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DEPARTMENT OF MINES
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PAPER 62-28

SANDY LAKE (EAST HALF)
NEWFOUNDLAND

12 H E½

(Report and Map 40-1962)

E.R.W. Neale and W.A. Nash

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1963

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SANDY LAKE (EAST HALF), NEWFOUNDLAND

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By

E. R. W. Neale and W. A. Nash

DEPARTMENT OF

MINES AND TECHNICAL SURVEYS

CANADA

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INTRODUCTION

Field Work and Acknowledgments

Much of the eastern half of this area has been mapped on the scale of 1 inch to 1 mile by officers of the Geological Survey of Canada (Kalliokoski, 1953, 1955; Neale, 1958; Neale, Nash, and Innes, 1960)[1] and was not further examined. Part of the area west of White Bay has been mapped by the Geological Survey of Newfoundland (Heyl, 1937b; Betz, 1948) and was briefly re-examined by Nash during this study. Most of the western half of the area was mapped by Nash in the 1960 field season. Several small areas that remained unmapped were investigated by Neale during 5 weeks of the 1961 field season.

Nash was ably assisted in the field by W. E. Mroszczak, J. M. Fleming, S. M. Robbins, and Chesley Card. Neale is indebted to B. Van Oort, K. S. Toong, P. Joseph, and Ira Bartlett for assistance during the 1961 field season.

Maps and other information on the ultrabasic rocks were made available by Advocate Mines Ltd. through the courtesy of H. K. Conn and D. J. Straw; and maps, tours of mineral prospects, and many other courtesies were rendered by A. P. Beavan, S. Roderick, H. R. Peters, and other geologists of British Newfoundland Exploration Ltd. The writers also wish to acknowledge a visit from their colleague, L. M. Cumming, who collected and identified fossils from the Silurian strata in the map-area.

Access and Culture

The Trans-Canada Highway extends across the central part of the map-area and branch roads from it service the major population centres on White Bay, Baie Verte, Southwest Arm, and Halls Bay. The smaller coastal villages are serviced by Canadian National Railways coastal boats, but roads to many of them are presently under construction. The Canadian National Railways main line extends from Sandy Lake southeastward to the southeastern corner of the map-area and 'flag stops' can be arranged at several sectional points en route.

The economy of the larger towns depends chiefly on the woods operations of the pulp and paper industry. Fishing is a full-time occupation in a few of the smaller outposts. Vegetable farming is

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[1] Names and/or dates in parentheses refer to publications listed in the References.

carried on in several communities, but only in the villages of King's Point and Rattling Brook is it commercially important. Employment in various phases of mining, a major industry of the map-area 60 years ago, has assumed renewed importance during the past few years, particularly in the eastern part. Producing copper mines at Tilt Cove and Little Bay are just a few miles east of the map-area. A major asbestos deposit at Baie Verte and the Rambler gold and base-metal deposit, 6 miles to the southeast, are both being developed and are scheduled for production in 1963. The Whalesback copper deposit, between Green Bay and Halls Bay, is in an advanced stage of exploration. Considerable employment is also created by exploration of concession areas during the summer months.

Topography

The area is characterized chiefly by a north-north-easterly to northeasterly topographic grain that reflects bedrock structures enhanced by glaciation. Fiord-like bays, linear fault-line scarps, and fault-controlled valleys are the most striking features of the topography.

The highest parts of the map-area are in the northwest and southwest corners. The northwest corner is part of the Long Range Mountains. It is a hummocky upland surface with some accordance of elevations at approximately 1,500 feet and a high point of 1,752 feet. It contains no remnants of the erosion surface at 2,000 feet elevation reported in the western parts of the Long Range Mountains (Twenhofel and MacClintock, 1940).

A lowland, east of this upland, extends southwestward from White Bay to Grand Lake, beyond the map-area, with a protuberance near Sandy Lake. It is hummocky and stream-dissected, and contains upland remnants with elevations up to 1,430 feet.

The region east of the White Bay lowland is part of the physiographic unit referred to as the "High Central Plateau" by Twenhofel and MacClintock (1940). In the southwest corner of the map-area this upland consists of a gently undulating surface with an average elevation of 1,500 to 1,600 feet, whose regularity is broken by a few glacially modified hills known as "the Topsails" and Lobster House Hill. The peak of Lobster House Hill, 1,916 feet elevation, is the highest point in the map-area. The upland extends northward to the north boundary of the map-area where maximum elevations decrease and, west of Baie Verte, are less than 1,000 feet. This upland surface slopes gently eastward, and elevations of 200 to 600 feet are most common along the eastern boundary of the map-area. Drainage is meandering and random, and relief is small on the drift-mantled, isotropic rocks of the high, southwestern part of the upland surface. However, north of Black Lake, bedrock structure has controlled both glacial flow and post-glacial drainage, and local relief is greater. In many places, streams have cut through the till cover and have exposed the rock floors of incised preglacial valleys.

