-exposed country that further large deposits could remain undiscovered.

Other Pegmatites:

Exposed on the shore of Teakettle Cove is the seaward end of a pegmatite dike some ten to thirty feet wide, which was traced inland for 2500 feet, and which may extend intermittently for another 2000 feet. It is made up principally of milky white quartz, orthoclase and microcline, and a small amount of muscovite. The grain size is small, averaging about one inch.

The sea-cliffs north of Handy Harbor are seamed with small sills and dikes of fine-grained pegmatitic material.

The pegmatite dikes are considered to be related to the Dunamagon granite. The mineral composition - mostly pink microcline and orthoclase, quartz, minor albite and micas - is very similar to that of the Dunamagon granite. In addition the occurrence of the dikes as close as 500 feet to the granite contact suggests a genetic relation. The next nearest intrusive is the Cape Brulé granite porphyry, which lies beyond the outcrop of the Dunamagon granite. Though in no way conclusive this correlation of the pegmatite dikes with the Dunamagon granite seems most reasonable.

Granite Dikes:

At several localities north of the Dunamagon granite fine-grained, light-colored dikes made up of feldspar, quartz, and accessory dark minerals cut the rocks of the Ming's Bight series. The largest of these is on the shore about 600 feet southeast from the Grey Point pegmatite described above. It has a maximum width of about thirty feet but thins rapidly in both directions. It penetrates the Ming's Bight gneisses irregularly with gradational contacts. Another dike-like mass of the same rock about thirty feet wide and 1000 feet long, occurs about 3000 feet northwest of Pacquet.

The rock is pink on fresh surfaces, and weathers to a neutral grey. The average grain size is less than 1 mm. In thin section albite (An 8 - 11) makes up about 30 percent of the rock. Orthoclase with Carlsbad twinning is common. The feldspar crystals are full of swarms of minute, unidentified opaque inclusions, which are irregular for the most part, but are rod-shaped in some. Bent lamellae were observed on one albite crystal. Quartz, which constitutes about 20 percent of the rock, occurs as interstitial masses of irregular outline, without strain shadows or Boehm lamellae, and with irregular inclusions. Calcite makes up 15 to 20 percent of the rock in irregular interstitial patches and as small veinlets cutting it. The rock contains enough calcite to effervesce vigorously in dilute HCl in hand specimens. Magnetite and apatite are abundant accessory minerals. Minute shreds and flakes of chlorite as well as some epidote occur through the rock.

The abundant calcite in this dike rock lends credence to the hypothesis that the granites of the area supplied the carbonate-bearing solutions which effected the alteration of the ultrabasic masses of the district.

Cape Brulé Granite

Introduction:

The name Cape Brulé granite is here proposed for a mass of medium-grained porphyritic granite which occupies at least 75 square miles in the northeast part of the Burlington Peninsula. Snelgrove proposed the term 'Burton's Pond granite porphyry' for a small part of the mass which is included in the extreme southwest part of the Bett's Cove - Tilt Cove area (1931). However it is felt that the new name is better because

(1) The granite is not exposed at Burton's Pond.

(2) The nearest exposure to Burton's Pond is not easily accessible.

(3) Porphyritic granite which is typical of the mass is exposed at Cape Brulé and for about two and one half miles along the coast southward from Pacquet Harbor.

The Cape Brulé granite is part of an intrusive complex which extends from the northern part of the peninsula for at least forty miles to the south, and possibly even further to become continuous with the granite batholiths of central Newfoundland. The Cape Brulé granite itself occurs in a mass of irregular outline about ten miles long and ten miles wide. The outcrop of the mass is terminated by the older volcanics and sedimentary rocks on the northeast and west. On the unmapped southern boundary it is apparently terminated by the Burlington granite, which, though part of the same intrusive sequence, is probably older (see below).

Description:

The rock has a distinctive appearance in hand specimens. Cloudy grey eyes of quartz and phenocrysts of feldspar which average 3 mm in diameter are set in a fine-grained greyish groundmass. The rock weathers to 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 found as much as a mile into the interior of the mass.

Thin sections show that the phenocrysts of quartz and feldspar are embedded in a fine-grained groundmass of quartz, feldspar, chlorite, epidote and calcite. The phenocrysts are all embayed and replaced by the minerals of the groundmass (See Fig. 56). 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 the quartz. Carlsbad twinning is prominent. Microcline phenocrysts which show grid twinning on a very fine scale occur sparingly through the rock. Albite phenocrysts (An 7 - 10) with good polysynthetic twinning occur rarely through the slides. Embayment of the formerly euhedral crystals has produced very irregular outlines on some. Alteration has affected most of the feldspar phenocrysts resulting in a scaly aggregate with some recognizable sericite, and calcite.

The average grain size in the groundmass is 1/20th to 1/10th mm in most specimens, but in one slide from a border facies is 1/10th to 1/4 mm. Chlorite and altered biotite are present as small wisps and flakes in the groundmass in accessory amounts, though in some border facies may constitute as much as ten percent of the rock. 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 crystals with pleochroic haloes in biotite and chlorite, muscovite in irregular wisps and patches, apatite and an unidentified brown accessory which occurs rarely. Its determinable properties are: high relief, pleochroic-brown to almost opaque, absorption greatest when long axis parallel to polarizer, birefringence not greater than low second order, uniaxial negative.

Marginal Facies:

A distinctive marginal facies occurs along the boundaries of the Cape Brulé granite in many localities. Eyes of cloudy, grey quartz are set in a strongly foliated, sericitic groundmass. In thin section quartz, which occurs both as large grains up to 2 mm in diameter and as part of the groundmass mosaic in grains which average about $\frac{1}{4}$ mm in diameter, is seen to make up about 60% of the rock. The quartz crystals have well-developed Boehm lamellae and numerous tiny inclusions which probably impart the cloudy grey color observed in hand specimens. Biotite, which is pleochroic-straw to dark brown, occurs as irregular wisps with dense pleochroic haloes around minute inclusions of zircon. Muscovite, the sericite of hand specimens, makes up about 15% of the rock. 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 in diameter, and rarely as minute veinlets. Accessory minerals include epidote, apatite, opaques, zircon and a fine scaly aggregate (See Fig. 58).

The texture of this marginal granite is now almost completely metamorphic. In aggregates of quartz grains in the groundmass a mosaic texture is invariably shown by the masses of serrate-edged crystals (See Fig. 59). The strong foliation, which is produced by elongated shreds of muscovite and biotite, and lenticular aggregates of quartz with minor albite, 'flows' around the large eyes of quartz which were probably originally phenocrysts. It is apparent from the lack of cataclastic structures and the perfect parallelism of the foliation with the margins of the granite that the shearing took place during the cooling of the granite. It seems likely from the fact that large quartz phenocrysts, identical with those of the unfoliated interior facies of the granite, occur in the marginal facies that the shearing came at a late stage of the cooling, or at least after a partial consolidation.

Relation to Intruded Rocks:

Inclusions of the country rock are common along the margins of the Cape Brulé granite. From Pacquet Harbor to the Rambler district the marginal facies are full of inclusions of the Baie Verte volcanic rocks. In the Confusion Bay area the marginal facies sometimes contain so many inclusions that they resemble volcanic breccias (See Figs. 28 and 29). Large masses, possibly roof pendants occur at several places. The largest occupies about three quarters of one square mile in outcrop, east of Beaver Pond. Another occurs east of Rocky Pond (See Plate 16). The presence of other small roof pendants or large inclusions in the same district was suspected from the occurrence of glacial erratics of greenstones, in localized areas.

The dip of the contact of 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 the contact dips more gently toward the north. In the Cape Brulé region the dip is steep to the west.

The numerous inclusions and roof pendants, the variety of dips along the contact, the fine-grained facies in certain areas such as south of Confusion Bay, and the numerous 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 in the marginal facies is marked in most places, and is more prominent on the northern and western sides than on the eastern and southern sides. The foliation is nearly everywhere parallel to the boundaries and to the strikes of the rocks in the boundary formations. Lineation was not extensively mapped but the observations which were made indicate that the intrusion of the mass was from the southwest. The fact that the gneissic banding in the granite parallels the structure of the boundary formations suggests that the mass was intruded during the last stages of a period of intense folding of the volcanic and sedimentary rocks of the district.

Stocks and Bosses:

Numerous small masses of granite porphyry somewhat similar to the main mass occur through the area. They may be classed as two varieties: those in which the rock contains a larger proportion of sericite in the groundmass and which show a more marked foliation than the main mass, and those in which the phenocrysts are much larger than in the rock of the main occurrence and which are set in a dense, fine-grained reddish groundmass.

The granite porphyry which makes up the small masses that intrude the rocks of the Cape St. John series and the greenstones of the La Scie district is identical in most places with 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 drawn out in the plane of foliation. Fragments of greenstone are commonly strongly chloritized.

Along the shore of Notre Dame Bay and inland as far as Red Cliff Pond a series of small concordant masses of medium-grained granite porphyry occur in a line from Nipper's Harbor to Stocking Harbor. Clear, euhedral quartz crystals of prismatic habit up to 5 mm in length are corroded on the edges and deeply embayed along cracks and irregular channels (See Fig. 57). All gradations from unaltered crystals with good boundaries to shapeless, octopus-like masses are present. In most crystals inclusions are common. In some fluid inclusions minute bubbles were observed to be in constant motion due to the same causes as Brownian movement, (Alling, 1936, p. 181). Euhedral crystals of orthoclase feldspar up to 12 mm in length which commonly show Carlsbad twinning, are everywhere highly altered to a scaly aggregate in which sericite, epidote, and carbonate can be recognized. Albite occurs as altered, polysynthetically-twinned crystals. A few large microcline crystals also occur. Late-stage albitization of the potassic feldspars is common (See Figs. 63 and 65). Myrmekite occurs in some slides (See Fig. 61). Quartz phenocrysts in some places show perlitic cracks and a banding which is due to inversion from beta-quartz to alpha-quartz (See Fig. 60). This suggests that the temperature of consolidation was above 575°. The groundmass is a fine-grained counterpart of quartz and feldspar. In addition magnetite, chlorite, and epidote occur sparingly. The average grain size is 1/10th to 1/5th of one millimeter. Clumps, of irregular outline, of chlorite with magnetite and epidote may indicate the former presence of mafic minerals. One minute veinlet carrying chlorite, epidote, magnetite, and some muscovite traverses one slide.

On the shore between Middle Bill and La Scie several dikes of greyish granite porphyry cut the greenstones, and the rocks of the Cape St. John series. In hand specimens equidimensional phenocrysts of white feldspar and grains of clear quartz, averaging about 2 mm in diameter visibly make up about 70% 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 some albite (An 8), are, in addition, altered to a very fine-grained aggregate which is white is reflected light and probably accounts for the milky white color in hand specimens. The strong odor of the rocks suggests that the alteration is kaolin in part. Aggregates of minute reddish unidentified spots (probably hematite) occur in some places. The groundmass of these dikes is finer grained than the average of the other types of porphyry, being less than 1/20th mm. Chlorite is common in the groundmass and its parallel arrangement shows the strong foliation in the rock. Pyrite occurs as masses of irregular outline, 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 (1926, p. 379).

Burlington Granite Complex.

Introduction:

The name Burlington Granite is here proposed for the mass of medium-grained granite and granodiorite which is exposed in the southeast corner of the Burlington Peninsula and extends southward beyond the limits of mapping. The northernmost known exposure is about one and one half miles north of Stocking Harbor but it is considered likely that the granite extends somewhat farther north into the unmapped interior. The actual boundary formation on the north is not known, but it is probably that the granite terminates or grades into the Cape Brulé granite porphyry. Reconnaissance in the Flat Water Pond area indicates that the western boundary is irregular with abundant apophyses and offshoots cutting the greenstones of the Baie Verte formation. The boundary lies about three miles east of Flat Water Pond. An elongated mass of quartz diorite which occupies the ridge east of Baie Verte and extends southward to Gull Pond is an offshoot of the main mass to the south. Along the shore of Green Bay southward from Burlington Harbor a belt of fine-grained rhyolite and quartz-porphyry intrusions separates the main mass of the Burlington Granite complex from the shore. The fine-grained rhyolite-like intrusions extend inland at least three miles west of Middle Arm, Green Bay.

Description:

The rock is a massive, light-colored, medium-grained rock. On weathered surfaces it remains a light color. It is commonly stained a greenish-yellow along the seacoast where it is subjected to the action of seawater. Epidote in veins and as irregular masses sometimes lends a green color to the rock.

In hand specimens the rock is seen to be made up of white and pink feldspar, clear glassy quartz, black or dark green hornblende and biotite, irregular masses of brown sphene, and epidote. The rock is not conspicuously foliated in most outcrops, but in some places foliation is faintly developed.

In thin sections the following minerals are seen to occur: feldspar 50 to 65%, quartz 10 to 25%, hornblende 5 to 15%, biotite 5 to 10%, accessory minerals 5 to 7%.

Etching with hydrofluoric acid and staining with sodium cobaltinitrite indicates that over 75 percent of the feldspar is potassic. Most of this is orthoclase, but in some facies microcline, showing the characteristic grid twinning on a fine scale occurs abundantly. The albite is of a composition An 7 to 12. Zoning is not prominent, though in some sections is faintly developed. Quartz is present in irregular interstitial masses which sometimes show undulatory extinction. Swarms of needle-like inclusions of rutile (?) are present in the quartz in some specimens. Hornblende, (X-straw, Y-olive-green, Z-dark green, with $Z \wedge c = 18^{\circ}$), occurs through the rocks as subhedral masses as much as 3 mm long. Biotite, (X-yellow, Y-brown, Z-dark khaki-brown), occurs in clumps and aggregates up to 2 mm in length. It is commonly partly altered to chlorite and is then accompanied by 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 some places alteration of the feldspars has produced a scaly aggregate in which some sericite is recognizable.

Various façies of the granite complex have different compositions. Granite, biotite granite, hornblende granite, granodiorite and quartz diorite have been recognized as local variations. The differences between the facies are principally the result of differences in the proportions of the various minerals. The great bulk of the mass, however, is granite like that described above.

Relation to Country Rock:

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-southwest trend of the peninsula. The many small apophyses and offshoots of the main mass cut indiscriminately across the structure of the country rocks. The small peninsula between Stocking Harbor and Burlington Harbor is made up of about half altered volcanics of the Nipper's Harbor series and about half intrusive rocks which are mostly granite but include many dikes of diabase, aplite, lamprophyre, diorite, fine felsic intrusives and rhyolitic types. The western 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. On the basis of this somewhat sketchy information the Burlington Granite complex is considered to be dominantly concordant, with minor apophyses which may be either concordant or discordant.

Inclusions:

Inclusions in the main body of the intrusive are not common. In some of the small offshoots however, as for example along the shore between the mouth of Burlington Harbor and Stocking Harbor, inclusions may make up as much as fifty percent of the rock, and the mass has the appearance of a breccia. Most of the inclusions are of the immediately adjacent wallrock, although in one outcrop east of Garden Cove a number of inclusions of pink granite gneiss of the type familiar in Precambrian areas and unknown in outcrop in this peninsula were observed. These may be fragments of the basement complex brought up during intrusion from deep below, and thus may indicate the nature of the basement in this district (See Fig. 31).

Structure within the mass:

The arrangement of foliation in the interior of the mass was not mapped. Where observed it appeared to strike northeast-southwest except in the region south of Burlington where the general trend is about 100°. The most prominent set of joints in the latter area is parallel to this foliation which dips steeply to the west. In the interior of the mass little indication of foliation was observed. In slides of the rock a slight preferred orientation is visible. In many of the small masses cutting the greenstones, foliation is parallel to the edges, though in most outcrops is only faintly developed.

Other Rocks of the Complex:

Along the coast of Notre Dame Bay from Rogue's Harbor southward to the southernmost limit of mapping, at the mouth of Southwest Arm (Green Bay) a complex of intrusive rocks occurs associated with the Burlington granite complex. The order of intrusion of the dikes and small intrusive masses has been worked out as follows: (earliest to latest)

(1) Gabbro and pyroxenite

(2) Diorite

(3) Granodiorite

(4) Granite and quartz-rich varieties of granite

(5) Rhyolite porphyry series

(6) Aplites

(7) Pegmatites

(8) Diabase

(9) Lamprophyres

Rhyolite and Rhyolite Porphyry Series:

A variety of reddish or brownish, fine-grained intrusive rocks occur in dikes and irregular stock-like masses from a few feet wide to as much as one half of one square mile in outcrop. They cut all the rocks of the region except the small dikes of the types mentioned above. The rocks of the series are usually conspicuous from a considerable distance because of their bright pink color, as for example the masses of porphyry which occur in the crests of the two hills east of the post-office in Burlington, and in the hill south of the houses at the head of the harbor. Other localities where these rocks occur are the White Hills west of Burlington, along the coast south of the mouth of Burlington Harbor, and in Middle Arm Ridge.

The fine-grained texture of these intrusive rocks indicates emplacement under shallow-seated conditions. Some actually contain calcite-filled amygdules. Some show tiny phenocrysts that are barely visible to the naked eye and others are entirely cryptocrystalline. Other types approach the porphyries of the Nipper's Harbor district in that they show partially resorbed phenocrysts of quartz, orthoclase feldspar, and albite in a fine-grained, reddish groundmass.

In the White Hills, and in Middle Arm Ridge a number of rhyolitic rocks have the appearance of flows. Reconnaissance indicates that there is a gradation from porphyries which contain abundant phenocrysts and which are not conspicuously banded, to very fine-grained reddish and brownish rocks with no phenocrysts, which show conspicuous flow bands. The rock commonly splits easily parallel to the flow layers. 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 intrusives. The fact that most of the flows appear to be on hilltops further supports this possibility. Some of the fine-grained rhyolites in the Cape St. John peninsula possibly represent the intrusive equivalent of the rhyolite masses which are known to be flows in that area (See Cape St. John series). More detailed field work in both these areas will be necessary before definite conclusions regarding the relations of these rocks can be drawn.

Gabbro, Pyroxenite, Peridotite:

Small dikes 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 Harbor. Some of these small masses have been serpentinized.

Diorite:

Diorite occurs in sills and small dikes, cutting the rocks of the Nipper's Harbor series. 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 Ming's Bight-Baie Verte district which are described in more detail below.

Granodiorite, Granite, Qtz-rich Granite, etc.

These are part of the main mass of the complex described in detail above. They occur commonly as dikes and small stocks without chilled margins.

Aplites:

Very fine-grained light pink dikes, with small feldspar crystals as the only megascopically visible minerals are tentatively termed aplites. They sometimes have small inclusions of the adjacent country rock. Pyrite is common as small irregular masses and cubes.

Pegmatites:

On a small point southwest of Stocking Harbor a number of small pegmatite dikes were observed. They consist of quartz, orthoclase feldspar, albite, muscovite, and clusters of garnets. The average grain size is not greater than two inches.

Diabase Dikes:

Diabase dikes are not common as part of the Burlington granite complex except in a small area along the shore of Notre Dame Bay between Rogue's Harbor and Middle Arm. Here they appear in abundance as the latest intrusive rocks. The dikes, all of which are nearly vertical, show a marked parallelism at 35° to 60° throughout the district, but particularly in the shore exposures between Burlington Harbor and Middle Arm.

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 An 44 in the cores to An 18 on the rims. The pyroxene is pigeonitic augite ($2V = 45°$). 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 Dikes:

The latest intrusive rocks of the series are lamprophyre dikes, which are especially abundant between Stocking Harbor and the entrance to Burlington Harbor. On weathered surfaces they are light brown. Feldspar crystals which are more resistant toweathering than the other constituents of the rock are etched out on weathered surfaces and appear as a tangled aggregate of grey-brown fibres.

The rock is composed of euhedral phenocrysts of augite, and some hornblende in a groundmass of lath-like microlites of plagioclase feldspar with abundant accessories and considerable chlorite. Augite ($C \wedge Z$ 51°) occurs in clear, colorless eight-sided prisms up to 9 mm in length. Most of the augite crystals show strong zoning amd some are twinned. Common hornblende, (pleochroic in green and brownish-green with $Z \wedge C = 24^{\circ}$), occurs through the rock as euhedral and subhedral grains, usually smaller than the augite, but up to 3 mm in length. The augite makes up about 40% of the rock and the hornblende about 20%.

Feldspar microlites, of composition An 38 to 40, constitute most of the groundmass. They are in an irregular arrangement but show in a few places faintly developed trachytic flow structure. Accessory minerals include epidote, magnetite in irregular masses, chlorite as an alteration product of the mafics, sericite, calcite, and a fine, scaly alteration of the feldspars.

Partridge Granite

Granite occurs at the tip of Partridge Point as a dike-like mass, about one-fifth of one square mile in outcrop, with numerous dikes and offshoots. Microcline is the most abundant feldspar, with minor amounts of acid plagioclase. Quartz and muscovite are the other essential minerals. Garnet is the most common accessory. Simple granitic pegmatites and aplites intrude the granite and the adjacent country rock.

Relation of the Granitic Intrusives

Though no positive correlation can be made with the evidence at hand it is suggested that the series of granitic intrusives which is exposed in the Burlington Peninsula is 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 the Burlington granite which stretches 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. 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, together with the lineation (page 149) and the dips of the contacts 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 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, values being in copper and gold.

(3) Quartz-fuchsite veins were found (Rose, 1945, 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 wallrock adjacent. These veins were noted only in the region south of Ming's Bight, where abundant ultrabasic rocks occur. It is suggested that the chromium in the fuchsite may have been derived from the chromite which occurs as an accessory 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 the 'White Cow' on the eastern side of Ming's Bight, contain massive 'bull' quartz in the central portion and grade off into the gneisses and schists.

(6) Clear, glassy quartz veins occur commonly in the granites. The fact that many of the quartz veins follow the foliation of the gneisses and schists, and the volcanics whereas others cut across it indicates that the formation of the veins largely postdates the principal folding of the district (See Figs. 15 and 17). However, some irregular lenses of quartz in the Ming's Bight series appear to be quartz veins which have been broken and strung out during an early stage of metamorphism. The foliation of the gneisses wraps around the ends of the quartz lenses.

The great majority of the quartz veins of the district must be related to the intrusion of the granite masses. Not only are they more abundant near the granite contacts but they commonly occur within the granite masses. Zones of marked silicification are almost invariably within a few hundred feet of the contact of the granite or of apophyses from it. Certain irregular masses and clots of quartz, particularly common in the earlier gneisses and the Baie Verte series near Pacquet, may be the result of metamorphic differentiation (See page 94).

Diorite, Metadiorite and Metagabbro

Introduction:

In the northeastern part of the Burlington Peninsula about 50 small dikes, sills and irregular masses of diorite, metadiorite and metagabbro intrude the rocks of the Baie Verte series. The largest masses lie west of Baie Verte, between Baie Verte and Ming's Bight, and northeast of La Scie. A complex series of small, irregular masses occurs south of Ming's 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. There exists a complete range from narrow, trangressing dikes to well-defined, wholly-concordant sills.

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

Description:

The weathered surfaces 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 contrast between black amphibole and white plagioclase is much more marked.

The diorite, metadiorite, and metagabbro consist of saussuritized plagioclase feldspar and uralitized pyroxene or hornblende in about equal proportion. The plagioclase feldspar, which occurs as subhedral laths as much as one inch long with albite and carlsbad twinning, commonly makes up from 25 to 40% of the rock. Its composition varies considerably, but lies within the range albite-basic andesine. At one place in the sill which lies northeast of La Scie strongly zoned crystals have cores of An 38 and rims of An 12. The plagioclase is usually altered to a mass of albite, epidote, zoisite, calcite and an unidentified scaly aggregate. In the great majority of the rocks of this class no recognizable pyroxene remains. Hornblende, pleochroic in greens or blue-greens, which has come largely from the alteration of pyroxene makes up 35 to 60 percent of the rock. It is sometimes altered to actinolite and chlorite. The amphibole commonly occurs as anhedral masses which occupy the spaces between the feldspar laths, in a more or less sub-ophitic texture, although secondary textures obscure the original igneous texture. Biotite, straw to dark olive-brown, occurs in twisted lamellae and scattered flakes which make up as much as ten percent of the rock. Accessory minerals include calcite, apatite, epidote, magnetite and calcite. Introduced quartz, with strong undulatory extinction and rows of inclusions, was found in one slide (See Fig. 67). A zone in which magnetite constitutes about thirty percent of the rock occurs in the metadiorite sill just east of Rettis' Cove, near La Scie (See Plate 16). Pyrite is sometimes abundant.

Pegmatitic Facies:

Pegmatitic facies are of common occurrence and may best be observed in the cliff exposures between Rettis' Cove and the 'Turn of the Cape', east of La Scie. The coarse-grained facies occur as sharply defined, dike-like masses or irregular bodies with gradational contacts within the finer facies. At several places, particularly near Rettis' Cove, the crystals of saussuritized feldspar and uralitic hornblende are as much as two inches long. In some places in the same region considerable differences in grain size mark the layers of primary banding so that it is not uncommon to find layers of medium-grained metadiorite alternating with layers of pegmatitic metadiorite. In the pegmatitic zones it is not uncommon also to find that differentiation is more marked than in the ordinary zones so that light colored layers which consist almost exclusively of saussuritized plagioclase feldspar alternate with dark layers which consist almost entirely of coarse hornblende crystals. It is quite likely that the boulders of 'pyroxenite' and 'hornblendite' which are sometimes observed as glacial boulders in this region are fragments of the dark, massive, hornblende-rich bands of the metadiorites and metagabbros.

Alteration:

Uralitization has altered the original pyroxenes of the metagabbros to pale blue-green actinolitic hornblende almost universally. In the metadiorites the hornblende is sometimes altered to actinolite and chlorite. The feldspars are everywhere saussuritized and are obscured by a fine-grained mass of albite, zoisite, epidote, and an unidentified, fine, scaly aggregate. In the Baie Verte map area local alteration has produced a zoisiteprehnite rock which has been described by Watson (1939, p. 57). Silicification occurs in some areas, and near the ultrabasic masses carbonatization and steatitization are locally important in the metadiorites and metagabbros.

Intrusion Breccias:

At Rettis' Cove, which is about one mile northeast along the coast from the mouth of La Scie Harbor, a swarm of dikes, veins and more massive intrusive rocks of irregular outline intrude the coarse-grained dioritic rocks. The order of intrusion at this locality is

(1) Diorite
(2) Pegmatitic diorite
(3) Diorite 'aplite'
(4) Diabase
(5) Quartz-rich diorite
(6) Quartz porphyry
(7) Granite
(8) Granite aplite
(9) 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 wallrock. The series of photographs, Figs. 36 to 39, shows the process of formation of breccias, starting with thin veins of quartz diorite which have split off portions of the enclosing rock, through intermediate varieties, to breccias which are composed of a dilute mixture of fragments of diorite and early dike rocks in a matrix of quartz diorite. The photographs were taken within two hundred yards of one another on the southwest side of Rettis' Cove.

It is not clearly understood why one member of an intrusive series should almost invariably make intrusive breccias whereas the other members rarely do. Though no satisfactory reason is known, possible contributing factors are listed below:

(1) The quartz-rich diorites possessed greater penetrating ability than the others due to greater fluidity or greater pressure of intrusion.

(2) The quartz-rich diorites were intruded at a time when the country-rock was at a particularly brittle stage, or happened to be under stress. The quartz diorite may have been the first rock to have been intruded after the country-rock had been shattered and so was the first to have the opportunity of forming breccias.

(3) If the quartz-rich diorite possessed greater heat than the others then shattering of the wallrock by differential expansion would be more effective.

Age:

The rocks of this class are younger than the ultrabasic rocks of the region. This is shown conclusively at several localities by the occurrence of dikes of metadiorite which intrude serpentinized peridotite. At the Red Cliffs on the east side of Ming's Bight a dike of altered diorite about 130 feet wide cuts the ultrabasic rock. The metadiorite is veined by carbonate, which suggests that the diorite was intruded before the carbonatization and accompanying steatitization of the ultrabasic rocks. A zone of aggregates of radiating talc crystals which varies from one inch to one foot thick commonly occurs between the diorite and the unaffected serpentinized ultrabasic and is the result of later alteration along the contact which afforded access to rising solutions.

The common occurrence of dikes and sills of metadiorite and metagabbro with chilled edges in the Baie Verte series, the Snook's Arm series and the Nipper's Harbor series shows that these intrusive rocks postdate the volcanic rocks.

The granitic rocks of the region are younger than the metadiorites and metagabbros. In the Baie Verte region an off-shoot of the Burlington granite complex has altered the metadiorite in its contact zones. At Seal Island Bight, near the tip of Cape St. John, a small mass of granite porphyry has offshoots which cut metadiorite. At Rettis' Cove (near La Scie) a complete series of granitic satellite rocks intrude the metadiorite.

Serpentinized and Steatitized Ultrabasic Rocks.

Distribution:

Serpentinized and steatitized ultrabasic rocks occur in nine localities in the Burlington Peninsula. The individual intrusive masses are of diverse sizes, from dikes twenty feet wide and two hundred feet long to one mass which is nearly twelve miles long and two hundred feet to a half mile wide. Most of them are tabular bodies which are concordant with the rocks that they invade.