Glaciation

The entire area was glaciated during the Pleistocene epoch. All available data relate to the last glaciation, probably an independent ice-cap on the Island of Newfoundland, and to the fluvial-glacial deposits associated with it. The effects of glaciation at several localities within the map-area have been studied by MacClintock and Twenhofel (1940). A study of post-glacial uplift in White Bay and Notre-Dame Bay was undertaken by E. P. Henderson for the Geological Survey in 1961.

In the southern and west-central parts of the map-area, striae, crescentic gouges, and stoss-and-lee forms show that the ice moved northeasterly and north-northeasterly, with only local deviations due to bedrock obstructions. A divergence in ice-flow direction in the central part of the map-area, between Birchy Lake and Flatwater Pond, roughly coincided with the present drainage divide. East of this divide, ice-flow was east-northeasterly and easterly, whereas west of it the ice flowed northwesterly to merge with ice flowing northeasterly in the White Bay trough. Erratics from the Birchy Lake - Baie Verte ultrabasic belt, which occur as far as 8 miles west of Black Lake and as far east as Southwest Arm, serve to substantiate this divergence in ice-flow direction. In the northwestern corner of the map-area, ice flowed easterly and east-southeasterly off Northern Peninsula to merge with the northeasterly flowing ice in White Bay. Small cirque-like forms along the steep-sided east shore of White Bay suggest the presence of small glaciers following melting of the main ice-cap in this coastal region.

The southern uplands are covered by a thin veneer of till and numerous glacial erratics. Farther north, till is chiefly confined to the valleys and other bedrock depressions, and the ridge tops are bare and strewn with erratics. Morainal mounds with local relief of up to 100 feet are common in the lowland between Sandy Lake and the head of White Bay. Recessional moraines with typical kame-and-kettle topography are common in the Kitty's Brook valley - Gaff Topsail region and near the west boundary of the area south of Sandy Lake. Small eskers also occur in these regions.

Stratified outwash deposits of sand and gravel have been preserved along parts of the main proglacial channels, which include most of the present major stream valleys. Remnants of deltaic deposits, with basal marine clays and overlying sand and gravel, occur near Springdale on Halls Bay, near the heads of Southwest and Middle Arms of Green Bay, and at Baie Verte. MacClintock and Twenhofel (1940) reported that the base of the Baie Verte deltaic deposit includes a layer of glacial till that overlies the basal marine clay. If actually present, this till would testify to a re-advance of the ice prior to deposition of the thick proglacial sand and gravel that forms the upper part of the deposit. However, the presence of such a till layer could not be established by Henderson (personal communication) in his recent study of this deposit. A gravel terrace on the north shore of Seal Cove, White Bay, at 200 feet elevation (Henderson, personal communication), is the highest of these emerged shoreline features. Near the southwest end of Clam Pond, between Halls Bay and Southwest Arm, clay beds that contain marine fossils are about 100 feet above present strand line (MacLean, 1947, p. 3). The base of the marine clay at Baie Verte is more than 60 feet above strand line (MacClintock and Twenhofel, 1940, p. 1745).

GENERAL GEOLOGY

Rocks of the map-area range in age from Precambrian to Pennsylvanian, with most if not all of the intervening periods represented.

Precambrian gneiss and schist in the northwestern corner are part of the Long Range complex which underlies the core of the Northern Peninsula of Newfoundland. Marble, gneiss, and schist that underlie the region east of White Bay may also be Precambrian in part, but direct evidence of their age is lacking.

Fossils are rare in the Palaeozoic rocks and long extrapolations are made on the basis of lithology and structure. Quartzite and shale that overlie Precambrian rocks west of White Bay are interpreted as Cambrian. An overlying marble unit in this region is interpreted as Ordovician. Elsewhere in the map-area, rock groups interpreted as, or known to be Ordovician, consist chiefly of basic to intermediate flow and pyroclastic rocks with associated greywacke and black slate. Locally they are intruded by ultrabasic rocks. Fossiliferous Silurian strata are known only in the White Bay region and in a single locality south of Southwest Arm, Green Bay. However, for a variety of indirect reasons, unfossiliferous sedimentary-volcanic sequences in the central and western parts of the map-area are tentatively interpreted as Silurian. Also, the Springdale Group of red beds and volcanic rocks in the eastern part of the map-area are assigned a Silurian age by virtue of lithological correlation with the fossiliferous Botwood Group in the adjacent area to the east. Rocks of the Springdale Group are less metamorphosed and deformed than those of nearby Ordovician groups.

Radiometric age-determinations suggest that latest granitic intrusion and metamorphism took place during the Devonian period. However, both stratigraphic and radiometric evidence show that some granitic rocks were emplaced in an earlier period (Ordovician ?). Mississippian red and grey clastic sediments underlie the region that extends southwestward from the head of White Bay. Red beds, at least in part of Pennsylvanian age, underlie the region immediately south of Sandy Lake.

Precambrian

Long Range Complex (Map-unit 1)

The Long Range complex underlies the northwest corner of the map-area and consists chiefly of biotite-hornblende and biotite gneiss and schist and granite-gneiss. Minor amounts of basic intrusive rock occur within the gneiss and schist.

Biotite-hornblende gneiss (map-unit 1a) that outcrops south of Main River was described by Heyl (1937b) as a strongly layered rock in which the dark layers range in thickness from a fraction of an inch to several feet, with the light layers commonly somewhat thinner than the dark ones. Dark green to black hornblende is the dominant constituent of the dark layers; locally, biotite is also a major constituent. Garnet occurs sporadically. The light layers consist chiefly of quartz, locally with abundant intermediate plagioclase. Lenses of dark green to black amphibolite occur within the gneiss.

Biotite gneiss (map-unit 1b) that outcrops north of Main River is commonly a streaky to finely layered, pale to medium grey rock. Biotite is more abundant than it is in the gneiss south of Main River and, over large areas, is the sole mafic constituent. Leucocratic layers consist of pale bluish grey quartz and white plagioclase in approximately equal amounts. In a few places, layering is obscure or lacking in these biotite-hornblende-quartz-plagioclase rocks and they are best classified as biotite granulites. Thin layers of muscovite-biotite schist are intercalated with some of the biotite and biotite-hornblende gneiss. Pale pinkish grey granite-gneiss (1c) and also massive medium-grained granite (unit 17 ?) commonly occur as thin layers with unit 1b. The possible presence of Palaeozoic granite (17) within these Precambrian rocks has been discussed by Heyl (1937b) and is mentioned in a later part of this paper.

Granite augen gneiss (map-unit 1c) outcrops along the eastern margin of the Long Range complex both north and south of Main River. It is pale reddish grey and very coarse grained. Augen of microcline perthite more than 1 inch long are outlined by thin mafic layers that consist chiefly of chloritized biotite and, in some places, hornblende. Plagioclase (sodic andesine) and pale bluish grey quartz are other major components of this gneiss.

Meta-gabbro sills, dykes, and small plugs cut the gneissic rocks in many localities. Scattered outcrops of meta-gabbro suggest that a fairly large plug or sill is located about 2 miles east of the intersection of the west and north map-boundaries. The meta-gabbro (map-unit 1d) is commonly a dark grey, brown-weathered, medium-grained, massive to slightly gneissic rock, and consists chiefly of dark grey plagioclase and black, blocky pyroxene crystals.

TABLE OF FORMATIONS

ERA	PERIOD OR EPOCH	ROCK UNIT		LITHOLOGY
PALÆOZOIC	Pennsylvanian	Unit 21		Red and grey arkosic rocks
	Late Mississippian	Unit 20		Red sandstone and conglomerate
	Early Mississippian	Anguille Formation (19)		Grey and red siltstone, arkosic sandstone and conglomerate, plant fragments
	Unconformity			
	Devonian and earlier	Units 17-18		Granitic rocks and intermediate to basic intrusive rocks
	Intrusive contacts in most places			
	Silurian and (?) later	Unit 16		Intrusive quartz-feldspar porphyry and closely associated silicic volcanic rocks
		Springdale Group (15)		Massive, basic, and silicic volcanic rocks; red clastic sediments with predominantly volcanic fragments
	Middle Silurian	Unit 14		Schistose to massive, basic to silicic volcanic rocks with thin beds of fossiliferous limestone
		Natlins Cove Formation (13)		Grey, feldspathic and argillaceous sandstone with limy interbeds, locally fossiliferous
	Silurian (?)	Unit 12	Simms Ridge Formation	Shale and arkosic sandstone
			Jacksons Arm Conglomerate	Conglomerate with predominantly volcanic fragments
			Giles Cove Formation	Slaty grey shales, intercalated volcanic rocks

Table of Formations cont'd.