The nine localities are as follows:

(1) Fleur de Lys

(2) Between Upper and Lower Duck Island Cove Brooks, west of Baie Verte

(3) West of Butler's Pond, west of Baie Verte

(4) Near the Terra Nova Mine and behind the village of Baie Verte

(5) Between Devil's Cove Pond and Deer Cove

(6) Head of Ming's Bight southward to Three Corner Pond

(7) Red Cliffs, Ming's Bight

(8) Serpentine belt of the Bett's Cove - Tilt Cove district

(9) West of Flat Water Pond

The map, plate 8, shows the location of each of the occurrences in the Burlington Peninsula and Plate 7 the locations of the eastern and western "serpentine belts" of Newfoundland, which are referred to later in this chapter. The writer examined all but the first three of the localities listed and mapped in detail the Devil's Cove Pond mass, Ming's Bight mass, the Red Cliffs mass and the Flat Water Pond occurrence. The following descriptions show the general characters of the ultrabasic rocks of the area.

Character of Country underlain by Ultrabasic Rocks:

The altered ultrabasic rocks characteristically stand out as low, rounded hills. The rocks weather to a distinctive brown or reddish brown. Where rock-slides and caving have exposed fresh surfaces, the light and dark green colours of serpentine are apparent. In some places, as for example at the crest of the serpentine ridge a half mile south of the head of Ming's Bight, the surface is strewn with weathered brown plates of serpentine. Blocky jointing and faulting in the serpentine renders it susceptible to mechanical agents of destruction such as frost action, with the result, that steep talus-covered slopes are common. Glaciation steepened the walls of some of the valleys in the serpentine masses, accenting this feature. The cliffs, just east of the mouth of Trimm's Brook in Ming's Bight, which now have long talus slopes, were formed by the sea when it stood at the level of the terrace, which is now about 110 feet above sea level.

Where steatitization and carbonatization have affected the serpentinized ultrabasic rocks, valleys and depressions are characteristic. Trimm's Brook valley and the last mile of the valley of South Brook of Ming's Bight have been eroded by ice and stream action along the soft marginal talc-carbonate facies of the Ming's Bight ultrabasic mass. The transverse valley about a half mile south of the head of Ming's Bight has been carved out along a steatitized-carbonatized shear zone. The low trough, in which rests Burton's Pond, north of Nipper's Harbor, was apparently scooped out of a soft, altered part of the serpentinized peridotite by ice action. Similar low topographic expression of the talc-carbonate facies of the ultrabasic intrusion is characteristic in the Devil's Cove Pond district. The weathered surfaces of talc and carbonate-rich facies are light to dark reddish-brown. Fresh surfaces of carbonate-rich rocks may be light brown, whereas talc-rich portions are greenish or white. In many places, the talc has been sheared and weathering produces slippery slopes covered with minute platelets of talc schist.

A lack of vegetation is characteristic of hills which consist of altered ultrabasic rocks. However, in small depressions where a limited amount of glacial drift or plant debris has accumulated there is some stunted forest growth. The sterility of the serpentine areas may be explained on the following bases:

(1) There is a general lack of soil. Glaciation has removed any original cover and the rock does not weather rapidly enough to keep pace with the wash.

(2) Since the soils are at best very thin, the amount of water that may be retained is low.

(3) The sodium and potassium content of the soil is too low for ordinary plant nutrition.

(4) The high magnesium-calcium ratio may produce a magnesium substitution in the plant cells which alters the capacity for food assimilation. This restricts the growth of ordinary plants and makes the environment fit only for special types which prefer magnesium-rich soils. (Cf. Johannsen, 1928, p. 202; Lowe, 1899, p. 43; Wynn-Edwards, 1939, p. 19).

The prospect of finding good agricultural land in the valley-bottom of Trimm's Brook (Ming's Bight) is poor, since much of the fine debris which makes up the soil has been derived from the serpentine mass to the southeast. The high content of serpentine in the soils is undoubtedly one of the reasons why crops in the valley-bottom have consistently failed.

Rock Types:

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

When 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 percent of pyroxene which may be enstatite alone (harzbugite) or both monoclinic and orthorhombic pyroxene (lherzolite). 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, 1940, p. 46; Snelgrove, 1931, 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 still remnants of olivine grains, to rock which is more than 90 percent serpentine. The serpentine occurs as matted aggregates of minute fibres, sheaves and bundles of larger flakes, and in some places concentrically banded aggregates of radiating fibres. In some partially 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. Meshworks of secondary magnetite indicate the former presence of olivine (Harker, 1935, p. 93). One variety of serpentine which is especially common in the Red Cliffs occurrence and in the eastern portion of the Ming's Bight mass contains abundant, irregular, aligned dark patches which in thin sections are seen to be clots of finely divided, secondary magnetite.

Individual Occurrences in Burlington Peninsula:

A brief description of each of the occurrences in the Burlington peninsula is given to point out individual peculiarities (See Plate 8 for locations).

In the Fleur de Lys area Fuller (1941, p. 15) has described an elongated mass of serpentinized peridotite which intrudes the gneisses of the Fleur de Lys series. Along the margins of the mass, particularly along the footwall, and along faults, talc occurs as veins, and together with actinolite, as a general alteration 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 one mile wide. The Butler's Pond mass is about a mile and a half long and averages less than half a mile wide. Both masses are made up of partly serpentinized though recognizable peridotite. Indistinct primary banding or "pseudostratification" is characteristic of some parts of these masses. Serpentinization has completely changed about 50 percent of the olivine and about 20 percent of the pyroxene crystals (Watson, 1940, p. 40).

In the vicinity of the old Terra Nova Mine and behind the village of Baie Verte small serpentinized masses and dikes of peridotite have been observed by Watson (1940), Douglas (1940), and the writer. Masses of slightly altered pyroxenite occur also.

Between Deer Cove and Devil's Cove lies a mass of much altered ultrabasic rock. Serpentinization is complete. Talc and carbonate facies are common though no systematic arrangement with relation to the boundaries can be established. On the eastern end of the mass including the Red Point of Ming's Bight, a rock type made up of over 80 percent carbonate occupies about one half square mile in outcrop.

The Ming's Bight mass which extends from the head of Ming's Bight southward for about three miles to Three Corner Pond is about two miles in greatest width. Alteration of the original peridotite is nearly complete. The central portion of the intrusive body is massive serpentine. Talc-carbonate alteration occurs along the margins and along several fault zones within the mass. The relation of the ultrabasic intrusive rocks to the country rocks is very well shown in the bed of the South Brook of Ming's Bight about half a mile from its mouth. Frequent reference is made to this locality in later paragraphs. Carbonatization is especially prominent in the southeast corner of this intrusive body.

The Red Cliffs mass on the eastern shore of Ming's Bight is possibly the remnant of a much larger mass which might have extended out under what is now Ming's Bight. The bulk of the rock is serpentine. Some partly altered peridotite with remnants of olivine crystals separated by networks of serpentine occurs on the northern end of the shore exposures. Talc-carbonate alteration is prominent on the northern edge. The mass is greatly sheared and faulted.

In the Bett's Cove - Tilt Cove area serpentinized ultrabasic rocks occur in a sweeping arcuate belt about twelve miles long, and from two hundred feet to half a mile wide. In this belt, recognizable peridotite, pyroxenite and gradations to their completely serpentinized equivalents are found. Talc-carbonate alteration is locally prominent. Primary banding is prominent in many outcrops.

Along the shore of Notre Dame Bay, southwestward from Nipper's Harbor as far as Stocking Harbor, the altered volcanics of the Nipper's Harbor series are intruded by irregular dikes of serpentinized peridotite which are nowhere more than twenty feet wide. The volcanics themselves show serpentinization in irregular patches from two to a hundred square feet in outcrop. Occurrences similar to these were also noted in the Snook's Arm series to the northeast.

On the northwest side of Flat Water Pond, in the central part of the peninsula a previously undescribed, serpentinized ultrabasic mass which is about two miles long and three-fifths of a mile in its greatest width occurs. The best exposures are along the brook at the outlet of the lake and along the new Bowater road nearby. No microscope studies were made on specimens from this mass, but it appears to differ little from the others in the peninsula. Serpentinization is the most prominent alteration, but talc-carbonate facies also occur.

Serpentinization:

The problems of the genèsis of the serpentinized ultrabasic rocks are listed as follows ...

(1) The existence or non-existence of primary ultrabasic magma.

(2) Time and mode of serpentinization

(3) Time and mode of steatitization and carbonatization

(4) Source of solutions that produced carbonatization

(5) Form and time of intrusion and the relation to structure.

These problems are not specific for the Burlington Peninsula but have been discussed by writers working in many areas along the Appalachian chain, from Alabama to the Gaspé, and in other regions (Graham, 1917, etc.; Benson, 1918; Hess, 1933; Dresser and Denis, 1944).

Hess has advanced evidence to show that peridotites, which have later been serpentinized, crystallized from a primary ultrabasic magma (1938, p. 323). Following is a summary of the evidence which he advances:

(1) Large masses of ultrabasic intrusives occur in many regions without associated intrusive rocks of other types. If the ultrabasics were produced by differentiation from a basaltic magma, the other fractions should be in evidence.

(2) Analyses and hand specimens from the margins of such bodies show that each rock mass has the same composition right to its edges and that there is no chilled border zone of a composition to indicate interrupted differentiation.

(3) The contact effects of the peridotite intrusions are small compared to those which would be expected from intrusions of their size. The temperature of the intruding magma must therefore have been much lower than Bowen's studies on anhydrous melts of the same general composition would indicate and lower than refusion of

a gravity differentiate would require.

Thus it appears that the ultrabasic rocks of this region were most probably intruded as mobile masses with about their present bulk compositions, and that they have not undergone significant differentiation since their emplacement, except that which produced the rudimentary banding discussed below.

Evidence bearing on the process of serpentinization is summarized as follows:

(1) Serpentinization is confined to the ultrabasic intrusives except in rare cases where tuffs, pillow lavas, and other volcanics have been serpentinized as they have, for example, in the Snook's Arm series and in the Nipper's Harbor series between Rogue's Harbor and Stocking Harbor. This suggests that serpentinization was effected by solutions, held within the mass, which leaked out in very few places, and not by a flood of 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 relic olivine crystals are uniformly spaced and show approximately the same degree of alteration throughout.

(3) The alteration of the country rock is negligible, suggesting lower temperatures of intrusion than might be expected, as mentioned

above. A 10 percent to 15 percent water content in the original magma could account for the low temperature of intrusion and the serpentinization as well (Cf. Dresser and Denis, 1944, 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 areas similar evidence has led to the same conclusions.

Many reactions have been postulated to represent the changes that take place in the alteration of olivine and pyroxene to serpentine. Graham (1917), Hess (1933, p. 652), Dresser and Denis (1944, p. 437) and others conclude that the waters which effected serpentinization were silica-bearing. Cooke (1937, p. 67 et seq), on the other hand, has maintained that water alone may effect serpentinization. The evidence from the ultrabasics intrusives in the Burlington Peninsula supports the conclusions of Graham, Hess, et al. For a detailed discussion of the reactions that have been postulated to account for the change from olivine and pyroxene to serpentine, the reader is referred to Dresser and Denis, 1944, pp. 431 to 439.

Steatitization and Carbonatization:

Steatitization and carbonatization have affected every ultrabasic mass in the Burlington Peninsula except the two which lie west of Baie Verte. Talc and carbonate, which is usually a ferrodolomite with varying proportions of iron, calcium and magnesium (see below) occur as follows:

(1) Talc schist which contains 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.

(4) Carbonatized greenstones, not accompanied by steatitization

(1) Talc-carbonate rocks which 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 three-tenths of an inch to three inches long. Talc-carbonate rocks grade into serpentine rocks. Talc-carbonate rocks are exposed for example along the shore of Ming's Bight between Trimm's Brook and South Brook, and in the serpentine belt of the Tilt Cove-Bett's Cove region between Red Cliff Pond and Snook's Arm Western Pond. Quartz veins are common in talc-carbonate facies which are especially 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 which replace 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 as strong as that of the schists in which the lenses occur. The Trimm's Brook talc prospect, on the eastern side of the Ming's Bight mass about a mile southwest of the village of Ming's Bight, occurs in a series of such lenses.

Rocks whose composition is 80% to 100% carbonate are found along the eastern border of the Ming's Bight mass, in the Devil's Cove Pond district, and at various points along the Bett's Cove-Tilt Cove serpentine belt. Most easily accessible is the exposure at the Red Point of Ming's Bight. 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 series and the metadiorites. The rock is made up almost entirely of carbonate, with little or no talc. Quartz is present as small grains, which replace the carbonate. On weathered surfaces, the quartz grains stand out in relief and produce a sandpaper effect. Quartz also forms conspicuous veins and irregular masses which are sometimes 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 Ming's Bight, about half a mile from its mouth, several veins of talc and carbonate cut the gneiss and slate of the Ming's Bight series. The central portions of the veins are pure talc. The margins of the veins contain knots and crystals of brownish carbonate which extend beyond the walls of the veins into the country-rock. Along small faults and slip zones in the talc-carbonate facies of the altered peridotites, veins, as much as six inches thick, of sea-green talc in cleavable masses up to three inches in diameter are common. Veins of carbonate penetrate all the rocks of the district except the later intrusives. Small masses of actinolite schist four to six 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 belong to the high temperature facies of alteration. Talc-carbonate veins with a marginal zone of chlorite cut the actinolite masses in several places. The indices of refraction of the actinolite were determined as Na 1.615 and Ng 1.627, from which, on the basis of data given by Winchell, (1945, p. 245), the composition is calculated to be approximately 16 $(H_2Ca_2Fe_5Si_8O_{24})$ + 84 $(H_2Ca_2Mg_5Si_8O_{24})$

(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 strongly 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 metadiorites, particularly along shear zones. The most strongly carbonatized rocks, however, are the ultrabasic intrusives 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.

Significant in the problem of genesis of talc-carbonate are the following: (1) distribution of talc and carbonate, (2) source of the solutions which brought about the alteration and (3) composition of the carbonate.

(1) Talc alteration and most of the carbonate alteration occur along the margins of the ultrabasic intrusive bodies or along shear zones within them, which suggests that the alteration took place after serpentinization and solidification.

Carbonatization is not so localized. It is especially prominent in the marginal zones of the ultrabasic rocks, but also occurs widely in the other rocks of the region, notably in the area between Baie Verte and Pacquet. The ubiquity of carbonatization suggests that large quantities of carbonate-bearing solutions pervaded the area.

(2) Possible sources of the solutions are:

(a) The Dunamagon Granite: This small stock could possibly account for the carbonatization and steatitization in its immediate neighborhood, but could hardly be responsible for the widespread alteration over so much of the peninsula.

(b) Diorites: The diorites are strongly affected by carbonatization, so they must have been intruded relatively early in the igneous cycle before the invasion of the carbonatizing solutions. At the Red Cliffs of Ming's Bight, a carbonatized dike of diorite about 100 feet thick cuts the carbonatized and steatitized serpentine, with no obvious effects on the serpentine. The diorites in addition are too limited in extent to account for alteration on the scale observed and over such an area.

(c) Solutions derived from the ultrabasics themselves: If the solutions that were effecting the serpentinization gradually changed in their chemical makeup, perhaps due to additions from a magma chamber below, it is conceivable that a change from serpentinization to steatitization and carbonatization could take place. However, this would necessitate late-stage activity over a long enough period of time for the diorite to intrude the serpentinized peridotites.

(d) Cape Brulé Granite: This is the largest intrusive in the part of the Burlington Peninsula mapped by the writer and is the most likely source of steatitizing and carbonatizing solutions. It extends close to all the known altered ultrabasic masses except those west of Baie Verte. These, however, are not conspicuously altered beyond serpentinization. The Fleur de Lys serpentine masses are close to the Partridge Point stock, which according to Fuller (1941, p. 6) represents a boss on the roof of a larger unexposed mass.

(e) It is possible that the source of the solutions is not exposed.

(3) Composition of the carbonate. The composition of the carbonate is widely variable. Snelgrove (1939, p. 118) gave the recast analysis of carbonate from a vein which cuts the serpentinized ultrabasics on the north shore of Red Cliff Pond as follows:

$MgCO_3$	..	84.93%
$FeCO_3$	..	9.88%
$CaCO_3$	..	5.19%
		100.00%

The material is thus magnesite in which part of the magnesium has been isomorphously replaced by iron and calcium. Rose (1945, p. 20) presents an analysis of fresh white carbonate from veins in talc-carbonate schist as follows:

$CaCO_3$	.. 59.08%	
$MgCo_3$	.. 37.00%	It is an iron-bearing dolomite
$FeCO_3$	.. 3.70%	
	99.78%	

Following are three analyses of carbonate from the district:

	1	2	3
$CaCO_3$	50.7	49.6	9.6
$MgCO_3$	38.0	40.6	79.2
$FeCO_3$	3.2	3.2	7.6
Insol.	6.7	6.0	3.1
Total	98.6#	99.4#	99.5#

#Samples were not dried before analysis

No. 1 White carbonate from quartz - carbonate vein in carbonate-rich rock, Red Point, Ming's Bight

No. 2 White carbonate from lens in talc schist, South Brook, Ming's Bight

No. 3 Brown carbonate from lens in Baie Verte series near contact with ultrabasic rocks, south of Ming's Bight

From these analyses, the variations in colour, from white to dark brown, the variety of rocks in which carbonate is found and with which the carbonate-bearing solutions had a chance to react, it is seen that the carbonate is a widely varying mixture of calcium, magnesium and iron carbonates.

Origin of the Talc:

A variety of equations may be written to represent the change from serpentine to talc. Rose (1945, p. 21) accounts for the changes as follows:

$H_4(Mg,Fe)_3Si_2O_9 + 3CaCO_3 + 2H_2O \rightarrow 3(Ca,Mg,Fe)CO_3 + 2SiO_2 + 7O + 3H_2O$,

that is, iron-bearing serpentine + calcium carbonate + water → ferrodolomite + quartz + oxygen + water; and

$2(H_4(Mg,Fe)_3Si_2O_9 + 3CaCO_3 + H_2O \rightarrow H_2(Mg,Fe)_3(SiO_3)_4 + 3(Ca,Mg,Fe)CO_3 + H_2O + 3O$,

that is, iron-bearing serpentine + calcium carbonate + water + iron-bearing talc + ferrodolomite + water + oxygen.

He thus postulates that carbonatization was accomplished by hot calcium carbonate-bearing waters and that steatitization occured as the solutions became progressively lower in carbon dioxide. These reactions are in accord with the hot, dilute, aqueous solutions bearing carbonate which Hess (1933, p. 643) calls upon to effect steatitization. Hess, however, observed that carbonatization takes place at lower temperatures than the alteration to talc. In the Ming's Bight ultrabasic mass, essential contemporaneity of steatitization and carbonatization is indicated by the different relations the two minerals have to one another in different places. Thus, veins of pure carbonate cut the talc schists on the eastern border in the valley of South Brook of Ming's Bight. In the same region, thin talc folia replace carbonate crystals along cleavage planes and on the corners of crystals. Veins of sea-green talc cut talc-carbonate rocks along small faults. From the evidence in this region it is considered that carbonatization and steatitization were overlapping processes, but that carbonatization continued to lower temperature levels.

Reactions more simple than those postulated by Rose might have been going on during steatitization and carbonization. Dresser and Denis (1944, p. 437) suggest that serpentine may be altered to talc simply by the addition of silica or the removal of magnesia. If the solutions coming into the zone of alteration contained silica, calcium and carbon dioxide, then reactions similar to those of Rose, and Dresser and Denis might go on together. Such a combination would better allow pure talc, and pure carbonate facies to form. The processes of steatitization and carbonatization are considered to have been essentially the following: the alteration of serpentine to talc by reaction with introduced silica and possibly also by removal of magnesie; fixation of magnesium and iron from the serpentine with introduced calcium as carbonate; with decreasing SiO_2 in the solutions and declining temperatures, more carbonate would be formed; with decreasing CO_2 a larger proportion of talc would result.

Relation of the Ultrabasic Rocks to Structure:

Each of the masses of ultrabasic rock in the region is concordant with the formations it intrudes. In other regions similar concordance is characteristic (Hess, 1938, p. 639; Dresser and Denis, 1944, p. 415, et al).

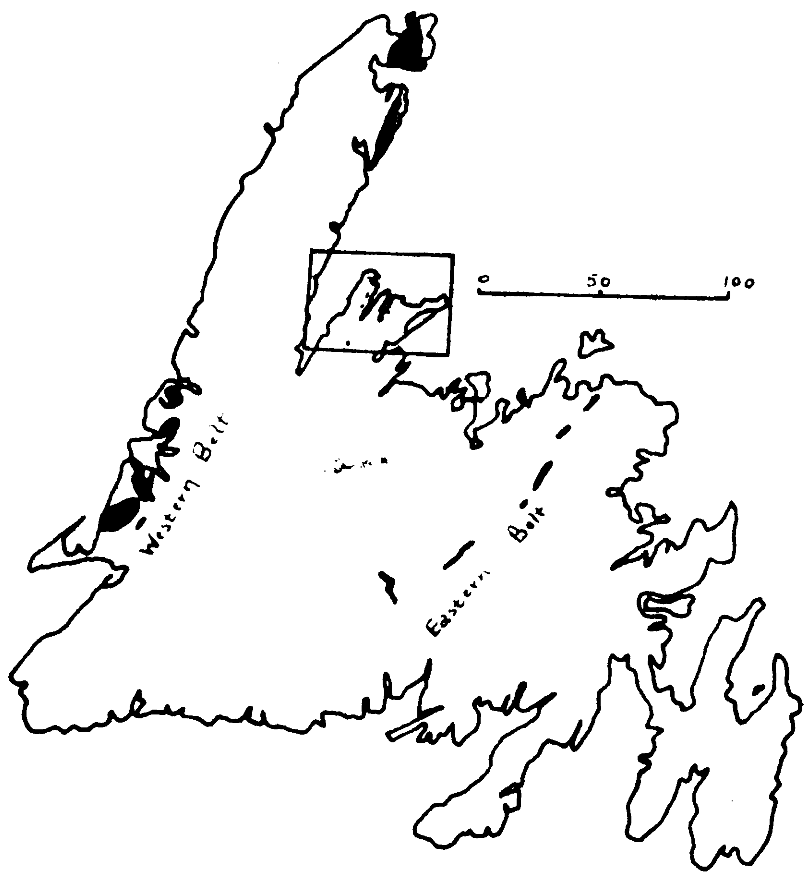
The Fleur de Lys serpentine body is a concordant sill-like mass which parallels the general strike and dip of the Fleur de Lys series. It is not apparently related to any of the major structures of the peninsula. It is offset by the east-west faults of the district.

The two masses of serpentinized peridotite west of Baie Verte are essentially concordant. They occur near the axial portion of an irregular syncline in the Baie Verte series, (Watson, 1940, p. 70). Several small, dike-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 of the Deer Cove - Devil's Cove region may possibly be an inclusion in a large metadiorite sill. The few strikes available in the adjacent greenstone indicate that it is a concordant intrusive.

The eastern and western margins of the Ming's Bight mass parallel the general trend of the Baie Verte and Ming's Bight formations. The western end of its southern boundary is a series of interfingering lobes which are generally concordant with the trend of the formations. The eastern part is more complex. Part has been intruded by metadiorite, and further east, the boundary is apparently a fault (See Plate 16). The alignment of clots of magnetite in the serpentine, mentioned above, is parallel to the boundaries and further suggests that the intrusion was concordant. This large mass occurs near the axial portion of an irregular syncline in the Baie Verte series. The possibility that a major fault occurs in Ming's Bight is discussed under Structure. The small Red Cliffs serpentinized peridotite mass is not far from the axial portion of an anticline in the Ming's Bight series. It may, however, be an apophysis of a larger mass which once occupied Ming's Bight and which was continuous with the Ming's Bight mass.

The long, thin serpentine belt in the Tilt Cove - Bett's Cove region is for the most part a concordant intrusion. The ultrabasic rocks were intruded along the boundary between the tightly folded Snook's Arm series on the south and east, and the Cape St. John series on the north and west. Toward its southern end, however, the serpentine belt swings across the belt of greenstones near the boundary of the Snook's Arm series and the Nipper's Harbor series. Discussion of the possibility that the serpentine belt follows a



<u>Plate 7.</u> Serpentine belts of Newfoundland, as plotted by Snelgrove, (1934)

<u>Plate 8</u>. Serpentinized ultrabasic masses of the Burlington Peninsula. Localities are as follows:

1. Fleur de Lys
2. Duck Island Cove Brook
3. Butler's Pond
4. Terra Nova Mine
5. Devil's Cove Pond
6. Ming's Bight
7. Red Cliffs
8. Tilt Cove-Bett's Cove
9. Flat Water Pond

major fault in the region is deferred to the section on Structure.

The relation to structure of the small mass of serpentinized peridotite at Flat Water Pond is little known from the brief reconnaissance made there. Its long axis is about north-south, which parallels the general trend of the greenstones of the district. A number of "breaks" which run through the country about north-south are visible on aerial photographs. The most prominent of these runs along the eastern side of the serpentine.

Relation to Other Serpentine Belts:

Snelgrove (1934) has described some of the serpentinized ultrabasic rocks in Newfoundland and has grouped them into two belts, (See Plate 8). The eastern belt includes a series of masses along a line running generally northeast from Baie D'Est on the south coast of the island to the mouth of the Gander River, on the north coast. The western belt includes the large masses on the west coast. The ultrabasics of the Burlington Peninsula lie between these two belts and are apparently related to neither. Together with the ultrabasic rocks of the Hare Bay district they are classed by the writer as a third belt, the northern belt.

Age:

Snelgrove considered that the peridotites and pyroxenites of the serpentine belt of the Bett's Cove - Tilt Cove area were part of the same cycle of igneous action as the other intrusives of the region (1931, 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 the Acadian age. By analogy with the similar regional geology of the Eastern Townships of Quebec (Dresser and Denis, 1944) the ultrabasic intrusive rocks might be of Taconic age. Other altered peridotites and pyroxenites in Newfoundland are also of unproved age. On the west coast they are known to be pre-Mississippian, but Cooper (1936) suggests that they were intruded at the close of the Ordovician, whereas Ingerson (1935) suggests a Devonian age.

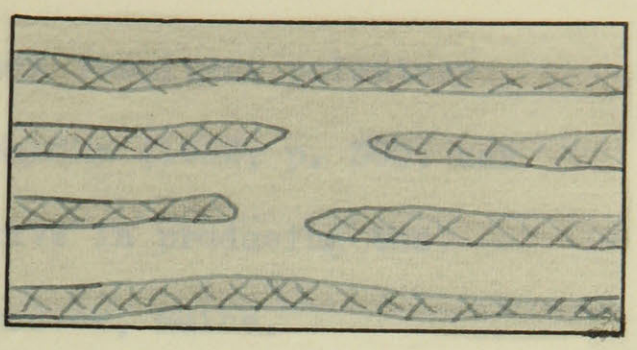
The Baie Verte series and the Snook's Arm series both of which are intruded by the ultrabasic rocks are most likely of Ordovician age. The serpentinized peridotites must therefore have been intruded in post-Baie Verte time, which could be late Ordovician or post-Ordovician. If the carbonatization and steatitization of the ultrabasics was accomplished by solutions from the main granite intrusions of the area, the ultrabasics are most likely pre-late-Devonian in age. The serpentinized masses have been involved in the later mountain building processes, since they are tilted, faulted, and sheared heavily on the margins. It is therefore concluded that the serpentinized ultrabasics are post-Baie Verte

(Ordovician) and pre-late-Devonian in age. A more exact dating is not possible with the existing information.

Primary Banding

The metadiorites of the Burlington Peninsula commonly show well-defined composition banding or pseudostratification. It is outstandingly well shown in the coastal exposures of the sill which lies northeast of La Scie. The banding which is well shown in Figs. 34 and 35 is the result of variations in the proportions from layer to layer of saussuritized plagioclase to uralitic hornblende. The individual bands range from half an inch to four feet in thickness and may be continuous along the strike for as much as 200 feet. The bands sometimes undulate slightly and terminate by pinching out or grading into an adjacent band. Individual crystals, particularly the hornblende, commonly tend to be oriented parallel to the banding. No lineation was observed. The layers are almost invariably gradational into one another with crystals of one band in some cases projecting into another. The banding is parallel to the boundaries of the sill. A few examples of sharp boundaries were observed between layers, but at no place did the banding suggest a series of flows. In some bands the proportion of light to dark minerals shows a progressive increase toward the top. On the other hand abundant examples of quite the reverse were also observed. The majority show an even gradation from hornblende-rich to plagioclase-rich to hornblende-rich with no marked breaks. There seems to be no systematic relation between the thicknesses of the dark layers and the adjacent light layers.

In the serpentinized ultrabasic rocks of the district the same type of banding was observed at several places. The classic locality is one mile S60°W of the Bett's Cove Mine, on the northwest side of the trail that leads from the mine to Burton's Pond. In these highly serpentinized rocks, the original layers approached peridotite and pyroxenite in composition respectively. In addition to composition banding some layering is evidently due to marked variations in grain size. The relations between adjoining bands are very much similar to those in the metadiorites. The thicknesses of individual bands range from six inches to three feet. Gradational contacts are the rule with the crystals of one layer commonly projecting into the next. There is little evidence of preferred orientation although the larger crystals of hornblende tend to be oriented parallel to the banding, as in the dioritic rocks. Layers are persistent along the strike for 150 to 200 feet. In some instances layers were observed which were broken off abruptly and the space between filled with material from the adjacent layers.