PALÆOZOIC	Silurian (?)	Unit 11	Schistose to massive, silicic to basic volcanic rocks, and clastic sediments with predominantly volcanic fragments and, locally, granitic fragments
	Unconformity		
	Ordovician (?)	Unit 10	Greenish grey granodiorite
		Unit 9	Meta-diorite and meta-gabbro
		Unit 8	Serpentinized ultrabasic rocks
	Intrusive contact		
	Ordovician	Baie Verte Group (7)	Schistose basic volcanic rocks, greywacke, black slate, chert
		Exploits Group (6)	Schistose to massive, basic and silicic volcanic rocks, black slate, greywacke, chert; a few Middle Ordovician graptolites
		Lush's Bight Group (5)	Schistose basic volcanic rocks, minor greywacke, slate, and chert; (one early Ordovician fossil)
		Doucers Formation (4)	Grey marble, interbeds of micaceous schist
	Cambrian	Beaver Brook Formation (3)	Grey shale and phyllite with micaceous quartzite at base
PALÆOZOIC and/or PRECAMBRIAN		Fleur de Lys Group (2)	Micaceous schist and gneiss; minor gneissic conglomerate and marble; meta-gabbro sills and dykes
	Unconformity (between Units 1 and 3)		
LATE PRECAMBRIAN (ca. 950 m.y.)		Long Range Complex (1)	Biotite and biotite-hornblende schist and gneiss; granite augen gneiss, small meta-gabbro plutons

GSC

The Precambrian age of the gneisses of the Long Range complex has been established in the adjacent map-area to the west (Baird, 1959) where they are unconformably overlain by fossiliferous Cambrian strata. In Sandy Lake (east half) map-area, granite-gneiss (map-unit 1c) is overlain unconformably by the Beaver Brook Formation of possible Cambrian age. North of the map-area, granites within the Long Range complex have been dated radiometrically at 945 m.y. and 960 m.y. (Clifford and Baird, 1962; Lowdon, 1962). The intrusive meta-gabbro is tentatively interpreted as Precambrian and is probably related to bodies of anorthositic gabbro in the adjacent map-area to the west (Baird, 1959).

Fleur de Lys Group (Map-unit 2)

The Fleur de Lys Group was named and described by Fuller (1941) from exposures on the peninsula between White Bay and Baie Verte, immediately north of this map-area. Fuller estimated the total thickness of the group to be approximately 20,000 feet.

The group consists chiefly of coarse-grained, light to medium grey biotite and muscovite schists and gneisses. Typically they consist of 5 to 15 per cent biotite, 5 to 15 per cent muscovite, and the remainder is platy quartz and pale grey sodic plagioclase in various proportions. Some of the more quartzitic layers can be properly classified as micaceous and feldspathic quartzite. In a few places, crossbedding and scour-and-fill structures are preserved in these quartzitic layers.

Garnetiferous muscovite schist (map-unit 2a) occurs as concordant lenses within the gneisses near the eastern margin of the group, north of lat. 49°45'. Northeast of Southern Arm Pond and northward from there to the northern boundary of the map-area, numerous thin layers of graphite schist and rare beds of white marble (map-unit 2b) are associated with the garnetiferous schist. Graphitic schist and garnetiferous schist are also locally common within muscovite-biotite gneisses a short distance east of White Bay, south of Purbeck's Cove. Pink and white, coarsely crystalline marble (map-unit 2b) outcrops along and near the east coast of White Bay from Western Arm southward to the head of the bay and beyond. Thin beds of gneissic conglomerate (map-unit 2c) are associated with the marble of this region, particularly near the mouth of Big Chouse Brook and at the inlet of a lake 3/4 mile southeast of Westport village. Gneissic conglomerate is most abundant, however, in a region 2 miles southeast of the head of Western Arm, where a dominantly conglomeratic formation, approximately 1/2 mile thick, extends northward to the shore of Middle Arm, White Bay, where it wedges out. The stretched pebbles and cobbles of the conglomerate are composed chiefly of quartzite.

Thin sills and dykes of meta-gabbro, most of them between 35 and 200 feet thick, are common within the group. They consist of about 60 per cent hornblende and chloritized biotite and about 40 per cent plagioclase. Some contain plagioclase phenocrysts. Texture varies from massive to slightly gneissic. A few bodies are garnetiferous. A large body of diabasic gabbro (map-unit 2d) mapped by Betz (1948) near Hampden village may be related to meta-gabbro dykes and sills.

Chloritic schist and gneiss (map-unit 2e) with abundant epidote and magnetite are common near the contact of the Fleur de Lys rocks with Ordovician volcanic and ultrabasic rocks. Southward along strike, near Upper Indian Pond and Birchy Lake, thinly layered hornblendic gneisses (map-unit 2f), which resemble basic meta-tuffs, occupy the same apparent stratigraphic position as the chlorite schist and gneiss.

South of Wild Cove Pond the Fleur de Lys Group has been intruded by granitic rocks (map-unit 18b) and converted into a variety of hybrid gneisses. K/Ar age determinations on biotite and muscovite suggest that intrusion and the latest metamorphism of the group took place in Devonian time, approximately 355 m.y. ago (Lowdon, 1961).