There were no flow lines however to indicate that the material had flowed while in a viscous or half-crystallized state. Banding in the serpentinized rocks is also approximately parallel to the boundaries of the sill-like masses, although the banding in the Bett's Cove district seems to be less regular in its relations to the sill boundaries than in the metadiorites of the Baie Verte - La Scie region.

Several theories have been advanced to account for the origin of primary banding:

(1) Intrusion of an assemblage of different liquids which were the result of differentiation at depth. Harker (1909) thus accounts for the banded basic and ultrabasic rocks of Rum and Skye. In a discussion of the Bushveld norite, Bowen (1928, p. 168) suggested "auto-intrusion" during deformation of the more completely liquid fraction of a partly differentiated magma into the fraction which has a greater proportion of crystals. Further crystallization differentiation of the intruded liquid layers would heighten the effect.

(2) Pulsatory escape of mineralizers with resultant pulsatory crystallization and banding in depth. Wandke (1922, p. 300) has suggested that this mechanism was effective in producing the layering of the banded gabbro of Cape Neddick, Maine.

(3) Banding due to peculiarities of convection currents. Grout (1918, pp. 459, 639) postulated such an origin for the banding of the Duluth lopolith, and Foslie (1921, p. 713) suggested that movements of the fluid magma accounted for the banding in the Raana norite.

(4) Rhythmical fractional crystallization due to rhythmical rise of the isogeotherms due in turn to the repeated subsidence of the floor of the igneous mass. Wagner (1924, 1929) has thus explained some of the banding in the Bushveld norite mass.

(5) Gravitative crystallization differentiation with repeated filter pressing at the bottom of a magma chamber during repeated deformation as the lopolith subsides. Bowen has applied this idea to account for the banding of the Duluth lopolith (1919, p. 418).

(6) Daly has suggested that a repeated showering of crystals toward the bottom of an igneous mass would take place if the cooled top layer of magma were to be repeatedly swept away by convection currents and replaced by fresh parts of the melt. Daly has also emphasized the importance of the availability and the movements

of xenoliths in the melt (1933, p. 354).

(7) Hess (1938, p. 264) in a summary of the causes of primary banding has stressed the importance of two factors -- (a) the relative density-differences between the plagioclase and pyroxene and the magma, (b) Periodic disturbance of the cooling process by periods of mild flow. In the Stillwater complex Hess suggests that the cause of the disturbance was the sagging of the lopolith.

It is apparent from the diversity of theories and conflicting evidence that there is as yet no completely satisfactory explanation of primary banding in basic igneous rocks. In the Burlington Peninsula no positive evidence suggests the dominance of any one process or combination of processes. The following facts are pertinent however:

(1) The masses are all concordant sill-like bodies, and the banding is approximately parallel to the boundaries.

(2) In the sills which are as much as 5,000 feet thick no marked change in composition is noted from the top to the bottom. This suggests that gravity crystallization differentiation on a large scale was not very effective.

(3) No inclusions were found anywhere in the banded rocks. Xenoliths, unless they have completely disappeared, were therefore not important.

(4) There is evidently no systematic relation between the thicknesses or the compositions of adjacent bands. Bowen's theory of repeated

filter-pressing with light-colored bands derived from the underlying dark bands therefore does not seem applicable.

(5) Most of the intrusive masses are concordant sills without any evidence of slumping as seen in lopoliths. Rhythmic or periodic disturbance would therefore have to come from periodic loss of mineralizers or some type of deformation other than repeated slumping of the floor of a lopolith.

(6) The boundaries between adjacent layers are commonly gradational which suggests that at least some of the constituents of adjacent layers crystallized together.

(7) The fact that some bands are broken and the spaces between the ends of the broken bands are filled with the material of adjacent bands shows that some bands were solid enough to be coherent while others were still fluid or plastic.

Further investigation of this problem in this district should include detailed mapping to find accurately the relation of the banding to the boundaries of the sills. A series of analyses and thin sections across individual sills would show whether or not subtle differences of composition occur between the tops and the bottoms. Petrofabric analysis of unaltered masses might show the direction of the last movement of the crystals and thus help to indicate the process.

STRUCTURAL GEOLOGY

Introduction

The work of Süess (1904), Keith (1928) and Snelgrove (1929) has shown beyond reasonable doubt that Newfoundland is part of the Appalachian Mountain system. Not only is Newfoundland on the direct northeastward extension of the Appalachians, but the rocks of Newfoundland are similar to the rocks of the mainland to the southwest in many ways - structurally, lithologically, and in their general history.

Divisions of Newfoundland

Although no subdivisions of regional structure in Newfoundland correspond exactly to those of the more classic Appalachian localities as described by Willis (1892) and later by Keith (1928, p. 321) and others, and although the early Paleozoic histories are different, various parts of Newfoundland show different structural characteristics. Omitting the Precambrian areas, the structure in Newfoundland grades through the following phases from east to west:

(1) Open folds with some normal faulting, and perhaps renewed activity along Precambrian thrust faults (Conception Bay). This zone is perhaps similar to the 'District of Open Folding' as described in the Appalachians by Willis (1892, p. 224).

(2) Open to tight folding, with few major thrust faults, and numerous normal faults (Bonavista Bay district).

(3) The region of tight isoclinal folding with some open folds, and some overturned folds, which is also characterized by numerous major thrust faults and considerable normal faulting (any area in the Notre Dame Bay district).

(4) The region of batholithic intrusions. This corresponds in a general way with the outline of the region of tight isoclinal folding. At the present stage of erosion the principal batholiths lie around the edges of that division. Keith (1928, p. 331) recognized a division of batholith intrusion in the Appalachians.

(5) The western coastal strip of open folds and numerous normal faults. The distribution of structural characters shows a parallelism with that of the Appalachians .. in the east, gentle folding and progressing westward into a region of intense deformation, then into a zone of less deformed Paleozoic rocks, with the Precambrian Shield lying beyond.

The Burlington Peninsula forms a part of the zone of isoclinal folding and thrust faulting. The trend of the structures, both folds and faults, is consistent with the general northeast-southwest trend of the structures of the rest of Newfoundland. The sedimentary and volcanic rocks of the district have been not only folded and faulted but also intruded by a batholith and a complex of satellitic rocks.

Foliation and Bedding:

In many localities in the Burlington Peninsula the principal foliation was found to be parallel to the bedding. Near Big Head, on the western side of Ming's Bight, beds of ferruginous chert are visibly parallel to the foliation in the adjacent greenstones of the Baie Verte series. The foliation in the upper part of the Baie Verte series, west of Baie Verte, is parallel to 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 series, foliation is parallel to 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 which is parallel to the bedding is not a local phenomenon, but is characteristic of the whole of the Burlington Peninsula, and indeed of 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 to 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 (1946) 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 (1936, p. 16) found considerable isoclinal folding with consequent parallelism of slaty cleavage and bedding. In the rocks of the Baie Verte series, even in the more open folds, cleavage was found to be parallel to the bedding, which indicates that mimetic types of foliation are present in addition to flow cleavage developed in isoclinal folding.

Though some minor errors have undoubtedly been made, it is considered that an accurate picture of the structure of the area is provided by the mapping of the principal foliation, supplemented wherever possible with observations on the actual bedding planes, and secondary features such as drag folds.

Top and Bottom Determinations:

Top and bottom determinations in the area are everywhere difficult. In most of the altered volcanic rocks the primary structures have been completely obscured and determinations in most places were not possible. However, drag folds and graded bedding in altered greywackes were of assistance in some horizons. In the Cape St. John series, which is less altered than the other rocks of the Burlington Peninsula, primary structures of the sedimentary rocks and the lava flows are better preserved.

Folds

The rocks of the region have been intensely deformed into a series of folds which range from open to isoclinal, and from upright to overturned. The plunges of the major folds are for the most part to the northeast, but some to the southwest were also observed. The folds are commonly asymmetrical and the axial planes of overturned folds commonly dip to the southeast. The competency of the folded rocks varies widely. The widespread volcanic rocks of the Baie Verte series are commonly much crumpled and schisted, whereas the massive sedimentary beds and rhyolite flows of the Cape St. John series are not complexly folded within the individual units. Drag folds are very common in some areas, and range from a few inches to 100 feet across. In many places they were useful in determining major structures.

The probability that the peninsula between Baie Verte and White Bay is broadly anticlinal with small folds superimposed on it, and the alternate possibility that it is a series of close folds have been discussed under "Fleur de Lys Series" (See Plate 15).

A small syncline which strikes across Little Bay Head was determined by Fuller (1941, p. 17) from a repetition of recognizable units of the Fleur de Lys series and a reversal of dips. He suggested that the syncline plunges to the southwest because of the widespread occurrence of chlorite schists, which are similar to those in the centre of the Little Bay Head syncline, at the Terra Nova Mine, some twelve miles to the southwest. Subsequent mapping between the two localities by Watson and the writer has shown that there is little justification for this reasoning and the plunge of the fold must therefore be recorded as not determined (See Plate 16).

Several major folds have been recognized in the Baie Verte series. A northeast-trending, isoclinal syncline of irregular outline occurs between the western shore of Baie Verte and the boundary of the Baie Verte series with the Fleur de Lys series. A broad, asymmetrical anticline occupies much of the peninsula between Ming's Bight and Baie Verte, and extends southwestward where the axis has been intruded by a mass of quartz diorite. The axial plane of the fold dips to the southwest at about 75° and the plunge is northeastward at about 30°. The northern part of the fold has been cut to pieces by intrusions of ultrabasic rocks and gabbro. Both these folds were first mapped by Watson, (1939, p. 70). The writer remapped most of the area underlain by the eastern anticline, (See Plate 16). A syncline which is much complicated by drag folding on a large scale, and probably by faulting as well, lies adjacent to this anticline on the east. Determination of the structure in this area, south of Ming's Bight, is especially difficult because of the many drag folds, which are the result of both folding and faulting, and the scarcity of outcrops due to the heavy forest cover. In addition the rocks of the region immediately south of Ming's Bight are intruded by numerous masses of ultrabasic rocks and diorite, and are considerably altered by the subsequent serpentinization and carbonatization.

Southwest of the Dunamagon granite the writer has mapped an anticline which plunges at about 40° to the southwest. The anticline is postulated principally on the basis of the swing in trend of the strikes and dips of the rocks and is substantiated by a few observations on drag folds. Lineation, marked by the direction of elongation of hornblende needles, was noted in many places to plunge to the southwest. A swing in the strikes of the formations in the area between the granite and the ultrabasic rocks in the valley of South Brook of Ming's Bight suggests the presence of a minor syncline which is possibly a small fold on the flank of the anticline.

The relation of this anticline, which plunges to the southwest, to the structures (to the east) which plunge to the northeast is not clear. It is suggested that the folds are en echelon. It is likely that in the Baie Verte map area and in the district to the south more southwestward-plunging structures and horizontal folds occur than have been recognized. If all the structures of the area plunge to the northeast at about 30^{o}, as Watson and Rose have suggested, then the stratigraphic thickness of the Baie Verte greenstones exposed between the southernmost limit of mapping and the sea should be about 30,000 feet. But Watson has shown that the Baie Verte series is only about 9,000 feet thick (1939, p. 21). The fact that the syncline southwest of Ming's Bight is somewhat irregular in its plunge suggests that other folds in the area may also be irregular.

The long strip of rocks of the Baie Verte series that stretches northeastward to Pacquet shows consistent southeastward dips, which gradually steepen toward the granite contact in the southern parts of the area. It is the extended southeastern limb of the anticline described above. Tops, wherever determined, are to the southeast. Two determinations about one mile north of Beaver Pond, which show reversals of dip, suggest the possibility that some small folds occur on the flank of the major fold. The sequence of beds, compared with that of the type locality, indicates that there are no major repetitions and that the top of the series is to the southeast.

In the Side Pond area (See Plate 16 for location) several reversed dips suggest that a syncline lies to the southeast, and that the margin of the granite lies not far distant from the axis of the fold.

A series of steeply dipping, isoclinally folded rocks of the Baie Verte series occupies a wedge-shaped area between Gooseberry Cove and the head of Confusion Bay, and westward. Overturning of the beds is indicated by dragfolds in exposures close to the granite contact on the west shore of the head of Confusion Bay and in some outcrops near Cape Cagnet (See Plate 16).

The remnant of volcanic rocks which belongs to the Baie Verte series, between the head of Confusion Bay and Harbor Round is a portion of an anticline which is overturned to the north. Prominent jointing and the formation of a second foliation have made structural determinations difficult.

A minor syncline is exposed in Brent Cove Head, but in the shore section between Brent Cove and La Scie little definite structure can be established in the massive altered volcanic rocks which rarely show evidence of bedding and never recognizable tops and bottoms. Along the west side of La Scie Harbor the dips of the formations are uniformly to the northeast.

Along the eastern shore of Ming's Bight uniform strikes of N10°E and westward dips of 55° to 65° characterize the section of the Ming's Bight series from South Brook to Big Cove Brook. One mile to the southeast the dips are to the southeast. These divergent dips, together with numerous dragfolds in the gneisses of the shore section show that an anticline parallels the shore about one half to one mile inland, and that it plunges to the southwest at about 30°.

North of the Dunamagon granite a broad domal structure in the Ming's Bight series has its centre about a mile and a half southwest of Handy Harbor. Near the coastline the dips of the formations are towards the sea. The strikes change from about east-west at Cape Hat to northwest-southeast at Pacquet (See Plate 16 for location). Some nearly horizontal dips were recorded a short distance east of the centre of the peninsula. Near the margins of the Dunamagon granite the dips are toward the south, and the recorded strikes parallel the granite contact.

At Pacquet Harbor the trend of the formations is northwest-southeast. Isoclinal folding is indicated by the steep parallel dips and abundant reversals of tops and bottoms which are shown by dragfolds. The plunge of the structures is to the southeast. Infolded remnants of chloritized volcanics which are exposed near the mouth of Pacquet Brook are suggestive of the Baie Verte series, the nearest outcrops of which lie across the harbor.

On the seaward side of the peninsula on the northeast side of Pacquet Harbor, gneisses which are undoubtedly of the Ming's Bight series strike parallel to the coast and stand nearly vertical. On the harbor side of the peninsula the schisted and sheared greenstones probably belong to the Baie Verte series. The rocks are much faulted. Little light can be thrown on the relations of the two series, because the attitude of the bedding in the much altered volcanic rocks is not determinable at the contact. The strikes and dips which are available however, suggest that the greenstones are not conformable with the gneisses.

The shoreline of Cape St. John cuts across the strikes of the formations of the peninsula, exposing a cross-section of a tightly folded syncline which is overturned to the south. The axis of the syncline is near Cape Cove. The trend of the formations, in the interior of the peninsula, is uniformly to the northeast as far as the region south of the head of Confusion Bay. In this locality a swing in the strikes of the formations suggests that the syncline exposed in cross-section at the Cape continues southwestward this far and that it plunges to the northeast. Stratigraphic evidence is also suggestive. The formations which are exposed at the nose of the syncline are andesites and dark green lavas, similar to the formations below the Cape St. John series and in the lower parts of it. The detailed structure of the interior of the peninsula will remain obscure however until detailed mapping is carried out.

The arc of altered pillow lavas and volcanic rocks of the Snook's Arm series was considered by Snelgrove to be a tightly folded anticline, which plunges gently to the northeast. His principal evidence is that northeast of a line which joins Balsum Bud Cove and the southern end of Snook's Arm Eastern Pond the dips of the rocks of the Snook's Arm series are to the southeast whereas south of the line they are to the south. In addition an apparent repetition of certain stratigraphic units which are thought to be equivalent to one another suggests an anticlinal structure. A peculiarity of the structure suggested by Snelgrove which bears reinvestigation is the fact that the dividing line between the northwestward dips and the southeastward dips does not fit in with the distribution of the stratigraphic units as shown on his areal map (1931).

Along the shore of Notre Dame Bay southward from Nipper's Harbor a series of altered volcanic rocks has been termed the Nipper's Harbor series. The dips are everywhere steep and the strikes are in general parallel to the northeast-southwest-trending shoreline. At the mouth of Burlington Harbor and in the Stocking Harbor district remnants of the Nipper's Harbor series with irregular dips and strikes have been cut to pieces by the Burlington granite and offshoots of it. Minor faults have complicated the structure. On the south side of Middle Arm of Green Bay similar remnants of volcanic rocks occupy wedge-shaped areas in the coastal region.

Normal Faults

Over 150 faults and small slips were mapped on the sea coast between Ming's Bight and Shoe Cove. The great majority are normal faults and have dips of over 50 degrees. The slip on most of them is small. However, in some localities the aggregate movement along numbers of them may be considerable. Dragfolding of the wallrocks, tension cracks and offsetting of marker horizons assisted determination of direction of movement. Along most, however, little indication is given either as to the direction or the amount of displacement.

In the Fleur de Lys area a series of east-west faults has been described by Fuller (1941, p. 17). The displacement has been estimated to be from a few hundred feet to 5000'. In most cases the south side has moved to the west.

The contact of the Baie Verte series and the Fleur de Lys series has been interpreted by Watson as a fault contact, because of the occurrence of a thickness of only 2500 feet of the Baie Verte series between the centre of the syncline mentioned in the earlier section and the Fleur de Lys boundary, whereas on the eastern limb some 9000 feet are exposed. Supporting his theory is a minor disturbance of the trend of the strikes of the Baie Verte series near the contact and the fact that zones of different grades of metamorphism lie in contact with one another. The Baie Verte series on the east is in the greenschist facies and the Fleur de Lys series on the west is in the garnet zone.

A set of nearly vertical faults, which may join the main faults separating the Baie Verte series from the Fleur de Lys series, was mapped by Watson (1939) in the region of Duck Island Brook. Evidence of these faults is seen in the deep narrow valleys, sheared and slickensided wallrocks, and drag folds. The movement appears to have been south side down and to the west.

A north-south-trending vertical shear zone cuts the rocks of the Baie Verte series and the ultrabasic intrusive complex just west of the axis of the syncline which lies south of Ming's Bight. The movement has taken place apparently along a number of closely spaced zones, and the west side has moved to the north in each case. A northwest-southeast-trending vertical fault cuts across the Three Corner Pond area. Its position is marked by a dike-like mass of diorite on the northwest end and by the inlet on the southeast side of Three Corner Pond.

The writer considers it possible that a fault extends under Ming's Bight and southward along the Trimm's Brook valley to the Three Corner Pond district. Everywhere along the Trimm's Brook valley and in the immediately adjacent hills shear zones trend parallel to the direction of the proposed fault. Drag-folding and local disturbance of the trend of the greenstones of the Baie Verte series was observed at Three Corner Pond. Three Corner Pond itself owes its shape to the fact that it lies on the intersection of the northwest-southeast-trending fault mentioned above and a northeast-southwest-trending topographic break which is continuous with the Trimm's Brook valley and extends to the southwest for about two miles.

Along the eastern side of the Ming's Bight mass of ultra-basic intrusive rocks the talc schists and sheared talc-carbonate rocks also show the results of movement. At the southern margin of the serpentine mass an east-west fault which is traceable for about one and one half miles separates the serpentine from the Baie Verte series. To the east of South

Brook it disappears under a cover of glacial debris, but a line of swamps for about half a mile may indicate its extension in that direction. Where the fault crosses South Brook, a prominent dragfolded zone in the Baie Verte formation in the west bank of the brook plunges 40 degrees northeast and shows that the north side moved up and to the west. An abrupt change in the strike of the platy foliation in the talc schists and drag-folding in the Baie Verte series of the east bank are further evidence.

Innumerable small faults were observed in the Ming's Bight formation around the seacoast. From Handy Harbor to Cape Brulé a series of northwest-southeast trending vertical shears are prominent. They are marked by fractured rock and disturbed dips as well as sharp physiographic breaks.

A fault that strikes northwest-southeast and dips steeply southwest cuts across the headland of Cape Brulé. There are several smaller slips in the same region which are approximately parallel to it.

Duplication and apparent thickening of the Cape St. John series is effected by several nearly vertical faults which are visible in the cross-section exposed at Cape St. John. An example of this type occurs behind "Mother Burke", where it is easily visible because it affects brightly coloured formations.

Unrecognized duplication has undoubtedly been effected by undetected faults which lie along covered zones or in the thick rhyolite beds, which sometimes show closely-spaced fracturing and microfaulting.

A major fault extends northeastward from Shoe Cove approximately parallel to the strike of the formations of the Cape St. John series. At the shoreline at Shoe Cove a large smoothed and slickensided face of rock is exposed on the southeast side of the fault zone. The sharp, narrow gully in the adjacent hillside is underlain by a zone of finely-shattered and crushed rhyolite. From Shoe Cove the northeastward trace of the fault zone is clearly visible in a long, sharply-defined valley, which emerges at the coast near the southeastern end of Manful Bight. No evidence of the direction or amount of displacement was found, except in the distribution of the formations which suggests that the south side moved down.

In the Bett's Cove - Tilt Cove area, two sets of faults occur. The first set is tangential to the arcuate trend of the stratigraphic units of the Snook's Arm series, and the second set is radial to it (Snelgrove, 1931). In addition numerous normal faults of small displacement which are apparently not related to the sets described above were observed both in the field and on aerial photographs by the writer.

The most prominent fault along the coast of Notre Dame Bay is the Stocking Harbor fault. It is marked along its whole length by a sharply delineated depression. It is most conspicuous in the Stocking Harbor - Rogue's Harbor district. It has been traced from a point just north of the head of Middle Arm (Green Bay) northeastward to a point beyond the head of Bett's Cove, a distance of over twenty miles.

In the region south of the White Hills of Burlington a gulch along the Stocking Harbor fault is followed for several miles by the stream which enters Burlington Harbor from the southwest. The stream follows a steep-walled, narrow gulch through the granite and fine porphyries of the Burlington granite complex. The rocks in the walls of the canyon show fracturing and shearing but little other direct evidence of the fault. The fault follows the two arms of Burlington Harbor, the elongated arms of Stocking Harbor and the southwest arm of Rogue's Harbor. Sheared and slickensided volcanic rocks are characteristic near the copper prospect at Rogue's Harbor, which lies along the fault trace. At the head of a small cove, three quarters of a mile southwest of Walsh Cove, the fault is exposed in a cliff as a vertical sheared and smashed zone, about thirty feet wide. Little indication of the direction of movement can be seen. The fault trace passes northeastward under the isthmus at Walsh Cove and across the mouth of Nipper's Harbor, along Burton's Pond and then along a depression until it disappears north of Bett's Cove.

Evidence from the field and from aerial photographs suggests the possibility that a branch of the Stocking Harbor fault continues along the band of serpentinized ultrabasic rocks southwest of Bett's Cove. The serpentinized rocks are everywhere sheared and in many places schisted. The topographic breaks which mark the fault to the south continue into both the Bett's Cove mine area and the belt underlain by the ultrabasic rocks.

Several copper prospects lie along the Stocking Harbor fault and its subsidiary shear zones. The Garden Cove prospect lies only a few hundred feet from the fault in complementary shear zones. The Shiner's Prospect at Stocking Harbor lies on a set of shears, visibly related to the main fault. The prospect at Rogue's Harbor lies within a few hundred feet of the fault, and part of it actually along the fault zone itself. The Bett's Cove mineralized area which supported mining operations for more than ten years lies within a thousand feet of the main fault, at the intersection of two shear zones, one of which is parallel to the main break (See Plate 14). Another strong topographic depression which is probably another major fault parallels the Stocking Harbor fault about one mile northwest of it.

A prominent northwest-southeast-trending fault occurs in the upper reaches of the brook which drains into Middle Arm from the north. Its trace is visible in a sharp gulch over a mile long. A similar fault occurs northeast of the White Hills of Burlington.

The region between Middle Arm (GB) and Southwest Arm is cut by a systematic series of faults or 'lineaments'. There are two sets which are about vertical, since they do not vary in direction with the topography, and which strike about northeast-southwest, and northwest-southeast respectively (Cf. below).

In the Ming's Bight - Pacquet area an attempt was made to interpret the 'lineaments' which are readily visible on aerial photographs and visible only with difficulty on the ground. All major topographic breaks of reasonable length and prominence were plotted, as shown in Plate 10. From this map it may be seen that three sets of fractures occur. The most prominent is one which trends about east-west. Another set strikes about northeast-southwest and the third about northwest-southeast. A few do not fit this pattern. The prominent east-west lineaments cut across the country regardless of the rock types and the topography. They do not change direction with topographic changes so are probably vertical.

An aid to the interpretation of the origin of these lineaments is afforded by a study of the joints of the same area. All observations of the joints of the area were plotted on a Lambert equal area projection net, using the system of plotting the normals to the planes. Equal area contouring of the results showed that there are several sets of joints in the area (See Plate 11). The small concentration which shows the horizontal and nearly horizontal joints represents jointing which was not usually recorded more closely than "sheety jointing". The concentration shown on the net, therefore, is diagnostic but not quantitatively representative. The most common joint set is one which strikes about east-west and is nearly vertical. Another set, which is also nearly vertical, strikes northeast-southwest. A minor set of joints strikes northwest-southeast. The correspondence between the lineaments and the joints is excellent. The most prominent in each case is one which strikes east-west, and is vertical. It is suggested, therefore, that the lineaments represent joints on a large scale, or possibly faults of small displacement.

In most cases the field relations of these breaks are obscure. They are visible on aerial photographs because they are long, narrow gulches which are filled with woods in an otherwise barren country,

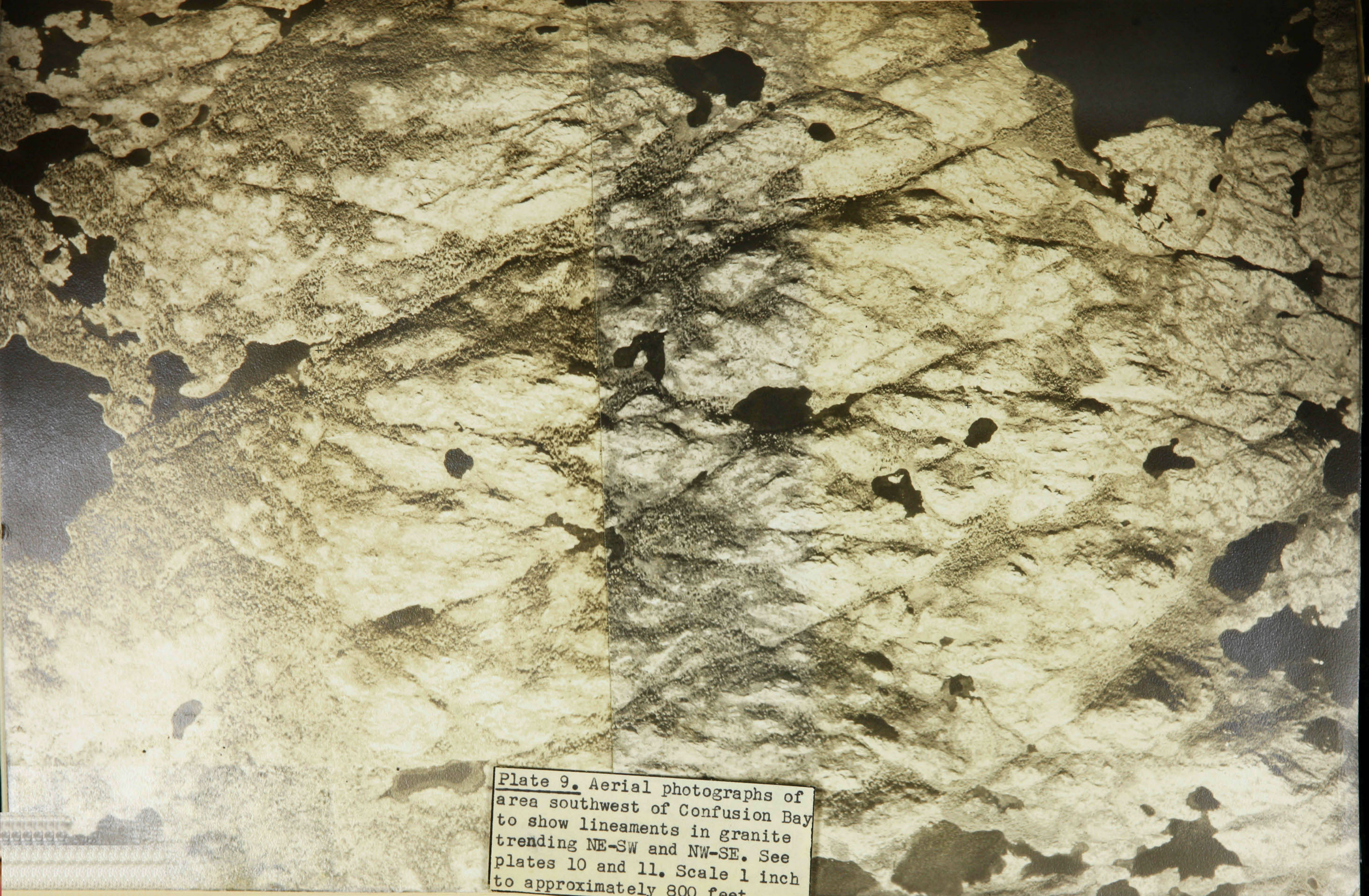


Plate 9. Aerial photographs of area southwest of Confusion Bay to show lineaments in granite trending NE-SW and NW-SE. See plates 10 and 11. Scale 1 inch to approximately 800 feet.