The age of the Fleur de Lys Group is in doubt. Murray (Murray and Howley, 1881) correlated the major part of the group with the gneisses of the Long Range complex (map-unit 1), and the marble sequence along the east shore of White Bay with the Lower Palaeozoic marble (map-unit 4) along the west shore of the bay. Betz (1948) proposed the name "White Bay Group" for the schists and marble along the east shore of the bay and stated that the age of these rocks and their relation to the Fleur de Lys gneisses were uncertain. Fuller (1941), Watson (1947), and Baird (1951) interpreted the northeasternmost exposures of the group as Precambrian—chiefly on the basis of metamorphic grade. Neale (1959) has suggested that the northwesternmost exposures may be Lower Palaeozoic on the basis of apparent structural concordance with the Ordovician Baie Verte Group. As discussed elsewhere in this paper, the Fleur de Lys Group occupies a northeast-trending anticlinorium. The present authors, on structural grounds, favour the interpretation that the marble and associated rocks along both the east and west flanks of this structure are of Early Palaeozoic age. The gneisses in the core of the anticlinorium may be Early Palaeozoic or Precambrian.

Cambrian (?)

Beaver Brook Formation (Map-unit 3)

The Beaver Brook Formation outcrops at the base of the Palaeozoic section on the west coast of White Bay. It is 910 feet thick in the section exposed in the bed of Beaver Brook (Heyl, 1937b). It consists chiefly of grey, limy, arenaceous and micaceous shales, which grade into phyllite and, locally, into mica schist. The basal member of the formation on Beaver Brook is a highly micaceous grey quartzite, 10 feet thick. West of Cobbler Head, the basal part of the formation is a pale grey quartz conglomerate characterized by subangular granule-size fragments of blue quartz.

The name "Beaver Brook" was proposed for this formation by Heyl (1937b). The formation rests unconformably on Precambrian rocks 2,000 feet from the mouth of Beaver Brook (Heyl, 1937b) and probably also west of Cobbler Head. Elsewhere it appears to be faulted against Precambrian rocks.

The formation is unfossiliferous, but it resembles Cambrian quartzite and shale units that overlie the Long Range complex in the adjacent map-area to the west (Baird, 1959) and, hence, is tentatively classified as Cambrian.

Ordovician

Doucers Formation (Map-unit 4)

This formation conformably overlies the Beaver Brook shale where it is present and elsewhere is faulted against the rocks of the Long Range complex (map-unit 1).

It consists chiefly of pale bluish grey to medium grey, fine- to medium-grained marble. In some places, thin dark grey laminae are discernible in the marble and, in others, thin beds of micaceous schist are intercalated with 1- and 2-inch-thick beds of marble. In the central and southwestern parts of the outcrop belt, the rock is not sufficiently recrystallized to be called marble and the term 'crystalline limestone' is more appropriate.

The formation has an approximate outcrop width of 4,800 feet at Coney Arm, but its thickness cannot be calculated owing to distortion and flowage folding of the steeply dipping beds at this locality. With the exception of algal forms in marble at Coney Arm, no fossils are known in this formation.

The name "Doucers" was proposed by Heyl (1937b) and the formation was assigned to the Cambrian. This age was questioned by Betz (1948). Baird (1959), on the basis of lithology and stratigraphic position, correlated the southwestern extension of this formation with the Lower Ordovician St. George Group. His interpretation is adopted in this report.

Lush's Bight Group (Map-unit 5)

This group underlies most the peninsula between Halls Bay and Southwest Arm of Green Bay in the east-central part of the map-area. In this area the group consists chiefly of schistose, greenschist facies, meta-basalts and meta-andesites. Distorted pillows and amygdules are common in these flow rocks. In some places, red chert fills interstices between pillows. Minor amounts of schistose, intermediate to basic tuff is associated with the flow rocks. Along the northwest shore of Southwest Arm and in a fault-bounded wedge south of Western Arm (Green Bay), near the eastern boundary of the map-area, deformation is less intense and original textures are preserved in the volcanic rocks. Beds of chert, slate, greywacke, and pyroclastic rocks are intercalated with the lavas at both these localities and, in some places, are the predominant rocks.

The group was named by Espenshade (1937) in an adjacent area to the east. The thickness has been estimated at 15,000 feet by MacLean (1947), but this is probably an exaggeration as the present study suggests that the Lush's Bight Group is tightly folded and that there has been more repetition of beds than recognized by MacLean.

A single Early Ordovician fossil has been recovered from a shaly member of the group about 2 1/2 miles south of the head of Western Arm (MacLean, 1947, p. 4).