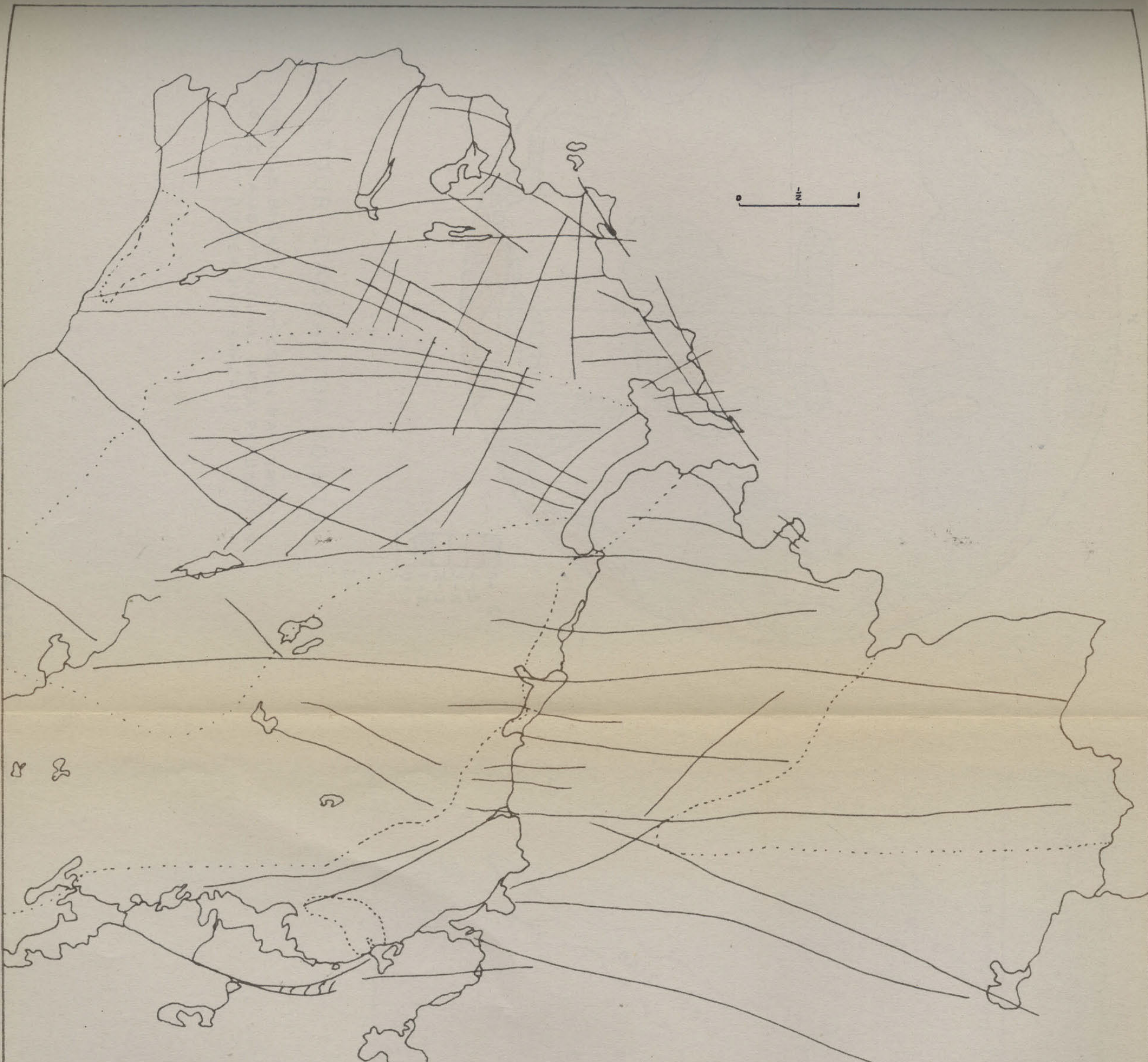
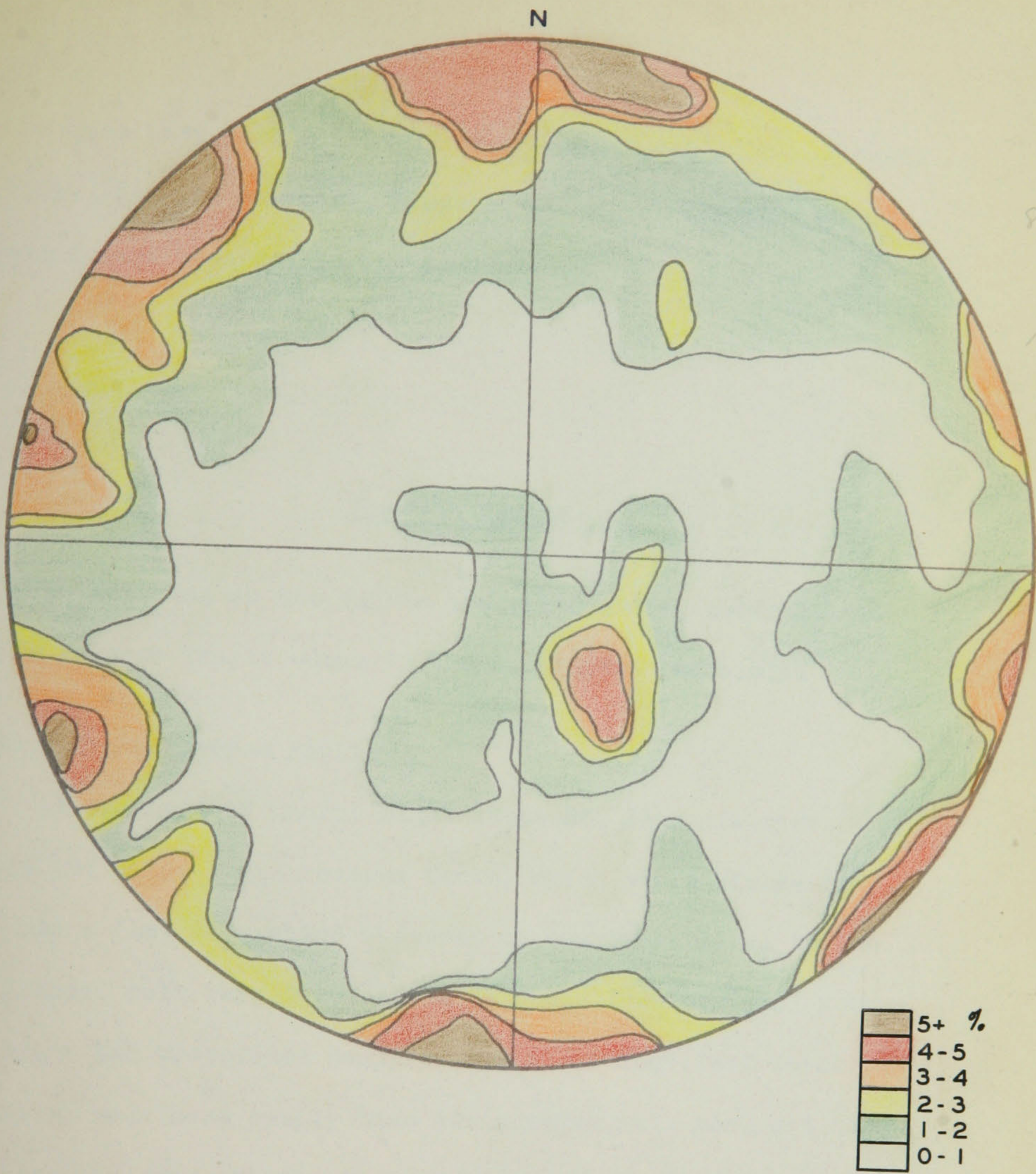


PLATE 10

SKETCH MAP TO SHOW "LINEAMENTS" OF THE
MING'S BIGHT - CONFUSION BAY AREA



Should match opposite side

CONTOUR DIAGRAM OF JOINTS

IN MINGS BIGHT - CONFUSION BAY AREA
USING LAMBERT EQUAL AREA PROJECTION
NET (UPPER HEMISPHERE)

PLATE II

or because they mark a line of cliffs with rockslides at their bottom. In some examples, however, actual slickensiding and breccia were observed in the depressions.

Reverse Faults

In addition to the faults described above, several low-angle reverse faults occur in the Burlington Peninsula.

Manful Bight Reverse Fault:

At the head of Manful Bight (Cape St. John district, Plate 16) a low angle reverse fault, which has a strike of 60° and a flat dip, which steepens to nearly vertical to the southeast, cuts rhyolites of the Cape St. John series. A zone of gouge and brecciated country rock about four feet thick weathers much more easily than the massive wall rock and in the zone of wave attack gives rise to overhanging cliffs. Drag folds and fracture cleavage show that the upper block moved southeast relative to the lower block. Quartz veins with some pyrite mineralization occupy gash fractures in the adjacent wallrock and in the gouge. The main reverse fault is intersected by later normal faults which dip to the northnorthwest at 65°, and on which the movement has been north side down.

Little Pacquet Reverse Fault:

On the seashore about one half mile northwest of Little Pacquet a thrust fault accompanied by a layer of gouge one to three feet thick is exposed at the base of a large cliff in the Ming's Bight formation. The strike is about northeast-southwest and the dip varies from nearly flat to nearly vertical. Tension fractures in the walls indicate that the upper side has moved toward the southeast.

Wild Bight Reverse Fault:

Snelgrove has described a reverse fault on the southwest side of Wild Bight which is about one mile southwest of Snook's Arm. It appears to strike about west-southwest, from a photograph shown by Snelgrove (1931). The upper side has moved to the southeast. Another reverse fault in the same area is the Snook's Arm fault, which is a high angle reverse fault of unknown displacement.

In a discussion of "Paleozoic Faulting in Newfoundland", Betz (1943) has attempted to line up a large number of isolated observations of faults through the west central part of Newfoundland and connect them into a system, radiating from a supposed fault which may run through the whole length of the island from the southwest coast to the north coast. Snelgrove is quoted as suggesting that the Wild Bight fault might be a continuation of Murray's line from the valley of Indian Brook. Indian Brook, however, is some thirty miles to the south. It does not seem reasonable therefore to attempt to connect any one minor reverse fault, such as the Wild Bight fault, in an area where several are know, to another fault from another area where several are known, or even to attempt to connect it with no positive reason, to a series of faults which occurs thirty miles to the southwest.

Abundant evidence along the eastern seaboard of North America suggests that the margin of the continent has been subjected to compressive stress from the southeast to the northwest or from the northwest to the southeast. In the Burlington Peninsula, and indeed in much of Newfoundland, there is no evidence to suggest that compressive stresses have come from any other direction during several orogenic episodes.

If a second series of stresses affects an area from much the same direction as an earlier stress, then the direction of relief of the later stress will tend to follow the lines of weakness set up by the earlier stress. Thus in the Burlington Peninsula the series of small granite porphyry masses near Nipper's Harbor were controlled in their intrusion by an early fault along the trace of the Stocking Harbor fault as shown by their elongation and their linear arrangement. The margins of some of these masses are sheared which shows that renewal of movement took place along the zones of earlier failure.

The fact that there have been several orogenic episodes in the history of the region (See Structural History) and no evidence of any but a northeast-southwest trend to folds further suggests that the direction of stresses was approximately the same and that the direction of relief has been the same.

Structural History

The Ordovician lava flows of the Baie Verte series lie unconformably on the folded gneisses and schists of the Ming's Bight series and the Fleur de Lys series. At several places in Newfoundland basal Cambrian rocks lie unconformably on folded and faulted Precambrian gneisses and schists, so there is little doubt that the first deformation which affected the rocks of the Burlington Peninsula took place before the beginning of the Paleozoic.

The folded and faulted Paleozoic rocks of the Burlington Peninsula are of Ordovician age. Thus from this peninsula alone the Paleozoic deformation can be dated only as late Ordovician or post-Ordovician. However, the close folding and faulting of the region are in every way comparable to those in other parts of Newfoundland, where later sediments give some evidence as to the time of folding.

The Ordovician formations in the New World Island district, about fifty miles east of the Burlington Peninsula in Notre Dame Bay, consist largely of volcanics and pyroclastics with local sedimentary formations of considerable thickness. The rocks which are known to be Silurian consist of several thousand feet of conglomerates with some interbedded fossiliferous shales. For many years it was thought that an angular unconformity separated the Ordovician and the Silurian in eastern Notre Dame Bay and it was on this evidence that the Taconic revolution was thought to have affected the rocks of the district. However, the contacts between known Ordovician and known Silurian formations have in every case been shown to be fault contacts by the writer (1946). Contacts between Silurian and Ordovician formations whose age has been established solely on the basis of lithologic similarity, in this region of complex history and complex lithology, have not been considered in this discussion.

Although the contact relations of the Ordovician and Silurian formations give no information as to deformation in late Ordovician time, the lithology of the Silurian formations suggests that northern Newfoundland underwent great uplift at that time and probably mountain building. The proven Silurian section on the easternmost end of New World Island consists of approximately 8,000 feet of conglomerates with interbedded shales which contain Silurian fossils. It is logical to suppose that to produce these great conglomerates the lands of the times must have undergone great uplift. The variety of boulders in the conglomerates suggests that the material originated in an area which was underlain by a complex of sedimentary, volcanic and plutonic rocks. This suggests that the uplift was regional rather than local.

To the west of New World Island, folded and faulted Paleozoic rocks as young as Silurian are widely exposed. Heyl (1936) in discussing the time of orogeny in the Bay of Exploits region, has suggested that the change in lithology from the volcanic-sedimentary formations of the Cambrian-Ordovician-Silurian, to the red-bed type, which was then regarded as characteristic of the Devonian, indicates late-Silurian or post Silurian orogeny.

The only positively dated Devonian rocks in Newfoundland occur on the Port-au-Port peninsula, and on the south coast.

On the Port-au-Port peninsula Schuchert and Dunbar (1936) have described gently folded fossiliferous marine sediments. On the south coast of Newfoundland Widmer (Pers. Comm. 1946) has recently mapped deformed, marine, Devonian formations. There is no evidence to show the time of deformation in either locality. The several occurences of red-bed type sediments, which have long been considered Devonian, are now known to be Carboniferous. Small patches of plant-bearing red beds at Cape Rouge, Cape Fox and on the Grey Islands were considered to be Devonian by Dawson and Murray (1880) but Johnson has recently shown that they are Carboniferous (Pers. Comm. 1946). The Spear Point formation on the west side of White Bay was formerly thought to be Devonian (Murray, 1864) but is now considered to be Mississippian (Heyl, 1937; Betz, 1941). Thus Heyl's argument for an orogeny at the end of the Silurian, based on lithologic contrast, is no longer completely valid. There is no doubt that the Silurian formations have been deformed, but they could have been folded in the Acadian or even the Appalachian revolutions as Schuchert and Dunbar (1934, p. 113) and Betz (1943, p. 687) have suggested.

The Acadian Revolution may have affected Newfoundland, although no positive evidence is at hand. Newhouse (1931, p. 399) has shown that the granites of the interior are post-Ordovician and pre-Carboniferous and possibly of Devonian age. In the White

Bay region, Heyl has shown that granitic intrusives are post-middle-Silurian and pre-Mississippian, (1937, p. 403). In the Maritimes and Gaspe, granites are considered to be Devonian at several localities (Alcock, 1935, p. 77; Bell, 1939, p. 77; Malcolm, 1929, p. 36, etc.). Thus the Acadian Revolution probably affected the area, though there is no evidence more positive than approximately dated granitic intrusions.

Several areas of Carboniferous rocks in Newfoundland which have been deformed, suggest that Newfoundland was affected by the Appalachian revolution. A strip of Carboniferous sediments along the coast of Bay St. George on the west coast of Newfoundland is folded and faulted, as shown by the studies of Hayes and Johnson (1938). It has been suggested that the deformation of the sediments was the result of renewal of movement along an ancient thrust fault to the east. To the writer, deformation on a broader scale is indicated, since the folding and faulting affect Carboniferous formations along this coastal strip, which is at least fifty miles long and as much as six miles wide. In the White Bay district the Spear Point formation of Mississippian age is highly deformed, (Heyl, 1937, p. 21). The basins of Carboniferous sediments in the Deer Lake region of Newfoundland are folded and faulted (Johnson, Pers. Comm., 1946). Thus there is no doubt that the Appalachian orogeny affected Newfoundland.

The large intrusive masses in the Burlington Peninsula have been affected by the deformations. Faults as much as four miles long occur in the Cape Brulé granite and the Burlington granite. The Dunamagon granite is criss-crossed by faults. The age of the intrusive rocks can be stated with certainty to be post-Ordovician, but as shown above by analogy with similar regions they are more probably of late Paleozoic age than of early Paleozoic age, so the deformation was probably also late Paleozoic.

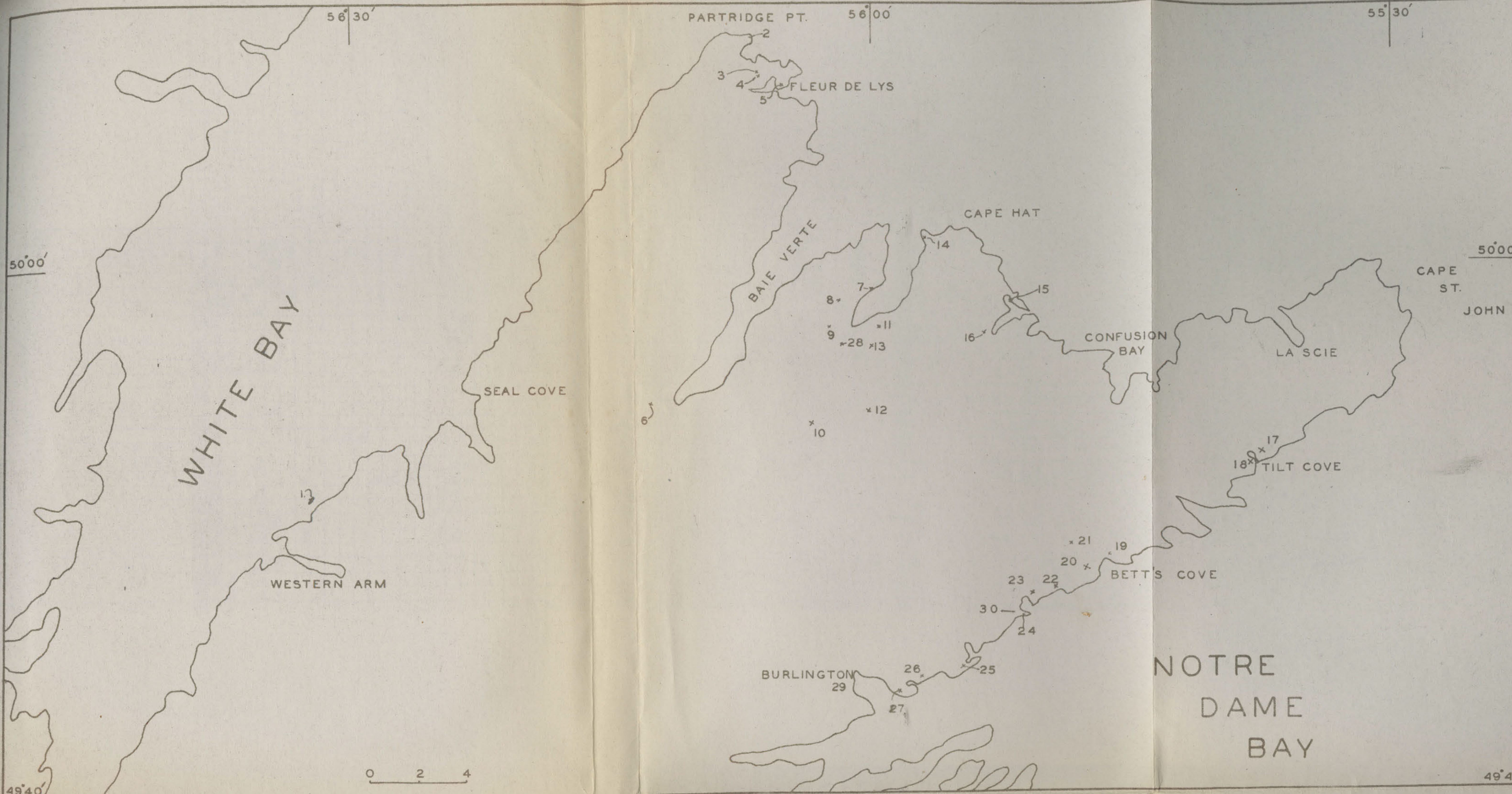
In summary, the Burlington Peninsula was probably affected by the following periods of mountain building:

(1) Precambrian

(2) Post-Ordovician, perhaps mid- or late-Silurian.

(3) Possibly the Acadian revolution.

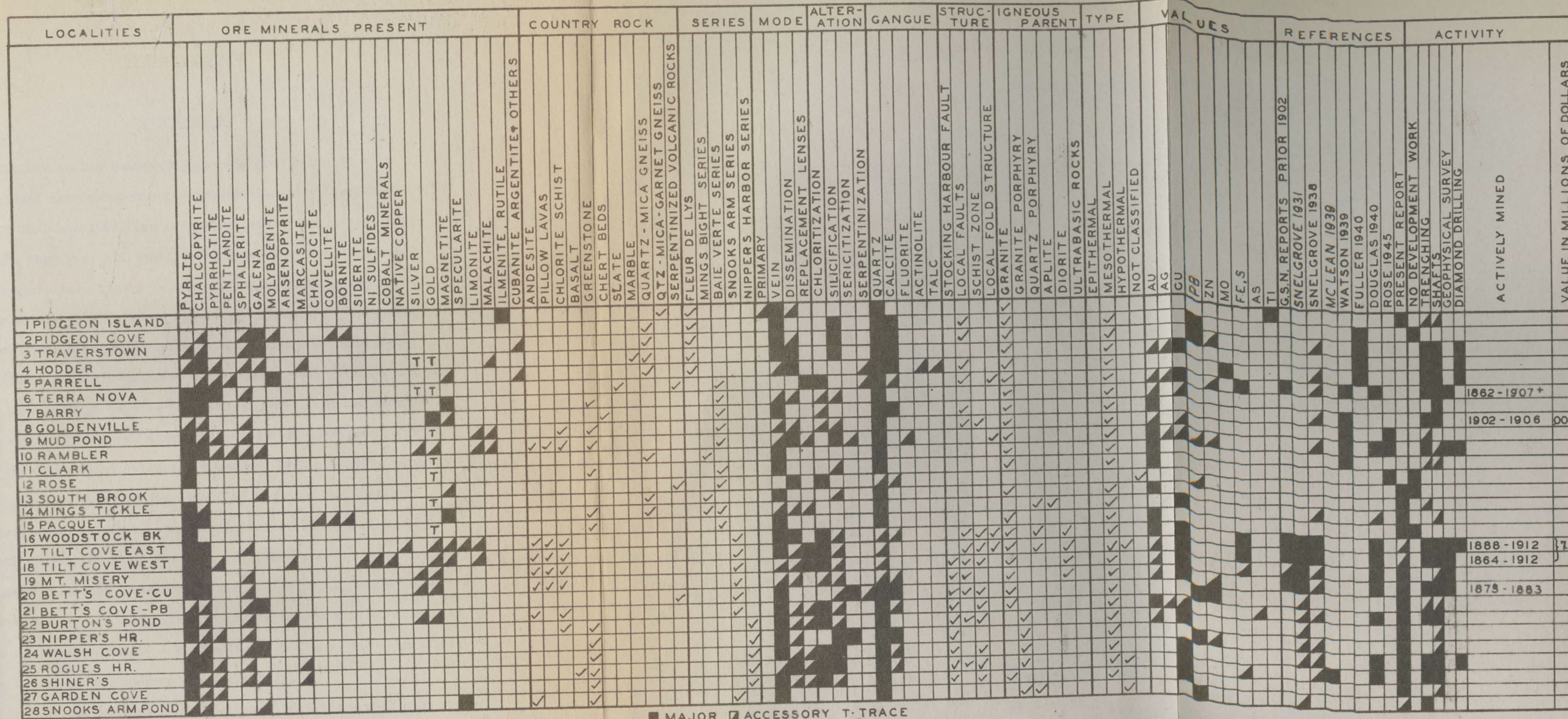
(4) The Appalachian revolution.



LOCATION OF PROSPECTS ON THE BURLINGTON PENINSULA

1. PIDGEON ISLAND
2. PIDGEON COVE
3. TRAVERSTOWN
4. HODDER
5. PARRELL
6. TERRA NOVA
7. BARRY
8. GOLDENVILLE
9. MUD POND
10. RAMBLER
11. CLARK
12. ROSE
13. SOUTH BROOK
14. MINGS TICKLE
15. PACQUET
16. WOODSTOCK BROOK
17. TILT COVE EAST
18. TILT COVE WEST
19. MOUNT MISERY
20. BETTS COVE CU
21. BETTS COVE PB-ZN
22. BURTON'S POND
23. NIPPERS HR
24. WALSH COVE
25. ROGUE'S HARBOUR
26. SHINERS
27. GARDEN COVE
28. TRIMM'S BROOK
29. BURLINGTON

PLATE 12



MINES AND PROSPECTS
OF THE
BURLINGTON PENINSULA

PLATE 13.

ECONOMIC GEOLOGY

Introduction

The Burlington Peninsula has long been known as a mineralized area favorable for prospecting. In the period between 1870 and 1910 four successful mines flourished, and although they were all small operations by modern standards, they contributed largely to making Newfoundland an important copper producing country of the time. The active mines were the Tilt Cove West Mine (1864 to 1912), the Tilt Cove East Mine (1888 to 1912), the Bett's Cove Mine (1875 to 1883) and the Terra Nova Mine at Baie Verte (1862 to 1907). In addition to these successful copper mining operations an unsuccessful gold mine was operated at Goldenville between 1902 and 1906. Large sums have been spent in the last five years on the Rambler prospect which is southeast of Baie Verte. Trenching, stripping, and the sinking of shallow shafts have been done on most of the prospects which are shown on the map of locations, Plate 12. Today, however, the Burlington Peninsula is a region of abandoned mines and disappointment - shafts are filled with water and slide-rock, buildings and wharves are falling in.

Each of the abandoned mines stopped operations when high grade ore was mined out. Poor mining methods caused cave-ins at Bett's Cove and Tilt Cove, which hastened the end. The methods of mining, transportation and extraction employed at the time of operation of these mines necessitated selective mining and hand-picking of the high-grade ore. If modern flotation methods of ore separation had been available the productivity of each of the mines would have been greatly increased. For example, at the Tilt Cove West Mine about 100,000 tons of 2% copper ore lie discarded on the dumps, 250,000 tons of 2% ore was left untouched in the old workings above sea-level, and an unknown amount of 2%+ ore remains unmined below sea-level (Williams, 1940, p. 117).

General Description

The copper deposits of the region are mesothermal replacement deposits in greenstones which have come from the alteration of lava flows of Ordovician age. Mineralization has almost invariably taken place along shear zones where chlorite schist is strongly developed. Pyrite with chalcopyrite and lesser amounts of other sulphides occur as veins, irregular replacement lenses and as disseminations in the sheared greenstones, Quartz and carbonates are usually present in small quantities as gangue minerals. Chloritization and silicification commonly accompany the copper mineralization.

Snelgrove has stressed the importance of dioritic intrusive rocks in the mineralization in the Bett's Cove - Tilt Cove area. In a classification of the mineral deposits of the area he has grouped the deposits 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". On a later page he states 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" (Snelgrove, 1931, pp. 36 - 39). In a later publication Snelgrove states, "a genetic relationship between the diorites and the ore bodies is ... indicated.", (1938, p. 53). The present writer suggests that the copper mineralization has come from emanations of the abundant granitic rocks of the region.

Plate 13, a plot of the characteristics of the mineral deposits of the Burlington Peninsula, shows that in the great majority of the copper deposits the most likely igneous sources of the ore-forming solutions are the granitic intrusives. Copper mineralization was observed in one place near Burlington in the granite itself. The granites and granodiorites of the area occur within a surface distance of 3/4 of a mile or less of every known occurrence of copper mineralization. Dioritic rocks and gabbroic rocks on the other hand are restricted to two small areas, near Bett's Cove and near Tilt Cove.

The structural setting of the copper deposits of the Notre Dame Bay coast of the Burlington Peninsula has been clarified by the discovery that every prospect from Burlington to Snook's Arm lies on the Stocking Harbor fault or a subsidiary shear zone. Thus it is apparent that a major through-going fault with its subsidiary shear zones has been particularly influential in localizing ore deposition. This in turn suggests that the diorites have not played a significant role in ore deposition except possibly to influence the position of local minor shear zones at the two localities mentioned above.

Wallrock Alteration:

Plate 13 shows plainly that the most common type of wall-rock alteration is chloritization. It is best developed in pillow lavas and along shear zones where abundant openings would allow access for hydrothermal solutions. Every copper prospect on the 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 Bett's Cove - Tilt Cove region where dioritic rocks are common, stresses their importance in bringing about chloritization along with mineralization (See above). Because chloritization occurs at many places where diorites are absent and because granite bodies are present throughout the district it appears more probable to the writer that chloritization was accomplished by emanations from granitic magmas.

Silicification has affected the country-rock at many places. At the 'Gold Pit' at the Rambler prospect, introduced quartz makes up over 75% of the rock. Mineralization at this prospect consists largely of pyrite, with values in gold. Other silicified zones which carry pyrite occur along the shores of Confusion Bay near Brent Cove.

Mild sericitization of the wallrock has accompanied the lead-zinc mineralization at Bett's Cove and Walsh Cove. Sericitization is marked at several places on the Rambler property. The specularite-bearing quartz veins at the north end of Snook's Arm Western Pond are accompanied by some silicification and sericitization.

Gangue Minerals:

Gangue minerels are prominent at very few of the copper prospects of the district. At Rogue's Harbor the chalcopyrite is associated with a quartz vein which is from ten to thirty feet wide. At Burton's Pond small quartz veins which usually contain some calcite occur with the chalcopyrite and pyrite. In the massive sulphide replacement deposits such as Tilt Cove, Bett's Cove and the Terra Nova Mine at Baie Verte, late-stage quartz veins with accessory carbonate, which are rarely over one inch wide, are common.

In the lead-zinc deposits at Bett's 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 makes up more than half the vein material at Bett's Cove. Fluorite was observed at one place at the Rambler.

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 on Plate 13.

Descriptions of Mines and Prospects

Rogue's Harbor Prospect:

The Rogue's Harbor prospect was first opened in 1899 according to Howley (1909, p. 424). Diamond drilling and mapping were carried out by the expedition under Douglas (1940). The writer visited the property in 1945.

The mineralization occurs in a quartz vein which varies from ten to thirty feet thick and which has been traced along the strike for about 2700 feet. The vein cuts amphibolites and altered volcanics of the Nipper's Harbor series. It trends southwest from the head of the western arm of Rogue's Harbor for approximately 1000 feet, then swings southward for about 1700 feet. It dips at a high angle to the eastward. For the first 900 feet the vein is underneath the swamp at the head of the harbor, and for the next 400 feet it underlies the debris along the bottom and shoulder of the cliff. Diamond drilling by Douglas shows that the mineralization is not persistent in depth. The ore minerals are chalcopyrite, pyrite, pyrrhotite and a little galena. Assays by Douglas (1940, p. 97) show traces of gold, and copper as much as 1.24% in channel samples, but the average is considerably less.

The country rocks are intruded by a series of small plugs of quartz porphyry of the kind described as the second type of the satellite masses of the Cape Brulé granite. Some chilling on the edges of the masses is evident. Silicified zones occur at several places, in the surrounding amphibolites.

The country rock near the vein shows slickensides and shearing. The main Stocking Harbor fault passes through the swamp in which the northeastern end of the vein is located. The vein is partly in the main shear zone of the Stocking Harbor fault and partly in a complementary shear zone. Other shear zones and lineaments which were detected on aerial photographs belong to the same fault system. Some of the movement on the Stocking Harbor fault is later than the intrusion of the granite porphyry, since the small masses immediately adjacent to the fault have been sheared. In the deposit itself the sulphides are offset by tiny faults.

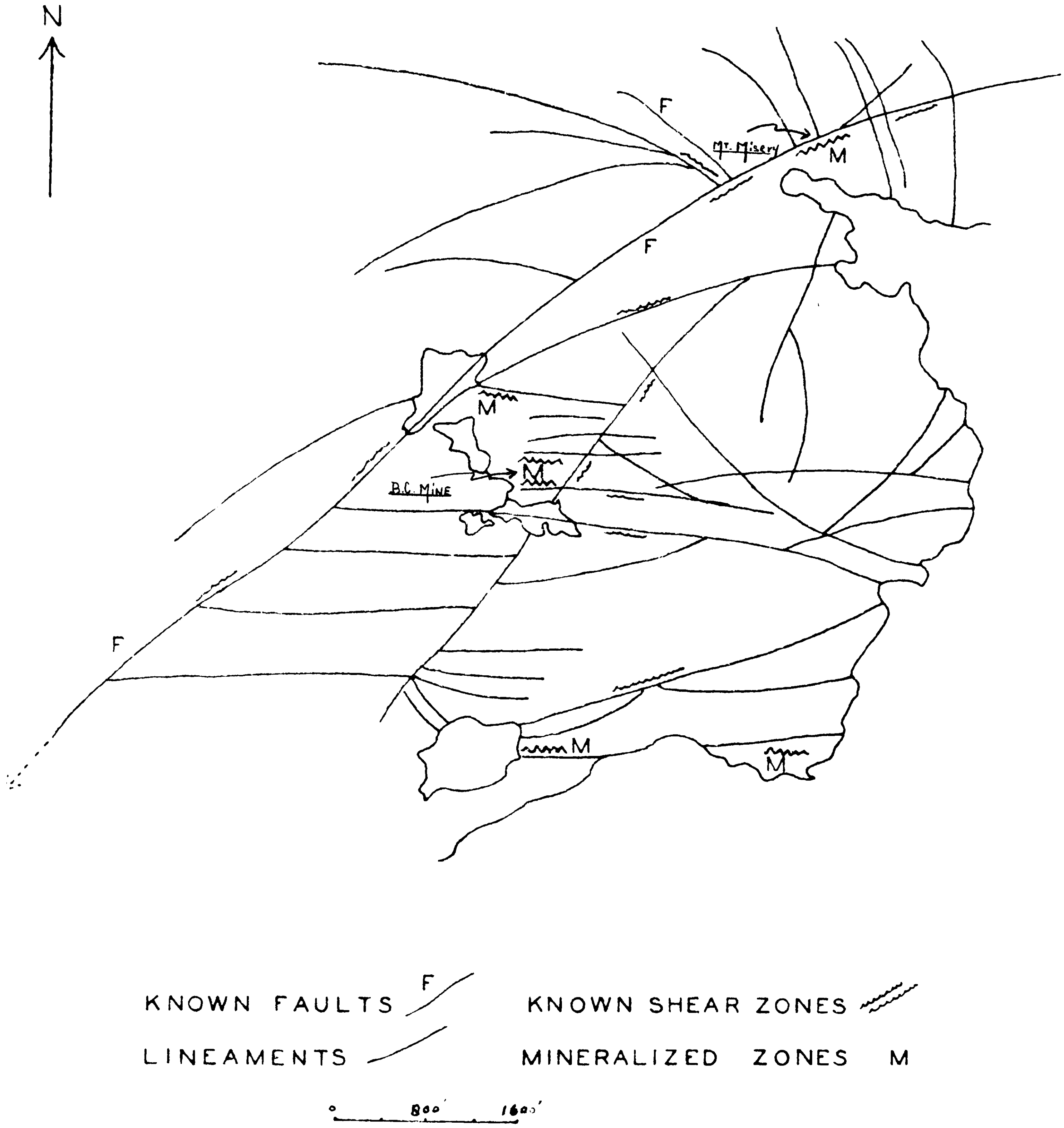
Bett's Cove Mine:

This abandoned mine was visited by the writer in the summer of 1945, and again in 1946. Reconnaissance of the area as well as detailed mapping in the immediate vicinity of the mine were carried out. The earlier reports on the occurrence have been mentioned under "Historical Résumé". The latest and most authoritative descriptions are those of Snelgrove (1931, p. 39) and Douglas (1940, p. 22).

The country rocks are pillow lavas, massive andesites, and pyroclastics of the Snook's Arm series. The formations strike northnortheast and the dip is nearly vertical. The volcanic rocks are intruded by a series of small bosses of diorite and quartz diorite. One small mass of olivine gabbro outcrops about 2800 feet south of the mine. Two thousand feet northeast of the mine is the margin of a mass of serpentinized ultrabasic intrusive rocks. Various dikes of lamprophyre, olivine diabase and pyroxenite occur within half a mile of the mine. An offshoot of the main Cape Brulé granite mass is exposed one mile northeast of the mine.

The oreshoots occur in strongly chloritized shear zones in the pillow lavas. Pyrite, chalcopyrite and sphalerite which were introduced in that order replace the chlorite schist. Mineralization has heretofore been thought to have been genetically related to adjacent masses of diorite since parts of the diorite are slightly mineralized (See p. 236). As stated above the writer considers that the ore-bearing solutions probably came from the granite.

Rove noted that the main ore-body lies in a block which is bounded by discontinuous shear zones trending east-west and north-



BETT'S COVE MINE AREA

northeast. He considered that the shear zones are small local breaks, which were probably related to "adjustments between the diorite masses rather than some strong through-going regional structure. Consequently it focuses attention on the immediate vicinity of the diorites for similar structural conditions" (1940, p. 26).

Not heretofore recognized in the area is the extension of the Stocking Harbor fault. According to the present writer's studies, this fault passes through a small pond within 1500 feet of the old Bett's Cove Mine. The accompanying sketch map Plate 14 shows the lineaments of the area (i.e. the major topographic breaks taken from aerial photographs) and in addition the known shear zones. One set of "breaks" crosses the district from east to west. Another trends generally parallel to the extension of the Stocking Harbor fault in a northeasterly direction. These two sets are particularly prominent in the immediate neighbourhood of the mine. The directions of the known shear zones of the region coincide perfectly with the two sets mentioned above, establishing beyond reasonable doubt that these "breaks" are structural breaks in the rocks of the region.

There is little direct evidence near the Bett's Cove mine itself of the major Stocking Harbor fault except the great topographic break that continues to the southwest for some twenty miles. However, at the north side of the head of Bett's Cove a strong shear zone lies exactly on the topographic break which marks 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 passing over relief of more than four hundred feet. This is particularly well seen in the trace of the main Stocking Harbor break which rises from sea level at Bett's Cove to the adjacent hills without changing direction.

The relation of the Bett's Cove mineralization to fractures which are related to a major structural break throws new light on the mineralization of the region. Rove's theory that the mineralization is associated with shears developed very locally by adjustment between the diorite masses, is no longer tenable without modification, since it seems apparent that the east-west shear zones are related to the main Stocking Harbor fault, and the mineralization is situated at the junction of this set of fractures with another set which parallels the main break.

Mount Misery:

Close to the northeasternmost end of the known trace of the Stocking Harbor fault at the head of Bett's Cove a series of parallel shear zones occurs in chloritized pillow lavas of the Snook's Arm series. The schistosity in the lavas trends about northeast and the dip is at a high angle to the southeast. Little of the bedrock in the mineralized zone is now exposed. In the dumps however, nodules and irregular lenses of pyrite and chalcopyrite, with some pyrrhotite indicate that the mineralization is in the form of irregular replacements of the chlorite schists in the shear zones. A geophysical survey carried on by the Douglas expedition indicated that there is little prospect of finding a large body of ore in this prospect (1940, p. 64).

The mineralization lies directly in the main Stocking Harbor break. Its presence at a distance from the diorite masses is further evidence that the mineralization in the Bett's Cove region is not necessarily related to shear zones developed locally by adjustment between the small diorite masses, but that it is more likely related to the major fault system. Similar mineralized shear zones occur at the Lowlands, about one mile south of Bett's Cove mine. They are apparently not related to the diorite masses.

Bett's Cove Lead-zinc Prospect:

The zone of mineralization outcrops on a hillside on the west side of a small swamp about 6500 feet due west from the head of Bett's Cove. The mineralization occurs in a lobe of altered volcanic rocks, of the Snook's Arm series, which is bounded on the west by a tongue of the Cape Brulé granite and on the east by the altered ultrabasic rocks of the serpentine belt. The volcanic rocks were originally of andesitic composition but have been severely altered by chloritization, serpentinization and steatitization. Boundaries between different facies of the altered rocks are very difficult to trace because of the irregularity and the overlapping of the different types of alteration.

Development work consisted of about three hundred feet of trenching and stripping, and the sinking of a shaft about 35 feet deep. The rocks which are exposed at the shaft and by the trenching are sheared and broken along a vertical zone which trends about east-west. Slickensides, and crumpled chlorite and serpentine schists are common. A fissure-type vein, which is from four to six inches wide, lies in the shear zone, and is approximately parallel to the foliation of the schists. Pyrite and chalcopyrite make up most of the central part of the vein, with more abundant sphalerite and galena on the edges. Quartz and calcite are the gangue minerals and may make up as much as 50 percent of the vein material. Polished sections indicate that the order of mineralization was pyrite, chalcopyrite, sphalerite, galena. A similar vein about three inches wide, which dips to the northeast at about forty degrees occurs near the level of the water in the shaft. Scattered pyrite stringers cut the volcanic rocks in the northeastern wall of the trench which leads southeastward from the shaft. There is no indication of further mineralization in the surrounding region.

Little wallrock alteration accompanied the mineralization. Sericitization is prominent along some parts of the vein, but it has not affected the wallrock anywhere for more than a few inches beyond the veins.

On the dumps there is nothing to indicate that bigger veins or more abundant mineralization were encountered during development. The prospect is not encouraging. It does indicate, however, that copper-lead-zinc mineralization accompanied the granitic intrusions of the district.

Burton's Pond Prospect:

This prospect occurs about 100 yards northeast of the outlet of Burton's Pond, which is between Nipper's Harbor and Bett's Cove. There are four shallow shafts and considerable trenching and stripping.

Mineralization occurs in the altered volcanics of the Nipper's Harbor series. The edge of the serpentinized ultrabasic rocks is less than three hundred feet to the west. The volcanics have been cut by a fault which strikes at about N30°E and dips from vertical to 65° to the west. Some silicification and abundant chloritization have affected the wallrocks adjacent to the fault and the rocks in the sheared and faulted zone which is as much as eight feet wide. The nature of the movement along the fault is not accurately known. However, slickensides which were observed nearly everywhere along the walls of the fault plunge at 12° to the southwest.

Mineralization consists of disseminated pyrite with some chalcopyrite and sphalerite in irregular veins and replacements of the chloritized greenstones, and associated with veins of quartz and carbonate which are rarely greater than one inch in thickness. The lenses of sulphides are as much as three inches thick and one foot long. A grab sample which was taken by Rove (1940, p. 33) showed that gold, silver and some arsenic accompany the copper mineralization. The dump contains the best ore visible and little more than disseminated ore in greenstones with thin quartz veins remains in the wallrocks of the shallow shafts and adit.

This prospect is located on a shear zone subsidiary to the main Stocking Harbor fault which crosses the southwestern end of Burton's Pond about 500 feet to the west.

Shiner's Prospect:

This prospect lies about 600 feet northwest of the edge of the cliffs at the western end of Stocking Harbor. Development work includes half a dozen shafts, as much as forty feet deep which are now filled in and flooded, and a considerable amount of stripping and trenching.

The mineralization occurs in rocks of the Nipper's Harbor series that have been intimately intruded by offshoots of the Burlington granite. Several small, irregular granite dikes occur in the immediate neighborhood of the prospect. Mineralization has taken place along an irregular set of parallel shear zones which trend at approximately 135°. The mineralized zone lies in a block which is between the main Stocking Harbor fault and a parallel break, which is a little less than one mile to the northwest. The mineral-bearing shear zones are apparently complementary to the major faults.

Wallrock alteration is not strong, but chloritization and silicification are present in some places. Mineralization consists of irregular veins and lenses of pyrite, chalcopyrite and pyrrhotite with small quantities of sphalerite and galena in the chloritized schist. Small amounts of quartz and calcite are the only gangue minerals.

Jenning's or Garden Cove Prospect:

This small prospect was trenched and a shaft sunk about forty years ago according to local residents. It occurs about a quarter of a mile along a trail leading from Garden Cove to Smith's Harbor on the northeast side of the mouth of Burlington Harbor.

The country rocks are sheared volcanics of the Nipper's Harbor series, which are in the amphibolite stage of metamorphism. Abundant granitic dikes and offshoots of the Burlington granite occur nearby in the greenstones. The rocks in the area of mineralization are covered with forest litter. The shaft is not more than twenty feet deep and is now largely filled. The dump is made up of slickensided and sheared chloritized greenstone. Some silicification is evident. Mineralization is almost entirely pyrite, with some small veins of later chalcopyrite and accessory pyrrhotite. It is not promising as a prospect.

Pacquet Copper Prospects:

Copper mineralization occurs at several places at Pacquet Harbor. The most important is situated at high tide level on the east side of the harbor, just below the southernmost houses of the village. At the back of a natural recess in the cliffs an inclined shaft about thirty feet deep was opened up about forty years ago. The shaft is now completely filled with wave-washed shore debris. Mineralization consists of pyrite, chalcopyrite and magnetite, in pockets and lenses as much as one inch thick and six inches long, which replace the country rock over an irregular zone about twenty-five feet long and six feet thick at its widest part.

The country rock is chlorite and hornblende schist which is thought to belong to the Baie Verte series, although the prospect is near the boundary between the Baie Verte series and the Ming's Bight series. The local strike is about north-south and the dips average about 30 degrees to the east (the mineralized zone is magnetite-rich and compass bearing are not dependable). The schists have been invaded by aplite dikes and are cut by quartz veins and calcite veins. The aplite occurs as irregular sills and dikes,up to eight feet thick,which are foliated parallel to the 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 six inches thick, carry chalcopyrite and cut the aplites. The calcite stringers are up to half an inch thick and are the youngest veins.

On the south side of the harbor, between Devil's Cove and

Sackery's Cove, 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 dikes, which are strongly foliated parallel to their walls, carry numerous flecks of pyrite and chalcopyrite. The constant association of the sulphide-bearing aplites with the copper mineralization in Pacquet Harbor suggests that they are related in origin. The Dùnamagon granite which is exposed along the northwest shore of the harbor is cut by numerous fine-grained aplite dikes which were presumably derived from the main granite mass. The Cape Brulé granite, which is exposed about a thousand feet to the south of the mineralized zones, has no aplites associated with it. The aplites were thus probably 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.

Nipper's Harbor:

This prospect is situated in the hills about one quarter of one mile north of Nipper's Harbor. The country rock is a dark chloritized lava of the Nipper's Harbor series. The mineralized zone occurs along a well-marked depression. Together with the abundant occurrence of slickensided chlorite schist it indicates that the prospect is located along a shear zone. Its proximity to the main Stocking Harbor fault and its parallelism with other faults which are known to be related to the main break suggests that it is a subsidiary of the main fault. Mineralization consists of replacement of the chloritized lavas by pyrite, chalcopyrite, and some pyrrhotite. Small quartz veins are the only gangue. Development work includes one shaft about twenty feet deep and a considerable amount of trenching. No commercial quantities of ore are in sight.

Walsh Cove:

At Walsh Cove, just south of Nipper's Harbor, pyrite-chalcopyrite-galena mineralization occurs in the greenstones of the Nipper's Harbor series. The mineralized area is now completely covered with beach debris. A flooded and caved shaft of unknown depth is located just above high-water mark near the east end of the beach.

Several dikes of quartz-orthoclase porphyry, which are related to the main mass of the porphyry about two hundred feet to the north, intrude the greenstones, and are probably responsible for the mineralization. Material from the dump indicates that the pyrite, chalcopyrite and galena occur in narrow quartz veins less than one inch wide, as thin lenses replacing the chlorite schist and as disseminations in the wallrock. Nowhere are there indications of a large deposit.

Woodstock Brook:

Small quartz veins which contain pyrite occur in Baie Verte greenstones just west of Woodstock in the bed of the small brook which flows along the Ming's Bight - Pacquet trail. Traces of chalcopyrite are found in the veins. At no place is the concentration sufficient to warrant development work. However, the occurrence of mineralized quartz veins makes the district favorable for prospecting.

South Brook:

Mineralization was observed in the west bank of South Brook, just south of the outcrop of the Ming's Bight series. An irregularly defined zone of quartz and carbonate which contains a little galena and a few specks of magnetite occurs in a remnant of the Ming's Bight series.

Ming's Tickle:

A series of small veins and irregular masses of quartz averaging about 18 inches in aggregate thickness and about 50 feet in length outcrops in the Ming's Bight series just north of the fishing shacks at Ming's Tickle. Pyrite and chalcopyrite occur in the edges of the quartz veins and in the adjacent wall-rock. It is not considered to be of economic importance.

Snook's Arm Ponds:

Specularite occurs at several places in the Snook's Arm Pond - Red Cliff Pond district. In each example the quartz veins occur in altered lavas or pyroclastics of the Snook's Arm series except on the northern end of Snook's Arm Western Pond where they are in a tongue of Cape St. John series. Pyrite, chalcopyrite and small pockets of galena commonly accompany the specularite. The veins occur in close proximity to the main outcrop of the Cape Brulé granite and were presumably derived from it.

Tilt Cove:

The writer visited Tilt Cove in the summer of 1945 and has only to report that since the latest recorded visit (Douglas, 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 complete town which once flourished on the shore of Winsor Lake have been demolished by salvagers. The wharf has fallen into complete decay and any contemplated salvage operations on the ore dumps of Tilt Cove would have to start completely anew.

Terra Nova:

Watson (1939) has described in detail the copper-bearing pyrite ores of the Terra Nova Mine at Baie Verte. In this report no further work was done on the deposit. The stockpile of ore, estimated as 20,000 tons by Rove (1940, p. 18) and commonly listed as an asset to future mining in the region burst into flame 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 pile of ore was nearly unapproachable due to the great heat and the sulfurous fumes.

Pigeon Island:

At Pigeon Island on the west coast of the Burlington Peninsula granite pegmatites intrude quartz-mica-garnet gneisses and schists of the Fleur de Lys series. Rutile and ilmenite occur in the pegmatites themselves, in subsidiary quartz veins and disseminated in the schists. In the same region rutile appears to be a primary detrital mineral of the sediments which gave rise to the gneisses and schists. Stripping and trenching on Pigeon Island on a small scale have failed to reveal any deposits of commercial importance.

Future Prospecting

From Plate 13 it is evident that prospecting for copper in the Burlington Peninsula should be correlated with:

(1) Areas which are underlain by greenstones

(2) Shear zones which show strong chloritization

(3) Local variations in structure such as prominent drag folds, abundant small intrusive masses or closely spaced shear zones.

(4) The contacts of the main granite masses.

The Rambler type of gold-copper mineralization can be related to the same type of structures but, instead of chloritization, zones which show silicification and sericitization are characteristic.

Several areas in the Burlington Peninsula offer prospecting possibilities. The new road being constructed by the Bowater Company between Baie Verte and Howley is opening up a large region which is underlain by Baie Verte greenstones which are intruded by numerous offshoots of the Burlington granite. The Rambler type of silicification and sericitization was noted in sporadic outcrops in the heavily wooded region about one mile north of Side Pond. The finding of glacial boulders of quartz heavily mineralized with chalcopyrite and molybdenite at Gull Pond, south of the Rambler, together with the clearly established northward movement of the last glaciation shows that mineralization occurs along the margins of the granodiorite to the south.

The coastal belt of the Burlington Peninsula has already been thoroughly travelled so offers little hope to the prospector. The interior of the peninsula presents considerable difficulty to thorough prospecting due to a heavy forest cover and widespread bogs. On a trans-peninsular traverse from Western Arm, White Bay, to Middle Arm, Green Bay, the writer found that bedrock, most of which occurs in the stream-beds, is exposed over less than one percent of the area. Initial prospecting therefore should consist of the traversing of the streams, with careful panning of the gravels and sands, traversing of the rock exposures which are visible on aerial photographs (already available) and then careful search along the boundaries of the intrusive masses.

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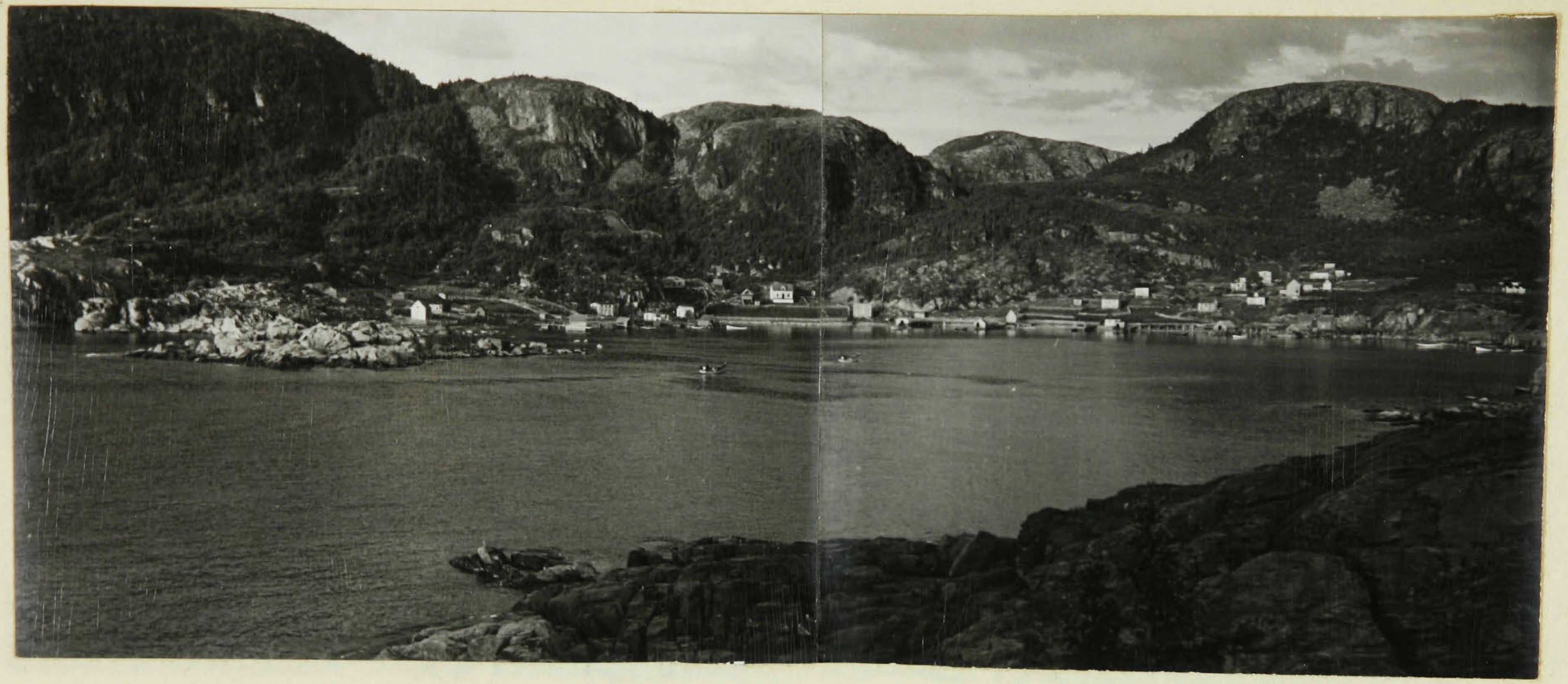


Fig. 1. The fishing village of Brent Cove, showing the tiny fields which are the only agricultural land available in the district. Note the several terraces and the rugged topography which is characteristic of much of the coastal region of the Burlington Peninsula.

Fig. 2. Terraces, east of the mouth of South Brook, Ming's Bight. The cabin and the fences are on one level, which extends into the woods on the left, and another level may be seen in the upper right hand corner.

Fig. 3. The flat skyline of the Cape St. John peninsula as seen from east of the mouth of La Scie Harbor. The flat surface is part of the Atlantic Upland province,(Snelgrove,1929), and is correlated with the Lawrence peneplane of Twenhofel and MacClintock,(1940).

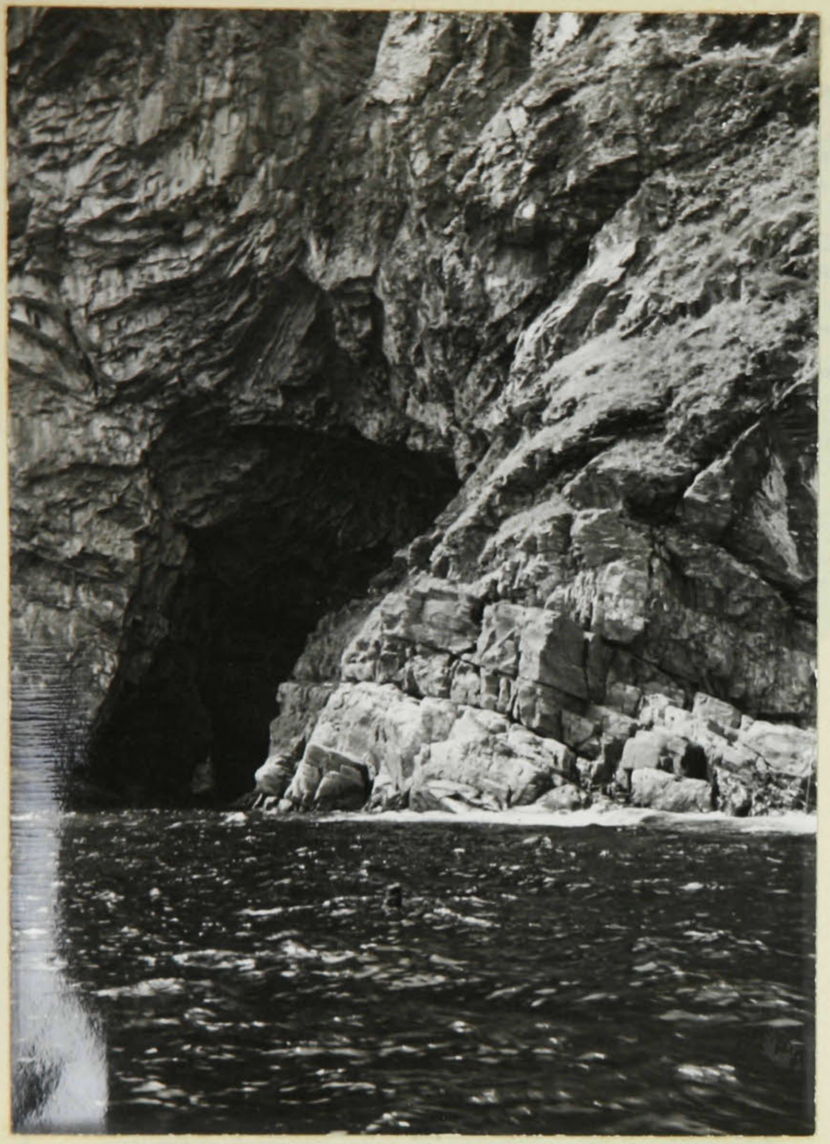


Fig. 4. Sea-cave developed along a fault zone in Baie Verte volcanic rocks. Faulted pieces of granite dike occur near top and near water level. East side of Cape Cagnet.