Exploits Group (Map-units 6A-C)

Much of the eastern boundary region south of Halls Bay is underlain by rocks of the Exploits Group[1]. According to Kalliokoski (1953, 1955) the oldest rocks of the group (map-unit 6A) consist of basal greywacke conglomerate and slate, which are overlain by a unit consisting of greywacke with minor slate, pyritic shale, conglomerate, and basalt which, in turn, is overlain by a pillowed basalt formation. Stratigraphically above this is the Crescent Lake Formation (map-unit 6B), which consists chiefly of siliceous and

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[1] The name "Exploits Group" (Heyl, 1936) has precedence over the name "Badger Bay Group" (Espenshade, 1937) previously used to refer to these rocks (see also Williams, 1962).

tuffaceous shale with minor chert, greywacke, and rhyolitic flow rocks. The Roberts Arm Formation (map-unit 6C) above the Crescent Lake, consists chiefly of basaltic flow rocks, minor basic intrusive rocks, pyroclastic rocks, and silicic flow rocks. The basaltic flow rocks are generally devoid of primary structures. Near Loon Pond and in the area immediately west of Dawes and Gull Ponds, Kalliokoski mapped a facies of the Roberts Arm Formation that consists dominantly of silicic volcanic rocks. Similar silicic volcanic rocks west of King's Point road, which Kalliokoski tentatively included in the Roberts Arm Formation, are now included in a Silurian unit (map-unit 13).

The Exploits Group contains Middle Ordovician fossils in the adjacent area to the east (Heyl, 1936; Williams, 1962). Kalliokoski collected graptolites (Diplograptus sp.) from unit 6A along the Canadian National railway in the southeastern corner of the map-area, which indicate a Middle Ordovician or later age. Seven miles south of this locality, on an island in Exploits River, New Jersey Zinc Company geologists have collected graptolites from the same unit. These were identified by L.M. Cumming as Climacograptus cf. Patus Elles and Wood, and also indicate a Middle Ordovician or later age.

Baie Verte Group (Map-unit 7)

This group underlies the northeastern corner of the map-area and also extends as a narrow belt southwestward from Baie Verte to Black Brook. Isolated outcrops of metamorphosed basic pyroclastic rocks along the eastern edge of the ultrabasic belt (map-unit 8), south of Black Brook, may also belong to this group, but are not large enough to map at this scale.

The Baie Verte Group is lithologically similar to the Lush's Bight Group. It consists chiefly of schistose, greenish grey andesite and basalt of the greenschist metamorphic facies, with lesser basic to intermediate pyroclastic rocks and a variety of meta-sedimentary rocks. Ellipsoidal and bun-shaped pillows, feldspathic, silicic, and calcitic amygdules, and variolitic structures are commonly preserved in the flow rocks. A few flows of rhyolite and rhyolite porphyry are apparently intercalated with the basic flow rocks in the region immediately north and northeast of Rambler Pond. Thin sills of leucocratic meta-diorite are common within the basic flow rocks. Sedimentary rocks include greywacke, black graphitic slate, red and black slaty argillite, and red and grey chert. In the region west of Baie Verte, the assumed upper part of the group consists dominantly of these sedimentary rocks (Neale, 1958).

The Baie Verte Group was named by Watson (1947), who estimated a minimum thickness of 9,000 feet. No fossils have been found within the group although all readily accessible sedimentary units were examined by L.M. Cumming during the 1960 field season. As the group is lithologically very similar to Ordovician sequences (e.g. map-units 5 and 6) of the Notre Dame Bay area, it is probably also of Ordovician age.

Ordovician (?)

Ultrabasic Rocks (Map-unit 8)

A discontinuous belt of ultrabasic rocks, 60 miles long, extends from the northeastern end of Birchy Lake north-northeastward to the region west of Baie Verte and beyond. This belt is located chiefly between Precambrian(?) rocks on the west and Baie Verte Group rocks on the east. It may terminate southward against the fault zone along Birchy Lake, but an outcrop of serpentinized ultrabasic rock at the southwest end of the lake suggests that it could extend parallel to the fault zone and underlie Birchy Lake and the Carboniferous cover rocks southwest of the lake. Ultrabasic plutons also occur within rocks of the Baie Verte Group near Ming's Bight, within Fleur de Lys granitized gneisses (map-units 2 and 18b), within rocks of the Exploits Group near Gull and Dawes Ponds, and within rocks of the Lush's Bight Group immediately south of Southwest Arm.