Fig. 5. Natural arch cut into massive lava flows of Cape St. John series. Cape Cove, near the tip of Cape St. John.

Fig. 6. Stack about one hundred feet high, composed of massive Baie Verte greenstones, between Brent Cove and La Scie.

Fig. 7. Irregular wave-cut bench in greenstones of the Baie Verte series at Pacquet. Ordinary high tides and storm waves cover this bench completely. Active erosion of the cliffs is shown by the caves and absence of talus.

Figs. 8, 9, 10. A series of photographs, taken at intervals of ten feet along a line from the base of a talus slope across a sloping beach to the edge of the water, to illustrate the evolution of coarse, angular talus boulders to fine, rounded, beach pebbles. Red Point Cove, La Scie. For completion of series see Figs. 11, 12, 13.

Figs. 11, 12, 13. Completion of a series of photographs to show progressive decrease in size and angularity between talus boulders and beach pebbles. See Figs. 8, 9, and 10. The beach at Fig. 13 is covered by very high tides and at all three places by storm waves. Note the disappearance of lichens between Fig. 10 and Fig. 11.

Fig. 14. Marine pothole, which has been eroded by wave-action into gneisses of the Ming's Bight series. One half mile west of Cape Hat.

Fig. 15. Irregular quartz veinlets, which pinch and swell irrespective of the position of crenulations, in gneisses of the Ming's Bight series.

Fig. 16. Crenulated gneisses of the Ming's Bight series, exposed on the eastern shore of Ming's Bight.

Fig. 17. Quartz vein in Ming's Bight series in part truncating and in part following the foliation of the gneisses.

Fig. 18. Crumpled chlorite-rich gneisses and schists of the Ming's Bight series near the contact with the serpentinized ultrabasic mass, east side of Ming's Bight.

Fig. 19. A typical, jagged, coastal exposure of the Ming's Bight gneisses and schists. In this example they are on the west limb of the anticline which parallels the eastern shore of Ming's Bight. Two icebergs are visible on the horizon.

Fig. 20. A much-altered pyroclastic rock of the Baie Verte series which shows elongated fragments lying parallel to the bedding. Woodstock - Beaver Pond road.

Fig. 21. Baie Verte greenstones in which the regional foliation, which is parallel to the bedding, has been folded with the development of axial plane cleavage. On the shore, south of Harbor Round.

Fig. 22. Chloritized and sheared pillow lavas of a type common in the Snook's Arm series. Note the massive pillows and the interstitial chlorite schist.

Fig. 23. Pegmatite dike which intrudes gneisses of the Ming's Bight series, on the eastern side of Handy Harbor.

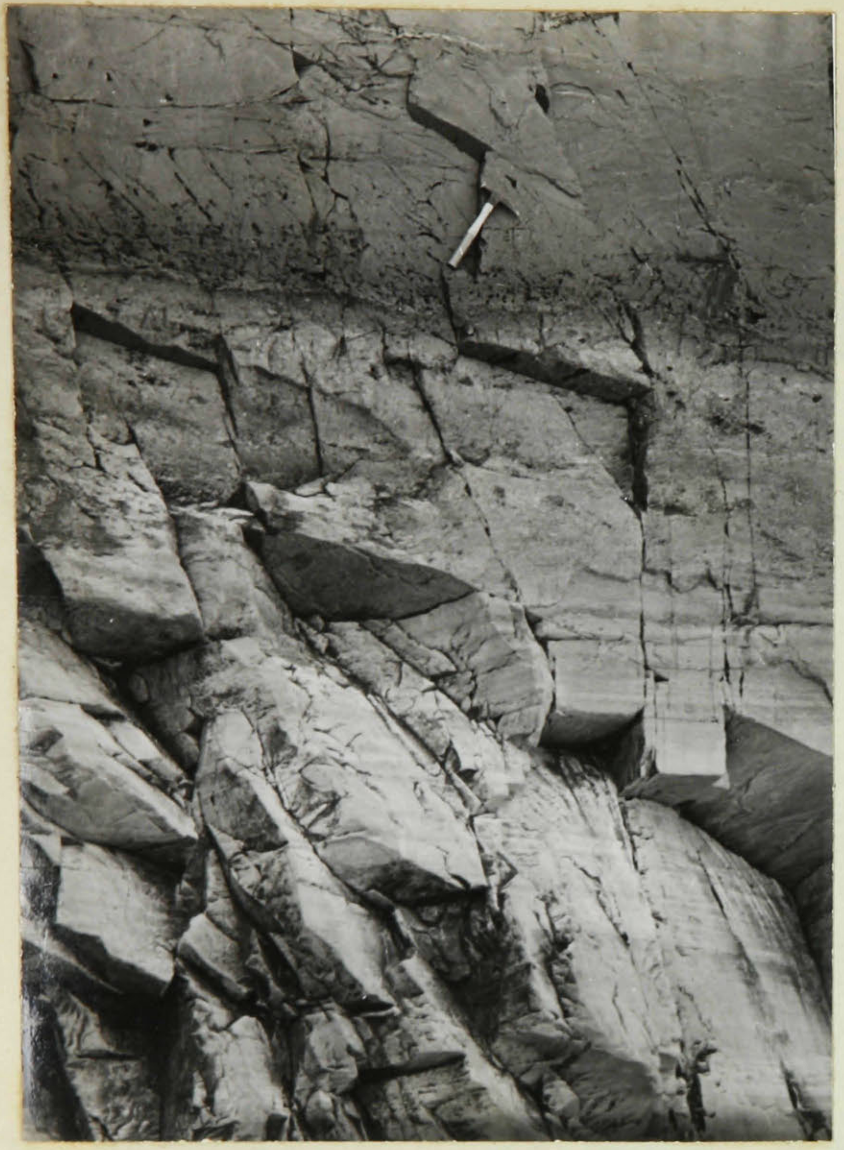


Fig. 24. Contact between the bottom of a massive andesite flow and the top of a finely-banded, tuffaceous sediment of the Cape St. John series.

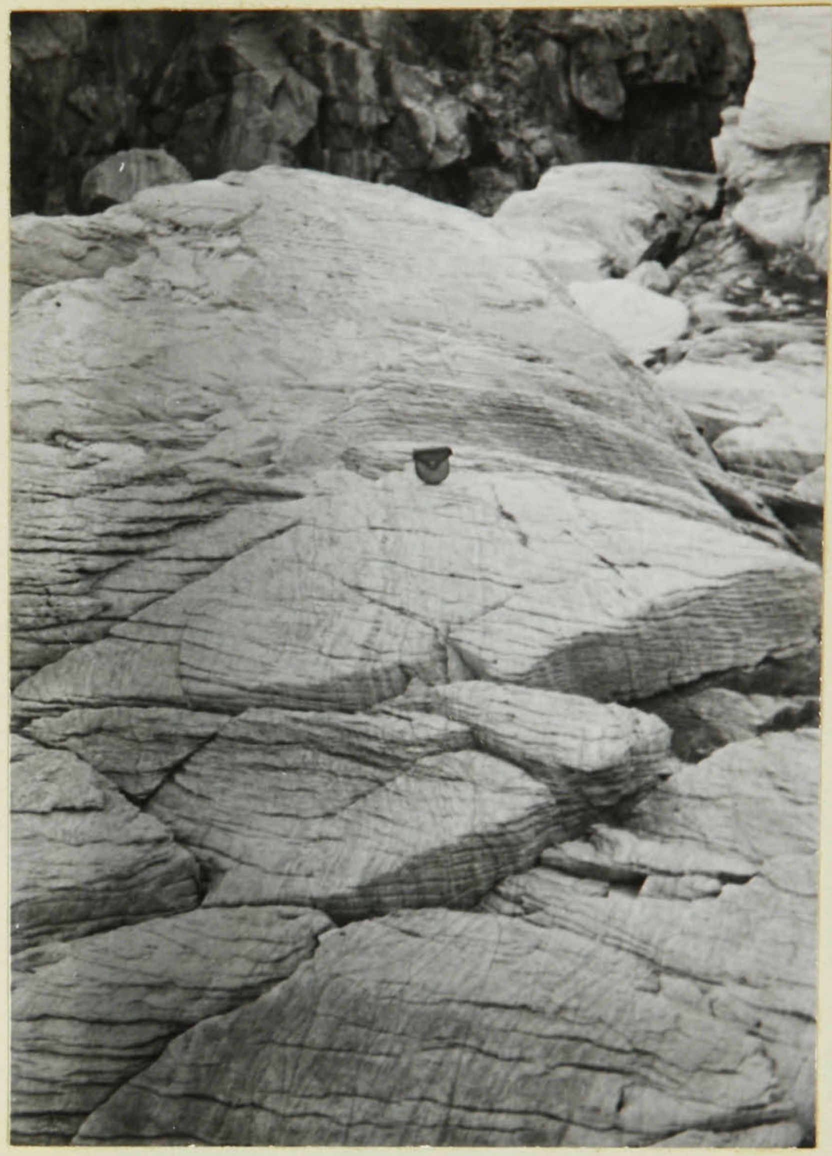


Fig. 25. Platy jointing which is approximately at right angles to the gneissic banding in the sheared marginal facies of the Cape Brulé granite and nearly parallel to the surface of the outcrop. Near Harbor Round.

Fig. 26. Closely-spaced, platy jointing which in the coastal exposures of the marginal facies of the Cape Brulé granite is commonly parallel to the surface. South of Harbor Round, east side of Confusion Bay.

Fig. 27. Rhombohedral jointing in the marginal facies of the Cape Brulé granite. The steeply inclined joint set parallels the foliation.

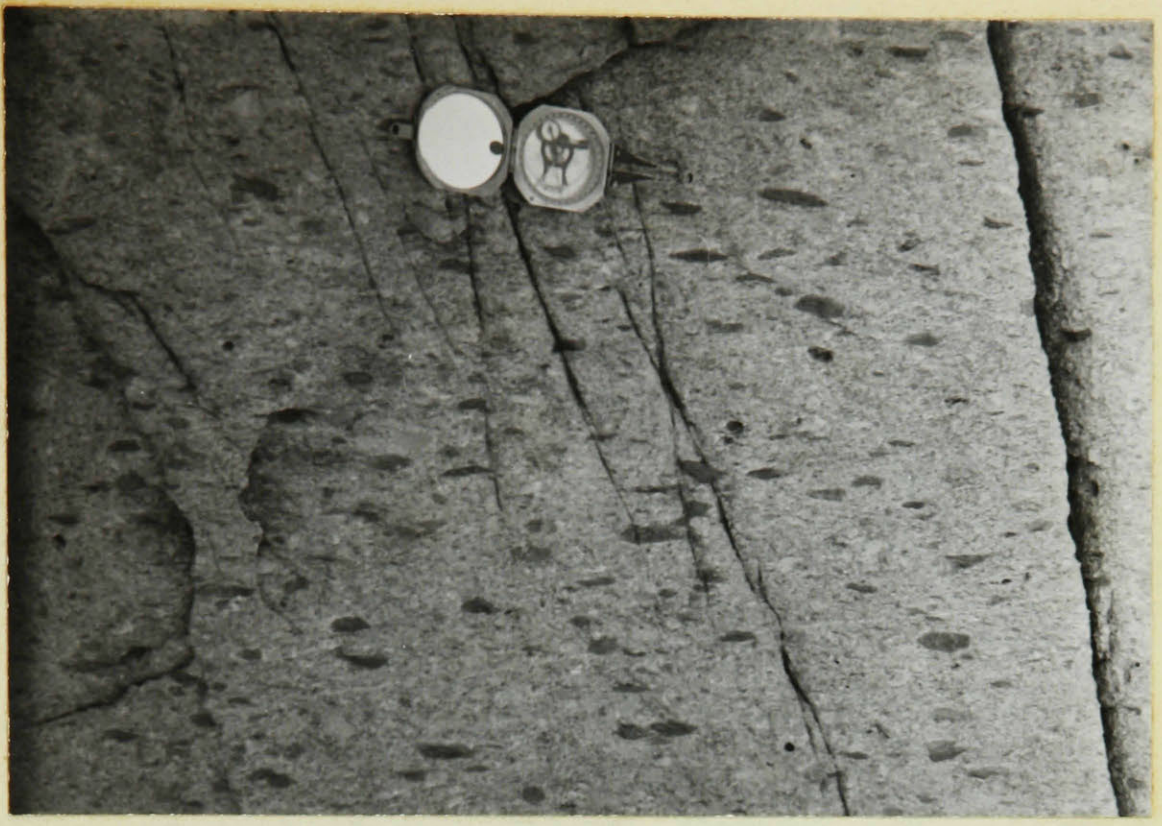


Fig. 28. Very small chloritized and sericitized inclusions in marginal Cape Brulé granite, in shore exposures between Brent Cove and Harbor Round.

Fig. 29. Large fragments of marginal type, sericitized granite engulfed by later intrusions of the same granite. In shore exposures northeast of Harbor Round.

Fig. 30. Quartz vein breccia in dioritic rock, near Stocking Harbor.

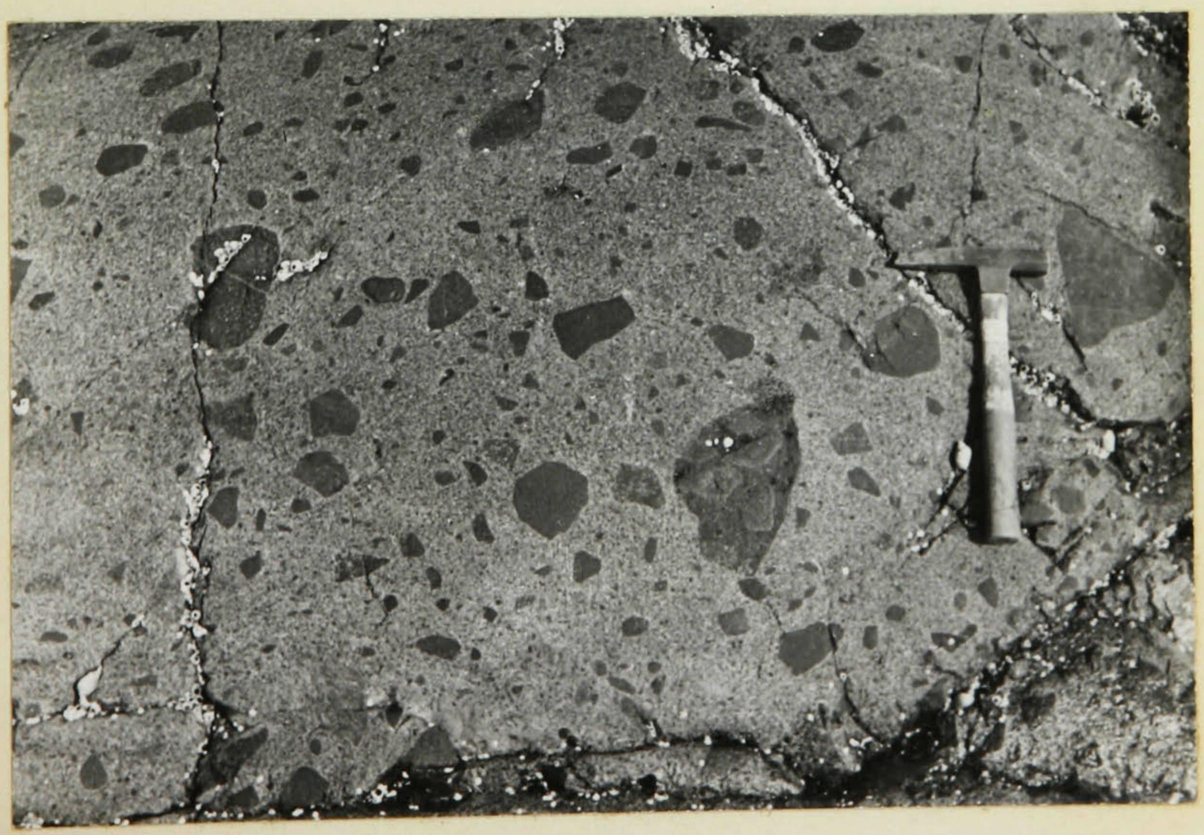


Fig. 31. Part of a dike of Burlington granite, about 200 feet wide, which has numerous inclusions of country rock, some types of which are not known to be exposed in the region. Between Burlington and Stocking Harbor.

Fig. 32. Quartz - carbonate veins cutting dark, serpentinized peridotite near the north end of Snook's Arm Western Pond.

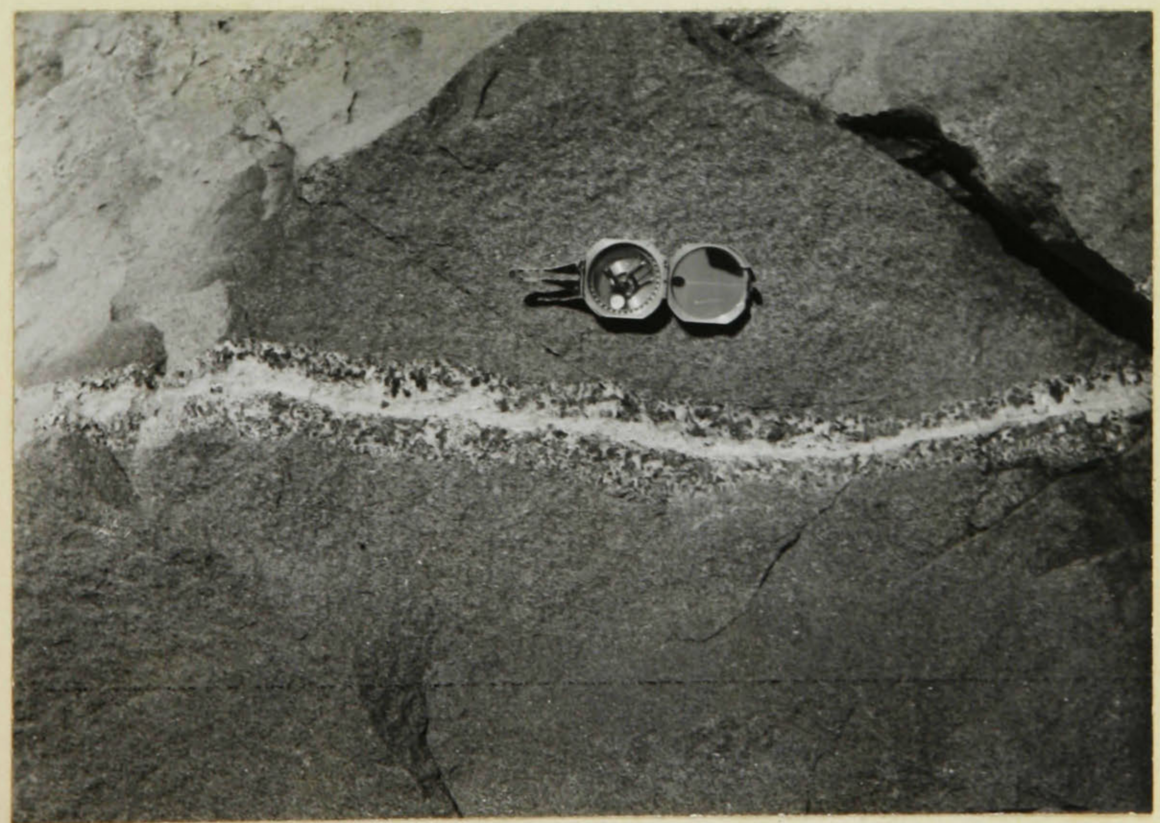


Fig. 33. Vein of aplite cutting diorite with resulting recrystallization of the adjacent wallrock, northeast of Rettis' Cove, near La Scie.

Fig. 34. Primary composition banding in metadiorite, northeast of Rettis' Cove which is northeast of La Scie. Black areas are pools of water.

Fig. 35. Thin, persistent, primary banding in metadiorite sill, Seal Island Cove, near the northern tip of Cape St. John.

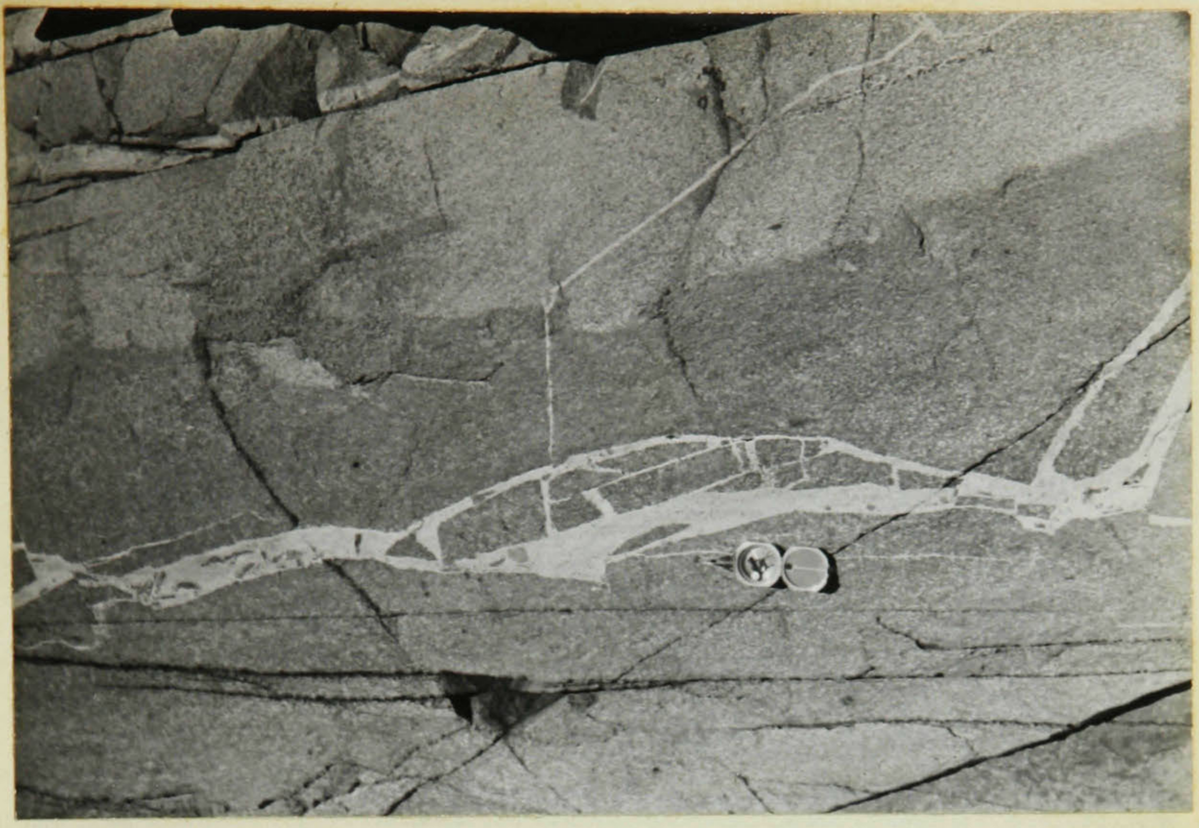


Fig. 36. The first stage in the development of intrusion breccias at Rettis' Cove, northeast of La Scie. Quartz diorite cutting metadiorite.

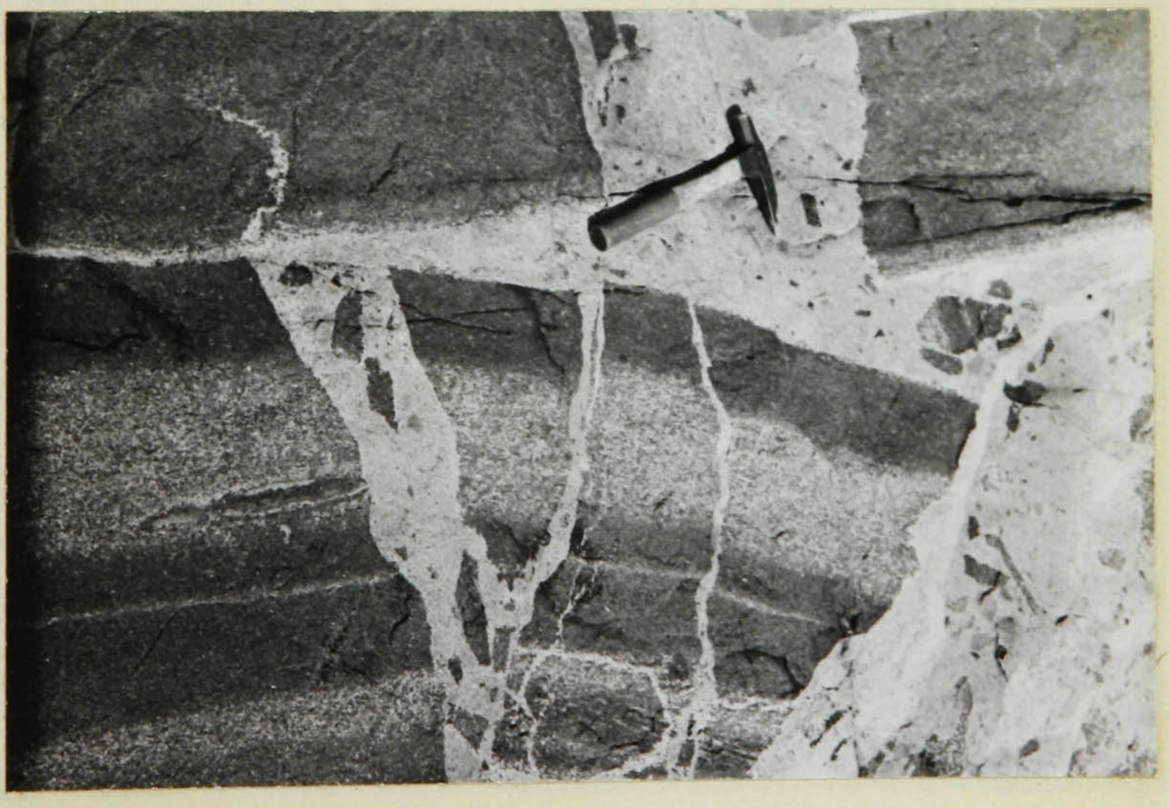


Fig. 37. A further step in the breakup of massive, banded metadiorite when it is intruded by quartz diorite. Rettis' Cove, northeast of La Scie

Fig. 38. Banded metadiorite which has been completely shattered by intrusion of quartz diorite. Rettis' Cove, northeast of La Scie.