West of Baie Verte, the ultrabasic rock is reddish-brown-weathered peridotite in which greyish green and greenish brown pyroxene crystals are set in an aggregate of dark green, serpentinized olivine grains. Serpentinization was more extensive in peridotite of the Flatwater Pond region than it was in the peridotite west of Baie Verte, but relic pyroxenes are discernible in more than half of the outcrops. Serpentinization of the main outcrop belt was more complete in the region from Mic Mac Lake southwestward to Birchy Lake than it was in the northern part of the belt, and relic pyroxenes are rare. The pluton south of Ming's Bight is also almost completely serpentinized. Dykes of coarse-grained pyroxenite are common in the region around Ming's Bight, and Kalliokoski (1955) has mapped a relatively large body of pyroxenite between Gull and Dawes Ponds. Rusty-weathered talc and talc-carbonate rocks, cut by numerous quartz stringers, occur along the margins of the Ming's Bight pluton, along part of the east margin of the Flatwater Pond pluton, and west of Mic Mac Lake. Ultrabasic rocks in the Fleur de Lys gneisses are also much altered to talc-carbonate rock.

The ultrabasic rocks are almost wholly within Ordovician or older rocks. Where they are in juxtaposition with younger rocks of map-unit 10 south of Black Brook, an intervening fault zone is suspected. Tentatively, the ultrabasic rocks are interpreted as Ordovician.

Meta-diorite and Meta-gabbro (Map-unit 9)

Meta-diorite and meta-gabbro, with minor pegmatitic facies, occur in the region around Baie Verte and Ming's Bight. They are chiefly light greenish grey, medium-grained, commonly massive rocks, and consist of saussuritized plagioclase, actinolite, and, rarely, relics of original pyroxene. West of Baie Verte, at and beyond the northern boundary of the map-area, massive to schistose white rock, composed chiefly of zoisite and quartz with minor amounts of albite and bright green chrome mica, may constitute a highly altered phase of the diorite and gabbro. The westernmost body of meta-gabbro, near the head of Baie Verte, is altered to a white zoisite-prehnite aggregate at its northern extremity (Watson, 1947).

A small body of gabbro mapped by Kalliokoski (1955), west of Joes Lake on the Badger - Halls Bay road, is tentatively included in unit 9.

The meta-diorite and meta-gabbro bodies are intrusive into rocks of Ordovician or probable Ordovician age. Near Baie Verte, spatial relationships suggest that the meta-diorite and meta-gabbro may be genetically related to the ultrabasic rocks.

Granodiorite and Associated Intrusive Rocks (Map-unit 10)

A distinctive suite of greenish grey and, less commonly, pinkish grey granitic rocks, which range in composition from quartz diorite to granite, outcrops east of the Baie Verte road. Granodiorite is the most abundant member of this suite, which has been called the "Burlington granitic rocks" by Baird (1951). Rocks of this suite are generally massive, but in places they are well foliated. They commonly consist of saussuritized sodic plagioclase, 10 to 30 per cent pale blue, smoky, or clear quartz, and 10 to 15 per cent chloritized hornblende and/or biotite. In a few places, e.g. immediately east of Southwest Arm of Green Bay, these quartz-bearing rocks appear to grade into greenschist-facies meta-diorite and meta-gabbro, which are not separately mapped.

This intrusive suite has previously been interpreted as Devonian (Baird, 1951; Neale, 1958). It cuts metavolcanic rocks of the Baie Verte Group (map-unit 7) and was previously interpreted as intrusive into rocks of map-unit 11 (Neale, Nash, and Innes, 1960) on the basis of intrusion breccias and basic inclusions that occur east of the north half of Mic Mac Lake. However, field work during 1961 in the region immediately south of Flatwater Pond showed that basal conglomerate of map-unit 11 rests unconformably on greenish grey granodiorite, and rhyolitic dykes and breccia dykes, which appear to be feeders to the rhyolite sills and flows of map-unit 11, cut the granodiorite.

In the light of this evidence, it is probable that the intrusion breccias and inclusions east of Mic Mac Lake involve rocks of map-unit 7 rather than those of map-unit 11. As map-unit 11 is tentatively interpreted as Silurian, the underlying granodiorite and associated intrusive rocks are tentatively interpreted as Ordovician. A K/Ar determination of 373 m.y. on biotite from granodiorite at

Middle Arm, Green Bay, is indicative of a Devonian age. However, in this locality, the granodiorite is cut by dykes of rhyolite and quartz-feldspar porphyry (map-unit 16) and a syenite pluton (map-unit 18a), so that it is probable that the biotite is a product of recrystallization during this later period of intrusive activity.

Silurian (?)

Map-unit 11

Intercalated silicic and basic volcanic rocks and clastic sedimentary rocks outcrop in a roughly linear belt, in places offset by faults, that extends from the south end of Flatwater Pond to Sheffield Lake and the southeastern shore of Birchy Lake. These rocks are bounded on the west by the Baie Verte Group and ultrabasic rocks and on the east and southeast by granitic rocks.