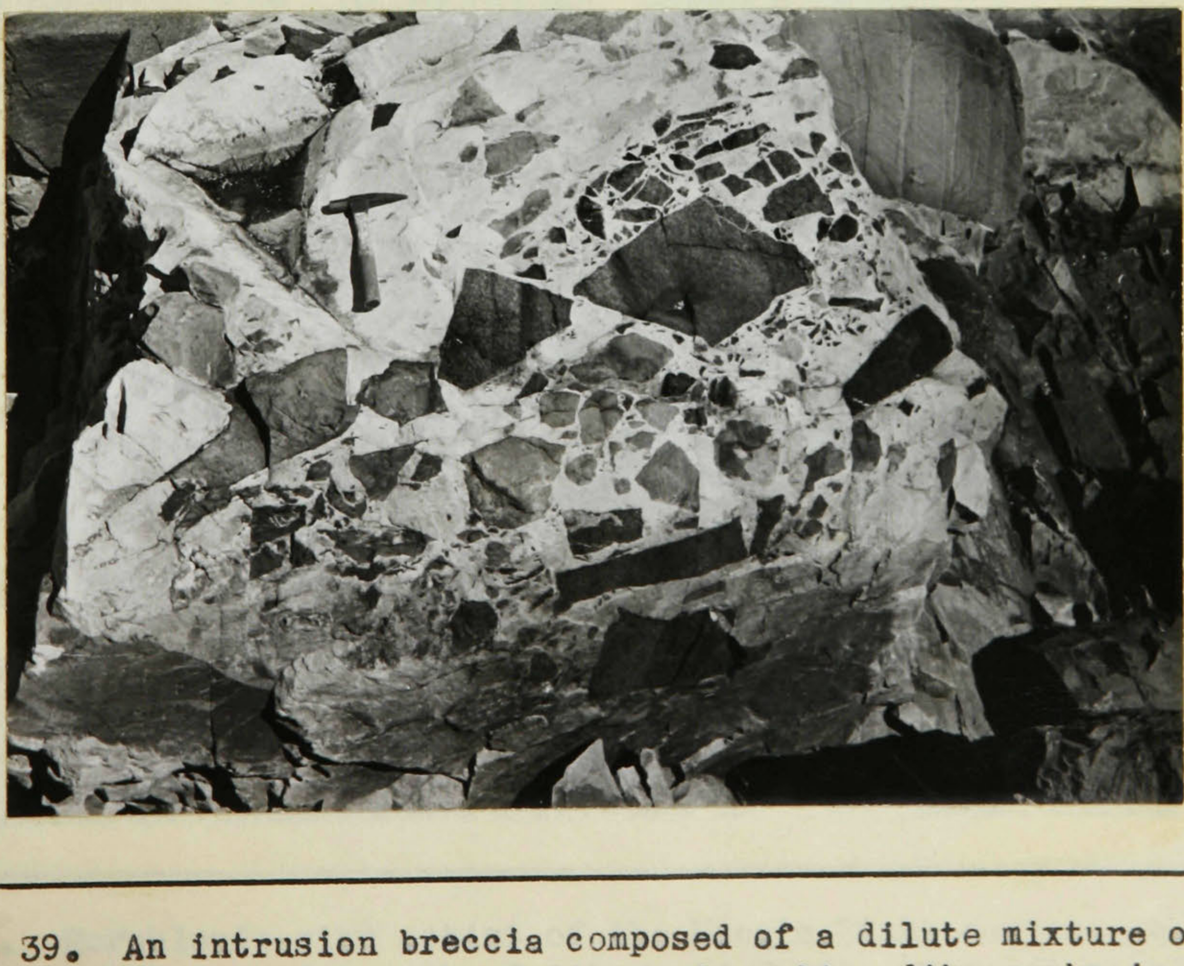


Fig. 39. An intrusion breccia composed of a dilute mixture of fragments of metadiorite and earlier dike rocks in quartz diorite - the end product of the process shown Figs. 36, 37 and 38.

Fig. 40. Quartz-mica schist of the Ming's Bight series which contains slender prisms of hornblende. One hundred feet from the contact with the Dunamagon granite on the shore of Pacquet Harbor. (Ordinary light, x 34)

Fig. 41. Hornblende-rich schist of the Ming's Bight series. One hundred yards north of L'Anse of Pardi. (Crossed nicols, x 34)

Fig. 42. Muscovite-rich band of a garnet-bearing, quartz-albite-mica schist of the Ming's Bight series. One half mile east of Pacquet. (Crossed nicols, x 20)

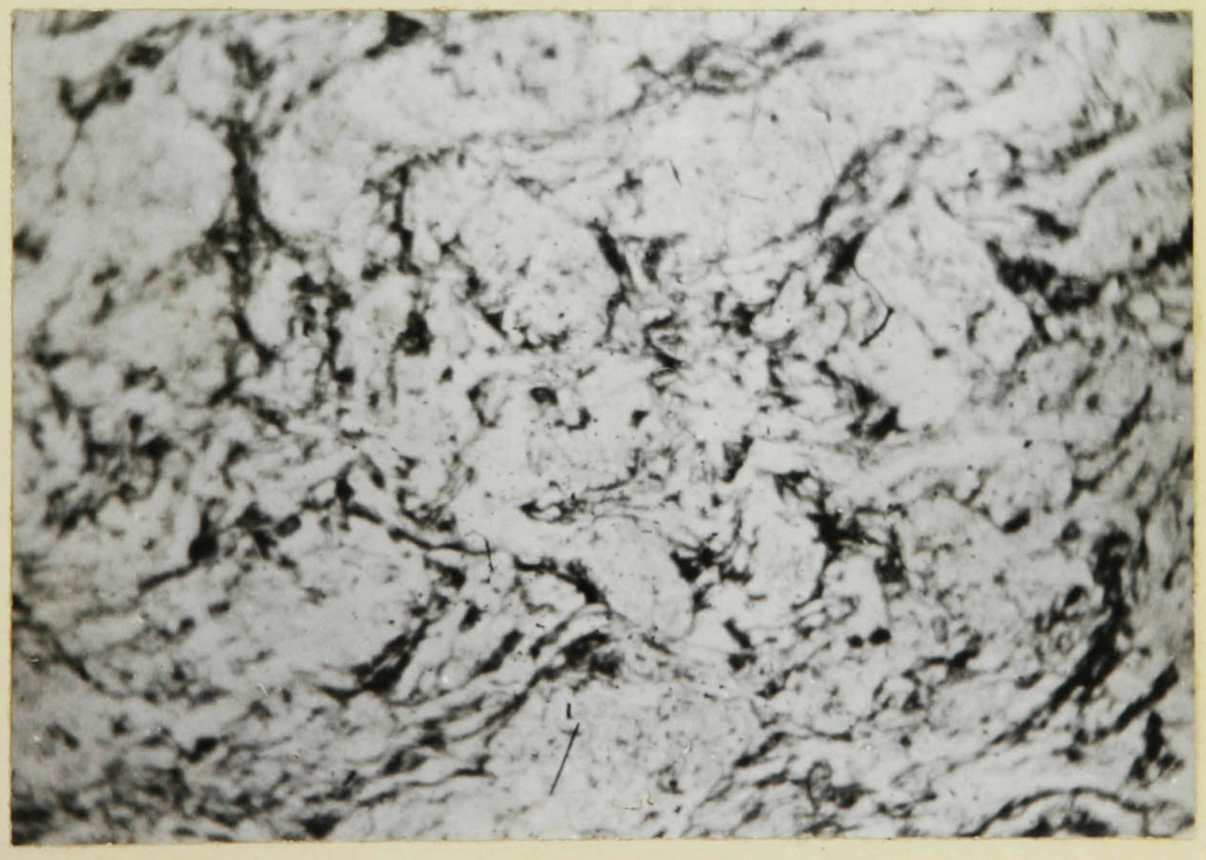


Fig. 43. Crenulated quartz-albite-mica schist of the Ming's Bight series. Tip of the Cape at Ming's Tickle. (Ordinary light, x 20)

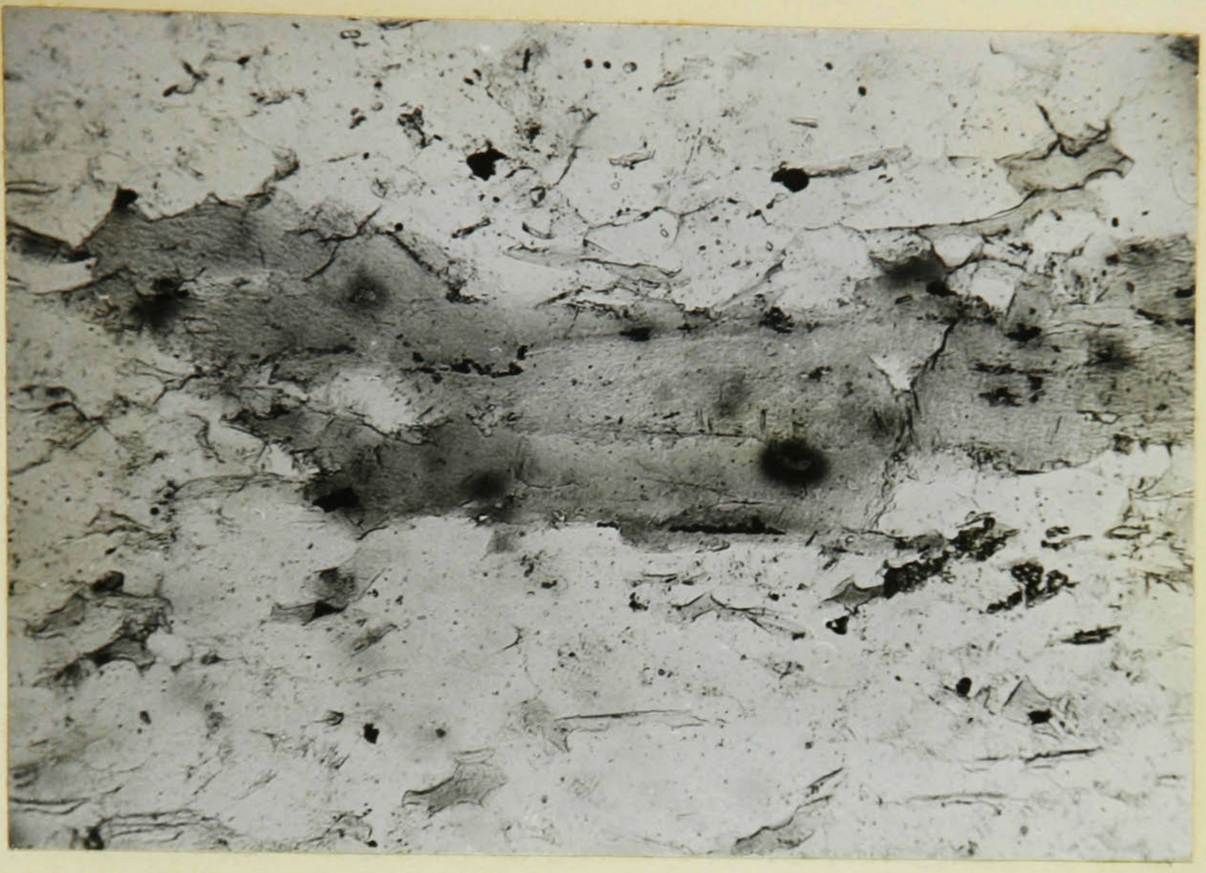


Fig. 44. Quartz-biotite gneiss of the Ming's Bight series, which consists of biotite, with strong pleochroic haloes around grains of zircon, in a mosaic of quartz which contains numerous tiny inclusions. East side of Ming's Bight. (Ordinary light, x 90)

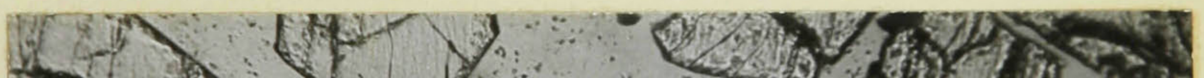


Fig. 45. Quartz-biotite-garnet gneiss of the Ming's Bight series, showing biotite with pleochroic haloes and euhedral porphyroblasts of garnet in a groundmass mosaic of quartz which has numerous, dust-like inclusions. One half mile east of Pacquet. (Ordinary light, x 90)

Fig. 46. Porphyroblasts of garnet with twisted lamellae of biotite, which show pleochroic haloes, in a mosaic of quartz grains. Quartz-biotite-garnet gneiss of the Ming's Bight series, east of Pacquet. (Ordinary light, x90)

Fig. 47. Same as above, with crossed nicols.

Fig. 48. Hornblende gneiss with augen of albite and quartz which contain abundant inclusions, the most common of which are grains of epidote. Scattered grains of tourmaline (t) occur with the hornblende. Mouth of Big Cove Brook, east side of Ming's Bight. (Ordinary light, x 20)

Fig. 49. Hornblende schist of the Baie Verte series. Pocket of chlorite with albite and epidote on the margins may be the remains of a vesicle. Southeast shore of Woodstock Harbor. (Crossed nicols, x 20)

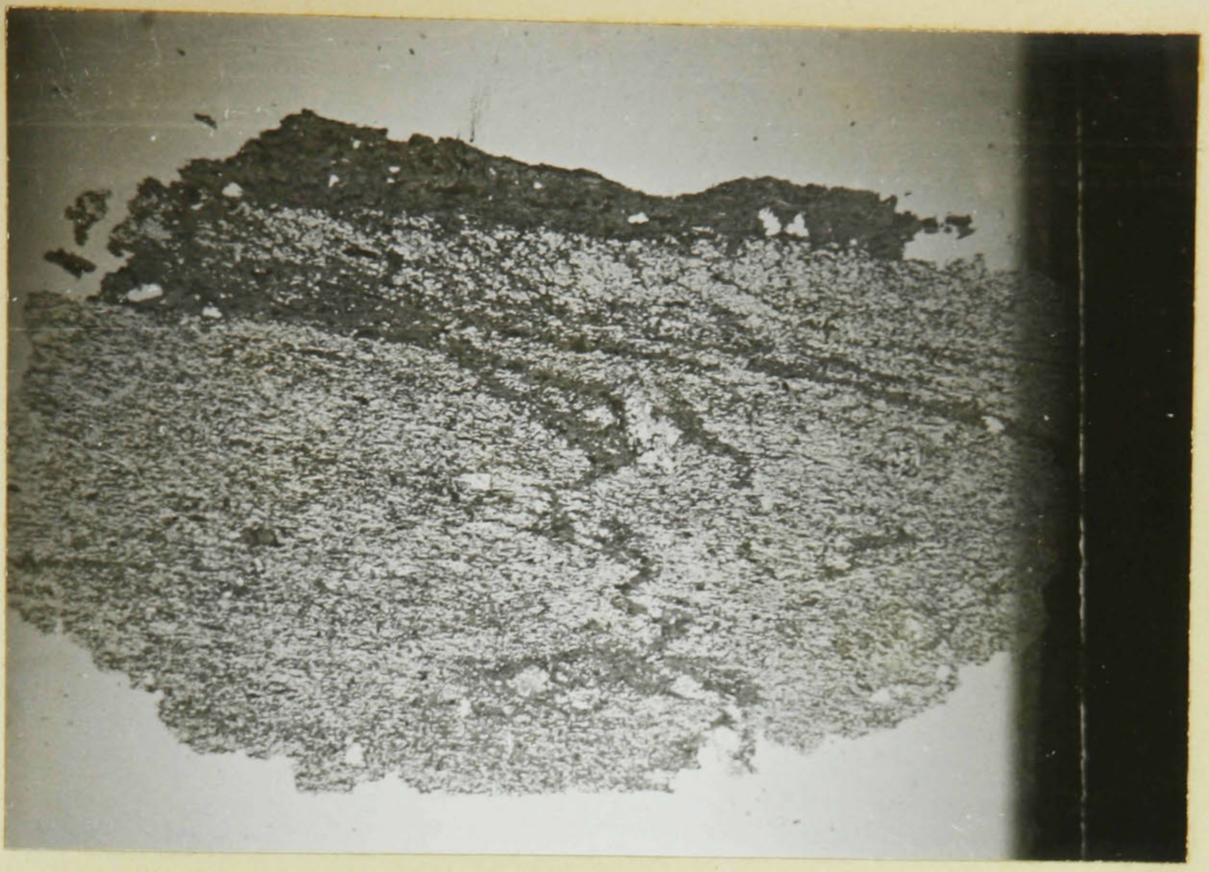


Fig. 50. Crenulated hornblende schist of the Baie Verte series, from the southeast side of Woodstock Harbor. (Ordinary Light, x 4)

Fig. 51. Hornblende schist with bands which are alternately rich in hornblende and albite-quartz. Southeast shore of Woodstock Harbor. (Ordinary light, x 20)

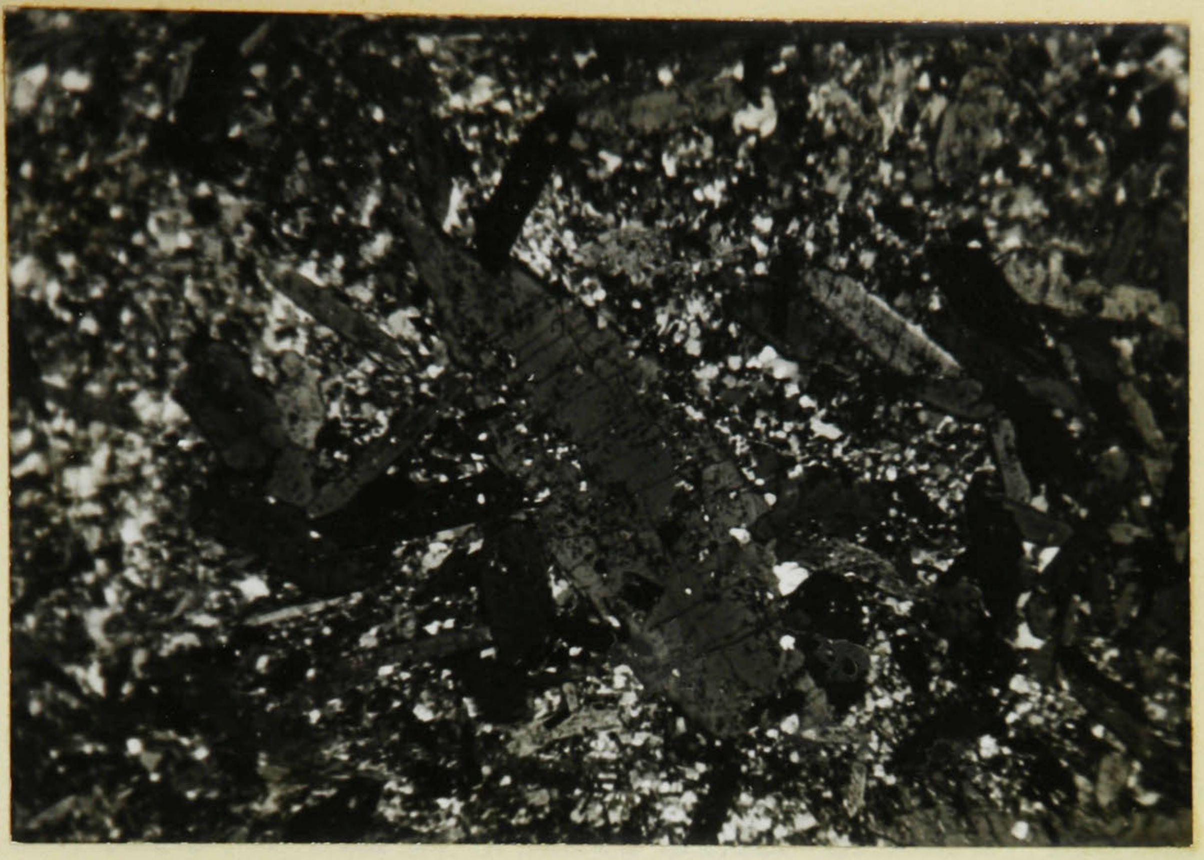


Fig. 52. Porphyroblastic hornblende gneiss of the Baie Verte series. The groundmass mosaic is mostly albite, with some quartz, epidote and biotite. East side of Woodstock Harbor. (Crossed nicols, x 20)

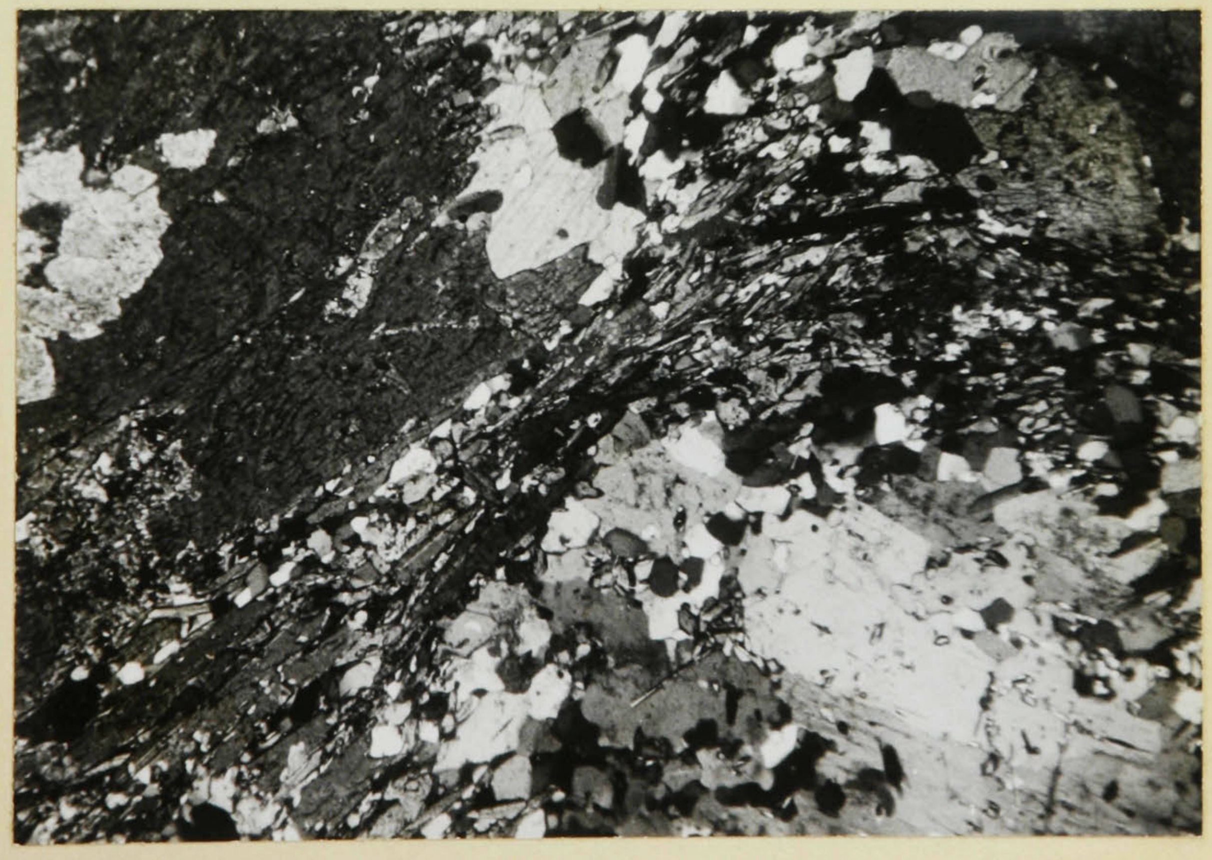


Fig. 53. Porphyroblastic hornblende gneiss of the Baie Verte series, with some large crystals of hornblende and swarms of smaller ones, albite in a groundmass mosaic, and scattered patches of calcite (c). Log Chute, Southwest Pond Brook. (Crossed nicols, x 34)

Fig. 54. Hornblende porphyroblast with poikiloblastic inclusions of quartz, albite and epidote in a fine-grained groundmass of quartz, albite, epidote, chlorite and biotite. Western shore of Confusion Bay. (crossed nicols, x 90)

Fig. 55. Uralitized pyroxene crystals with additions of pale green, secondary hornblende around the margins, in massive greenstones of the Baie Verte series. The light areas in the large crystals are unaltered augite. The swarms of minute needles in the groundmass are pale green hornblende. Log Chute, Southwest Pond Brook. (Ordinary light, x 6.6)

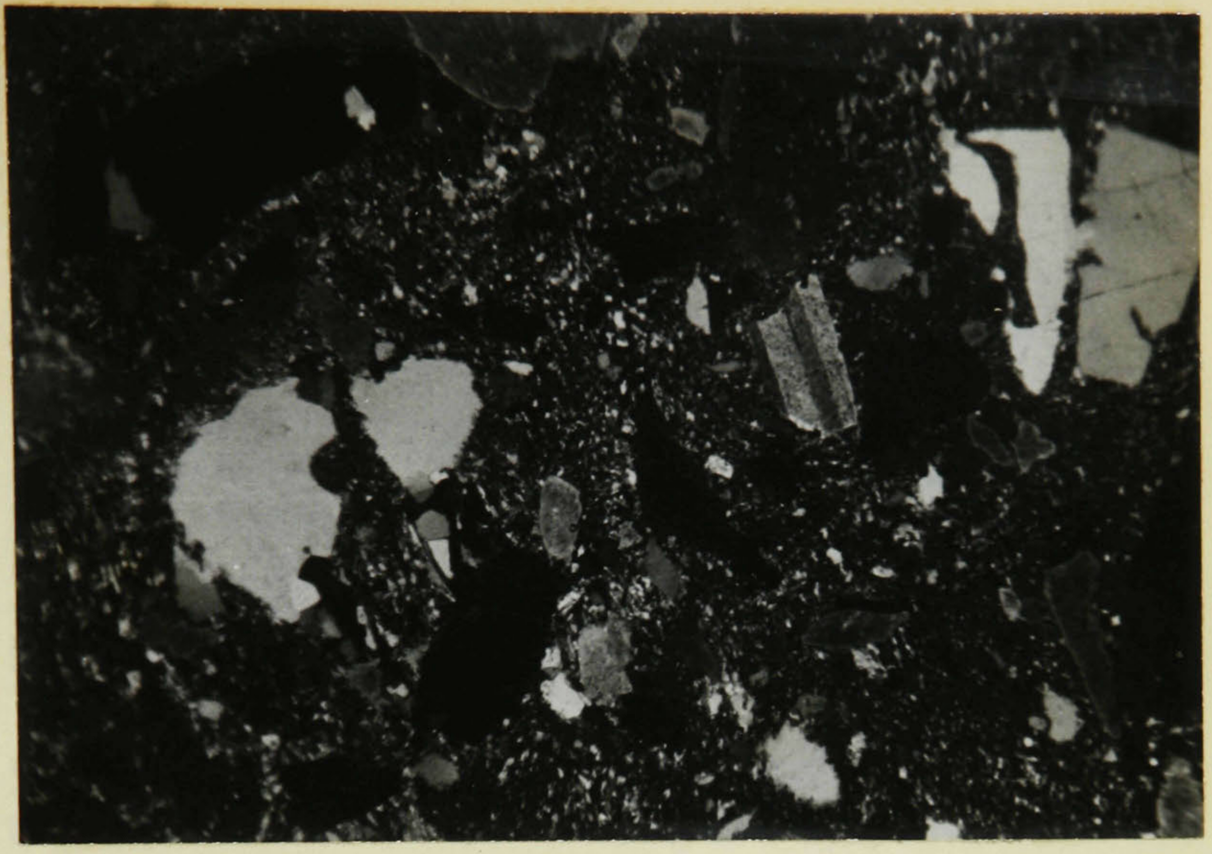


Fig. 56. Cape Brulé granite porphyry showing corroded phenocrysts of quartz, albite, and orthoclase in a sericitized groundmass of the same composition. (Crossed nicols, x 20)

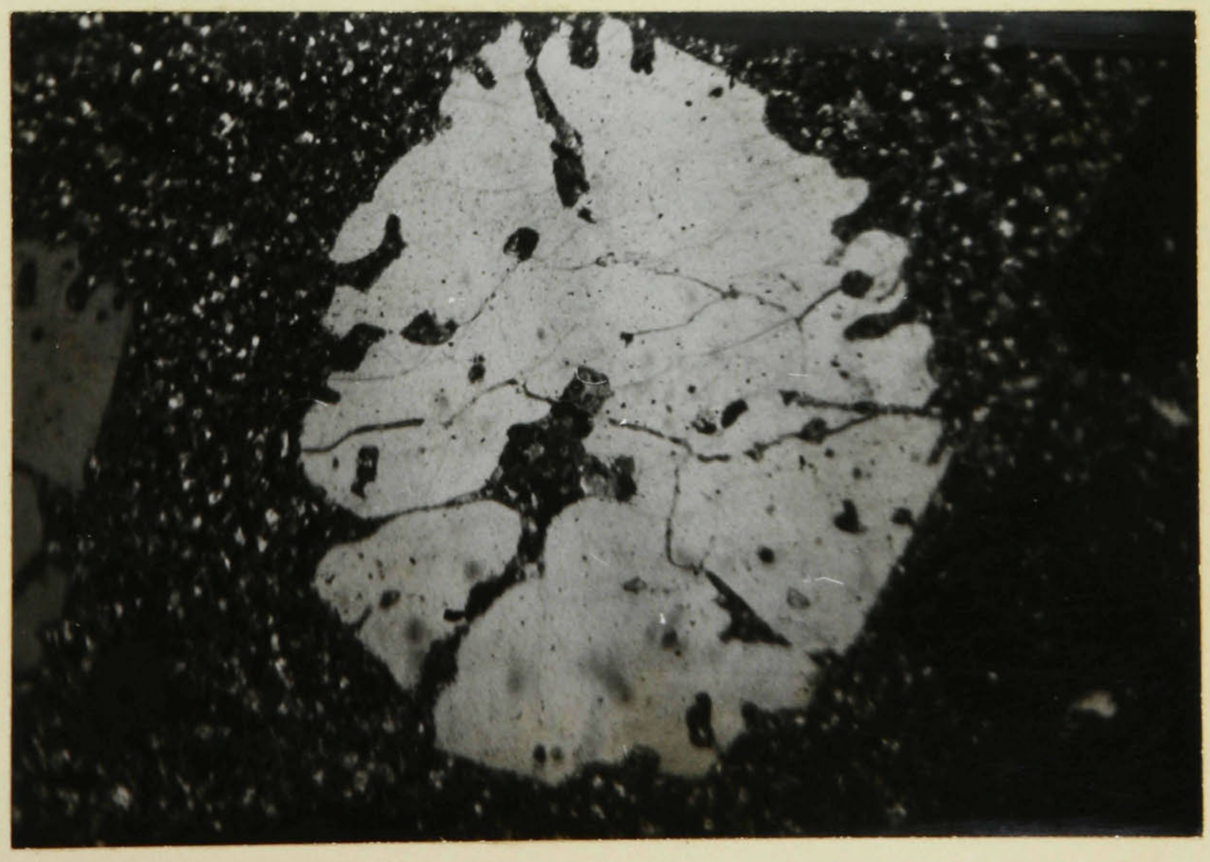


Fig. 57. Embayed quartz phenocrysts in a fine-grained groundmass of quartz, quartz, albite, orthoclase and sericite. From a granite porphyry dike, Nipper's Harbor. (Crossed nicols, x 20)

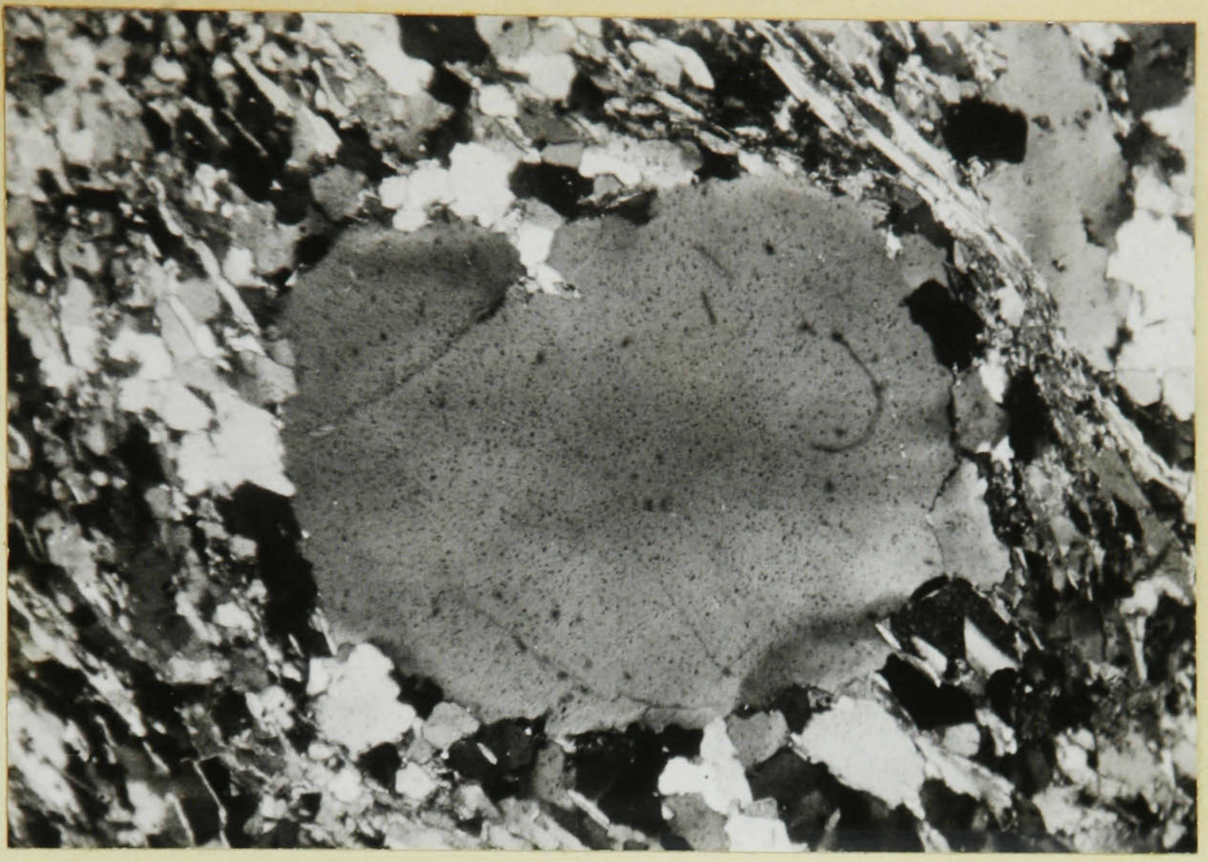


Fig. 58. Quartz phenocryst in the sheared marginal facies of the Cape Brulé granite, showing cracking along the edges, strain shadows and abundant inclusions. The foliation, shown by the micas, wraps around the phenocryst. South of Woodstock. (Crossed nicols, x 34)

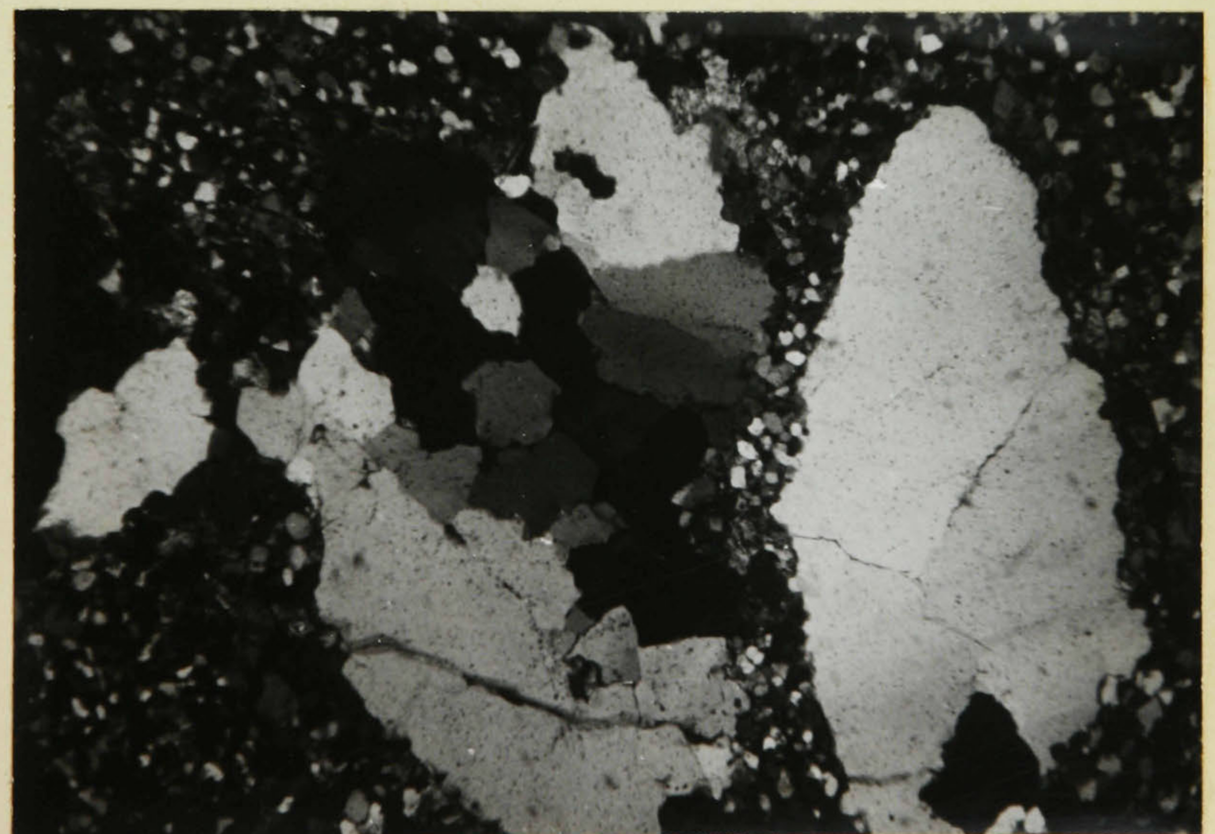


Fig. 59. Marginal facies of the Cape Brulé granite in which the texture is entirely metamorphic. Mosaic of large quartz grains in a fine-grained groundmass of quartz, altered feldspars and sericite. South of Woodstock. (Crossed nicols, x 34)

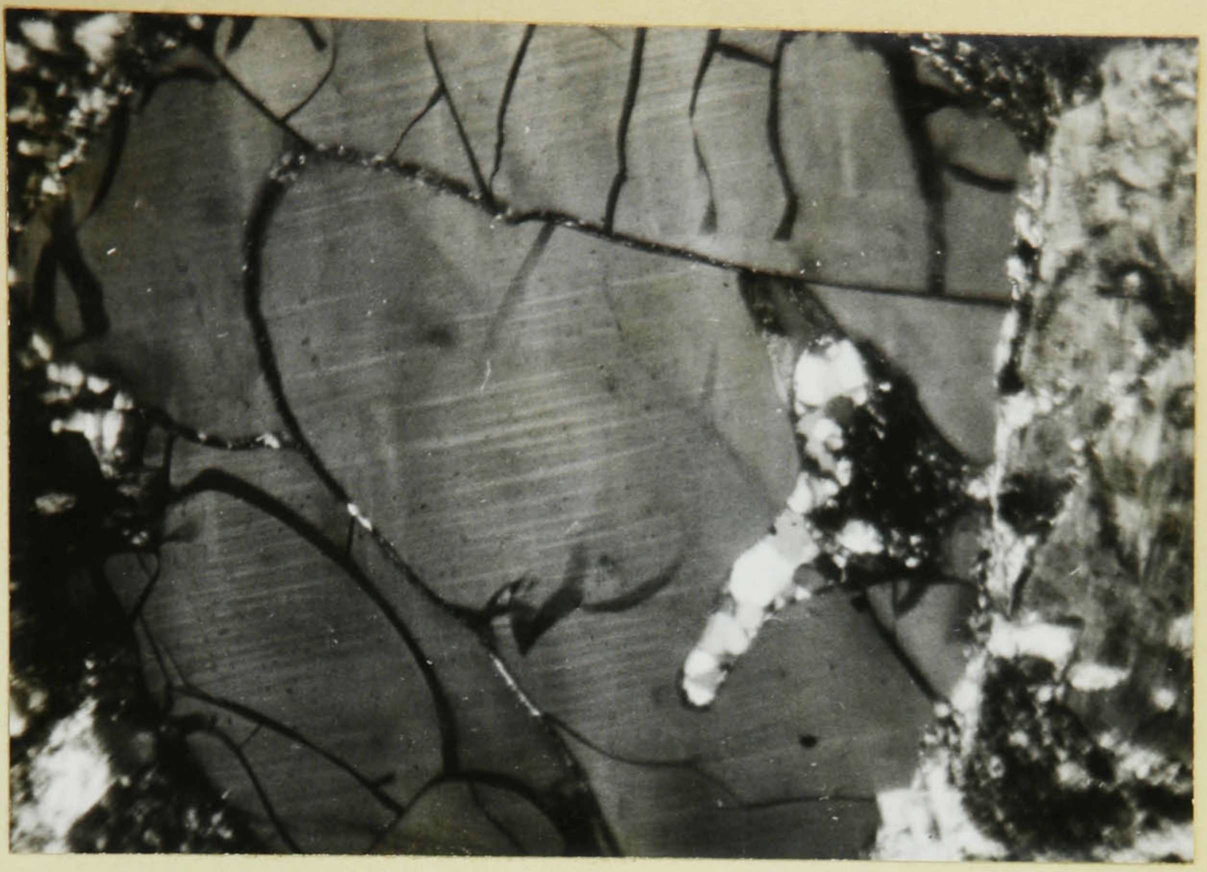


Fig. 60. Portion of a quartz phenocryst which shows perlitic fractures, and a banding which is due to inversion from beta-quartz to alpha-quartz. From a quartz-orthoclase porphyry, north of Red Cliff Pond. (Crossed nicols, x 64)

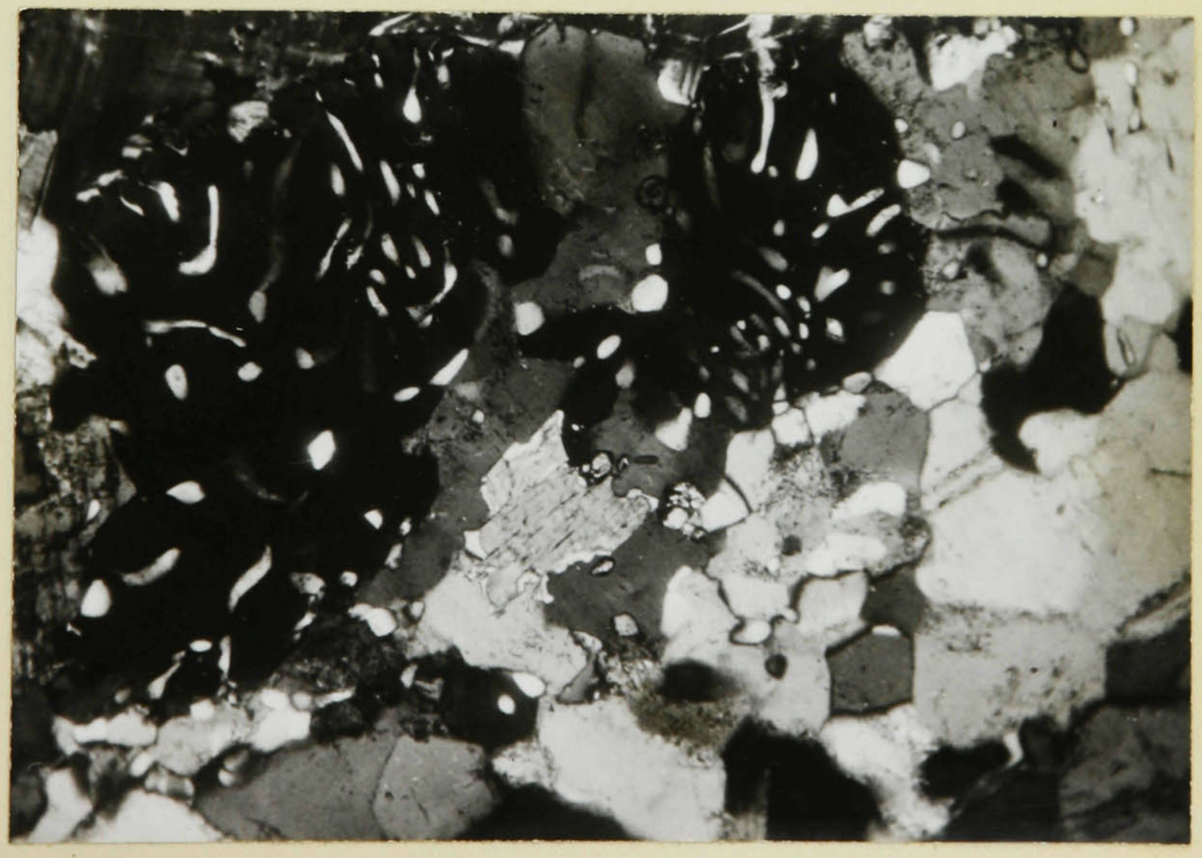


Fig. 61. Myrmekite from granite porphyry, north of Red Cliff Pond. (Crossed nicols, x 90)

Fig. 62. Carlsbad twin in perthite, Dunamagon granite. (Crossed nicols, x 20)

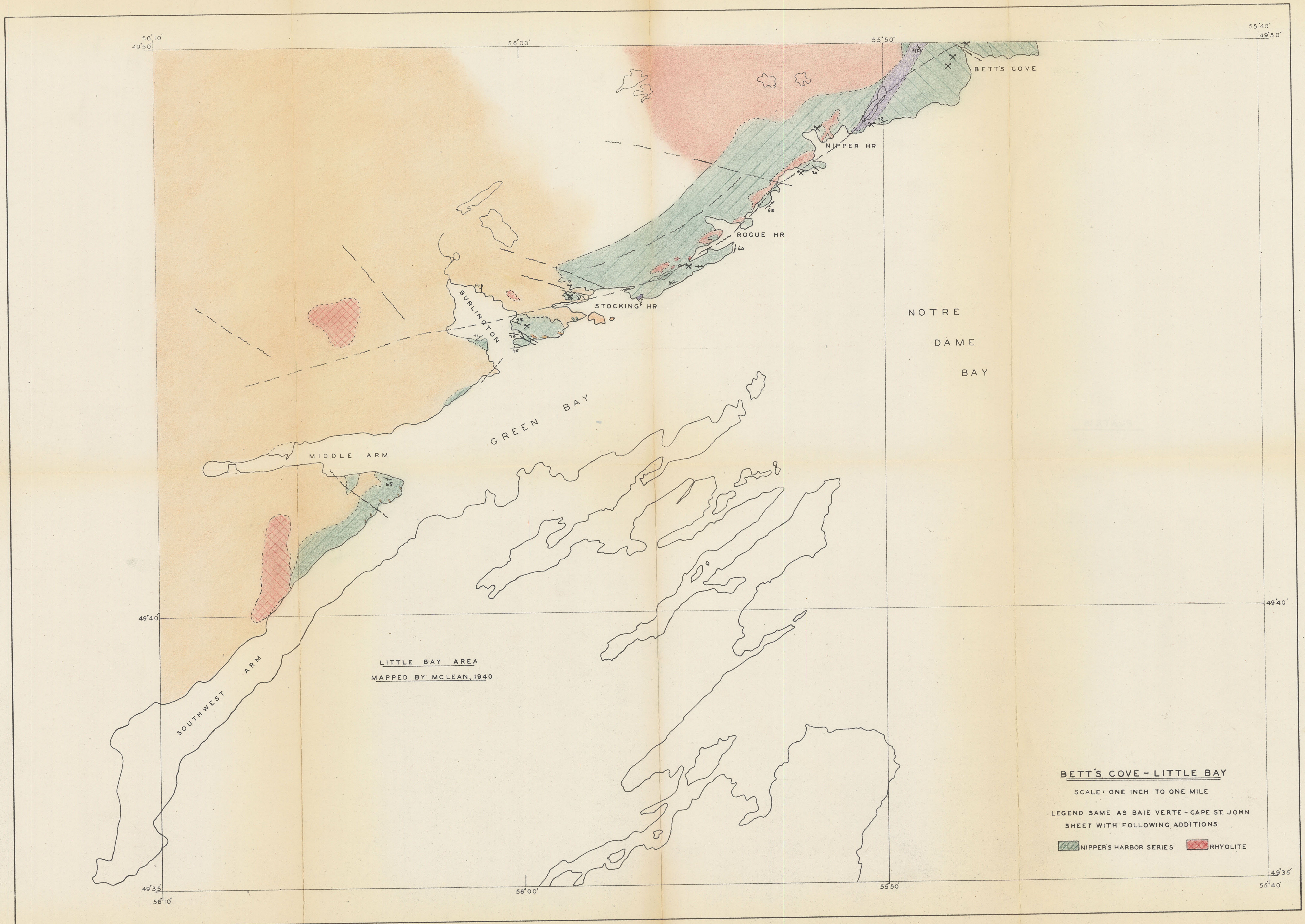
Fig. 63. Albitized orthoclase feldspar, from granite porphyry north of Red Cliff Pond. (Crossed nicols, x 64)

Fig. 64. Albitized perthite, Dunamagon granite, one quarter mile north of Seven Island Pond. (Crossed nicols, x 20)

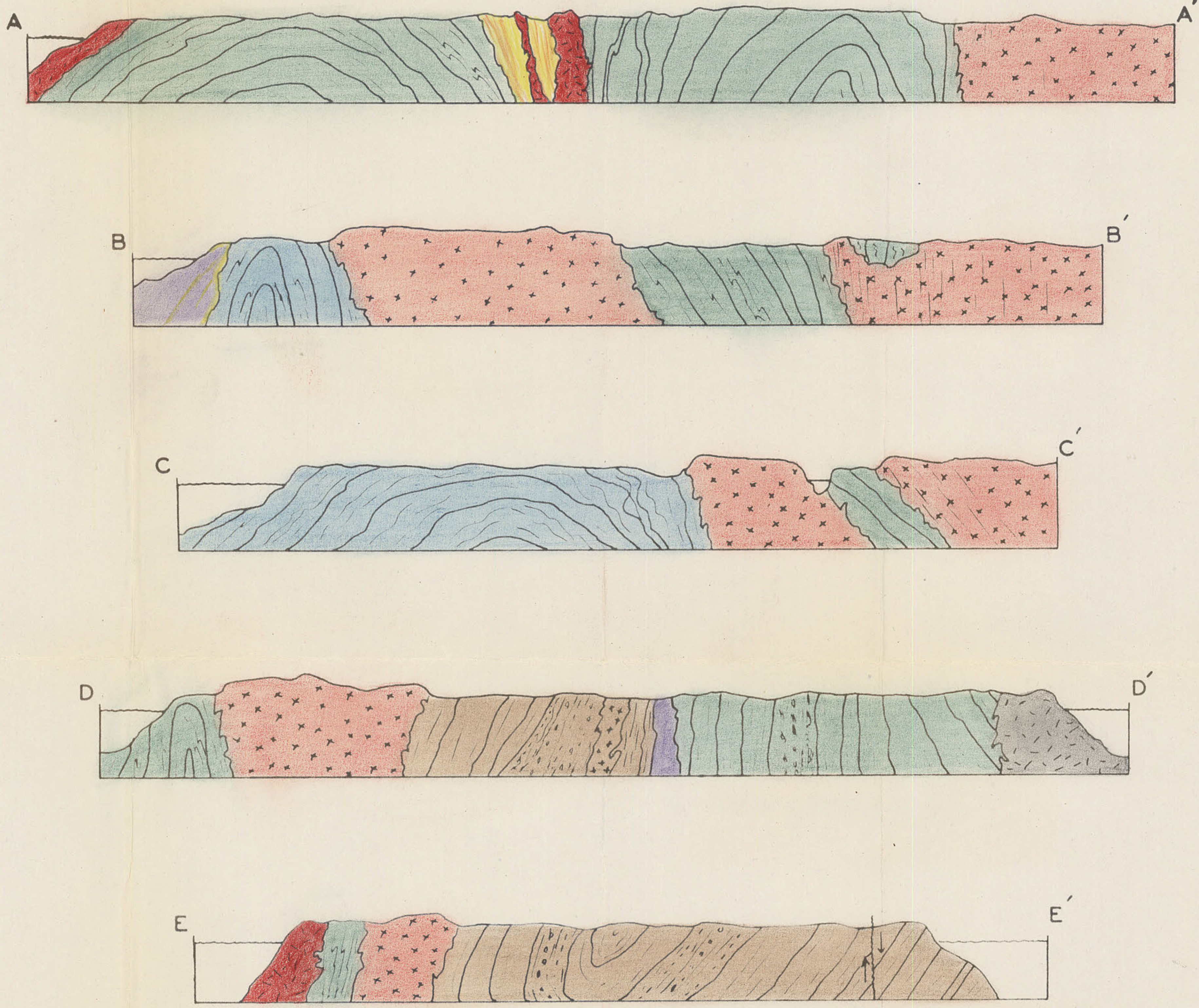
Fig. 65. Albite in microcline in granite porphyry, north of Red Cliff Pond. (Crossed nicols, x 64)

Fig. 66. Albitized perthite, L'Anse of Pardi granite. (Crossed nicols, x 34)

Fig. 67. Metadiorite which consists of saussuritized plagioclase, hornblende, chlorite, epidote, opaques and rarely accessory quartz. From the sill at Northern Bill, Cape St. John. (Crossed nicols, x20)



56°10′
49°50′
56°00′
55°50′
55°40′
49°50′
BETT'S COVE
NIPPER HR
ROGUE HR
STOCKING HR
BURLINGTON
NOTRE
DAME
BAY
GREEN BAY
MIDDLE ARM
SOUTHWEST ARM
49°40′
49°40′
LITTLE BAY AREA
MAPPED BY MCLEAN, 1940
BETT'S COVE - LITTLE BAY
SCALE: ONE INCH TO ONE MILE
LEGEND SAME AS BAIE VERTE - CAPE ST. JOHN
SHEET WITH FOLLOWING ADDITIONS
NIPPER'S HARBOR SERIES
RHYOLITE
49°35′
56°10′
56°00′
55°50′
49°35′
55°40′

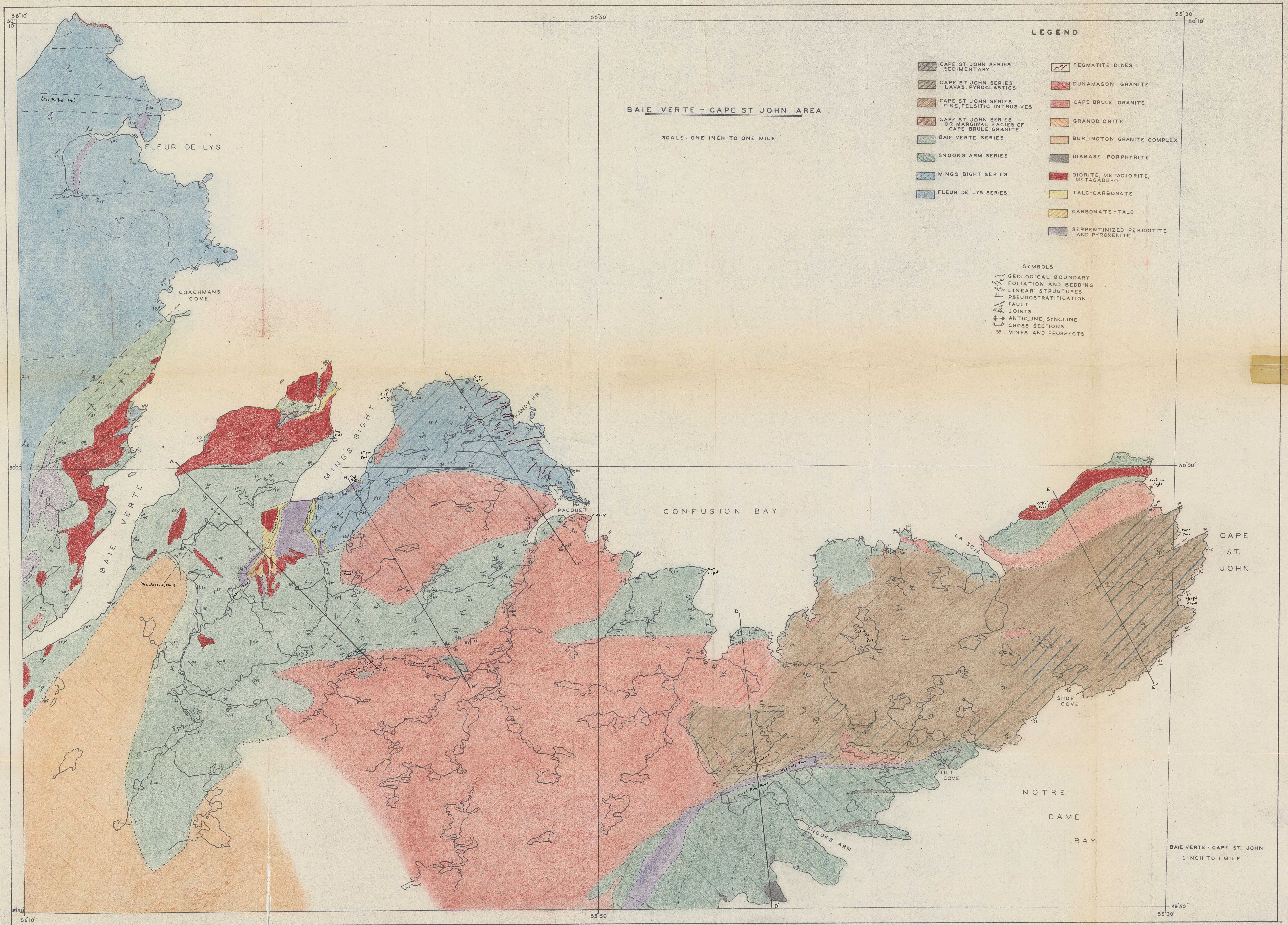


STRUCTURAL CROSS SECTIONS

TO ACCOMPANY BAIE VERTE - CAPE ST JOHN SHEET

HORIZONTAL SCALE: 1 INCH TO 1 MILE

VERTICAL SCALE: 1 INCH TO APPROXIMATELY 4000 FEET



BAIE VERTE - CAPE ST JOHN AREA
SCALE: ONE INCH TO ONE MILE
LEGEND
CAPE ST JOHN SERIES SEDIMENTARY
CAPE ST JOHN SERIES LAVAS, PYROCLASTICS
CAPE ST JOHN SERIES FINE, FELSITIC INTRUSIVES
CAPE ST JOHN SERIES OR MARGINAL FACIES OF CAPE BRULE GRANITE
BAIE VERTE SERIES
SNOOKS ARM SERIES
MINGS BIGHT SERIES
FLEUR DE LYS SERIES
PEGMATITE DIKES
DUNAMAGON GRANITE
CAPE BRULE GRANITE
GRANODIORITE
BURLINGTON GRANITE COMPLEX
DIABASE PORPHYRITE
DIORITE, METADIORITE, METAGABBRO
TALC-CARBONATE
CARBONATE-TALC
SERPENTINIZED PERIDOTITE AND PYROXENITE
SYMBOLS
GEOLOGICAL BOUNDARY
FOLIATION AND BEDDING
LINEAR STRUCTURES
PSEUDOSTRATIFICATION
FAULT
JOINTS
ANTICLINE, SYNCLINE
CROSS SECTIONS
MINES AND PROSPECTS
FLEUR DE LYS
COACHMANS COVE
BAIE VERTE
MINGS BIGHT
PACQUET
CONFUSION BAY
LA SCIE
CAPE ST. JOHN
SHOE COVE
TILT COVE
SNOOKS ARM
NOTRE DAME BAY
BAIE VERTE - CAPE ST. JOHN
1 INCH TO 1 MILE
55°50′
55°30′
50°10′
50°00′
49°50′

SKETCH MAP OF THE

BURLINGTON PENINSULA

TO SHOW THE

GENERAL AREAL GEOLOGY

SCALE 1 INCH = 2 MILES