Silicic volcanic rocks (11a) are most abundant. They include buff, pale red, brown, grey, and black aphanitic and porphyritic rhyolite, trachyte, and latite flow rocks, and pale red, crystal-lithic tuff, lapilli tuff, and agglomerate. Silicic tuff and agglomerate are relatively rare in the northern part of the outcrop belt but common south of Mic Mac Lake, especially in the area south of Birchy Lake. Flow structures and spherulitic structures are common in the flow rocks. Fragments in the pyroclastic rocks are chiefly silicic and basic lavas, with minor granitic rocks, metadiorite, and dark metasedimentary rocks. Quartz-feldspar porphyry, relatively common in the southern part of the outcrop belt, may be either genetically related to the intercalated silicic flow rocks or may represent later intrusive activity.

Basic volcanic rocks (11b) are comparatively rare north of Mic Mac Lake, but common on the islands and shore of the lake and also to the south. These rocks are mostly massive to slightly schistose, purplish grey, dark greenish grey, and black amygdular basalts and, locally, bright green andesite. Lapilli tuff and agglomerate of basaltic composition are relatively rare. Intersertal textures are common in the basic flow rocks. Amygdule fillings consist of chlorite and white and pink calcite. Pillows are known only within a few thin andesite flows exposed on the islands of Mic Mac Lake.

Sedimentary rocks (11c) include pale brown, greyish red, and pale grey conglomerate, sandstone, and siltstone, which outcrop as far south as Gillards Lake, but which are most common in the region north of Black Brook. Primary features, well preserved in most of these rocks, include crossbedding, grain gradation, and scour-and-fill structures. Pebbles, cobbles, and boulders in the conglomeratic facies vary from subangular to rounded and are commonly stretched parallel to schistosity in the deformed members of the group. These sediments are characterized by weak schistosity, commonly at small angles to bedding planes. Where associated with shear and fault zones, e.g. along Black Brook, they have been converted to sericite and chlorite-sericite schists. In a few localities, e.g. south of Gillards Lake, red sandstones of this sequence are massive and strongly resemble the sediments of the Springdale Group (map-unit 15c). Clastic fragments in most of these sediments consist almost wholly of the associated volcanic rocks (11a, b). However, conglomerates on the islands of Mic Mac Lake also contain pebbles and cobbles of quartz-feldspar porphyry and massive to gneissic, pale red granite. Conglomerates in the region immediately south of Flatwater Pond contain cobbles and boulders of medium-grained, greenish grey granodiorite (map-unit 10).

Field work in 1961 in the region immediately south of Flatwater Pond showed that this sedimentary-volcanic sequence unconformably overlies the granodiorite and related rocks (map-unit 10) that bound it on the east and that it is faulted against Ordovician volcanic rocks (map-unit 7) to the west. In places, rhyolitic rocks have been intruded along the western boundary fault. The rocks of unit 11 are less metamorphosed than the adjacent Ordovician volcanic rocks and greatly resemble those of the Cape St. John Group which unconformably overlies Ordovician rocks in an adjacent area to the east (Neale, 1957). These facts suggest that an important orogenic event, accompanied by granitic intrusion, took place following deposition of the Ordovician rocks of the central and eastern parts of the map-area and prior to deposition of unit 11. Tentatively, unit 11 is interpreted as Silurian.

Map-unit 12

This unit includes rocks on the west shore of White Bay that occur stratigraphically between the Ordovician(?) Doucers Formation (map-unit 4) and the fossiliferous, Middle Silurian Natlins Cove Formation (map-unit 13).

These rocks have been divided into four mappable units by Heyl (1937b) and Betz (1948), of which three (map-units 12A, B, C) are distinguished on this map. A fourth map-unit—the Deadmans Cove volcanic member of the Giles Cove Formation—is not shown separately on this map.

The Giles Cove Formation (map-unit 12A), named by Heyl (1937b) for exposures near Giles Cove at the head of Sops Arm, consists of well-bedded bluish grey and dark greenish grey shales, which in most places are characterized by a rude slaty cleavage. South of Sops Arm, the rocks of this formation are commonly schistose—especially near major granitic intrusive bodies. Evidence of pyrophyllitization is common near contacts with intrusive porphyry (map-unit 16a). Greenish grey andesite flows and tuffs (Deadmans Cove Member) are intercalated with shale and schist in the upper part of the formation. Silicic tuff and agglomerate and their water-worked equivalents are associated with the andesite and also occur elsewhere in the formation. Where closely associated with quartz-feldspar porphyry, they are separately mapped as unit 15.

The Jackson's Arm Conglomerate (map-unit 12B), named by Heyl (1937b) for exposures near the head of Jackson's Arm where it has an estimated thickness of 3,000 feet, was originally interpreted as a member of the Giles Cove Formation. Following the suggestion of Betz (1948, p. 8), it is here interpreted as a separate map-unit. It overlies the Giles Cove Formation in the region immediately south of Jackson's Arm. Typically, the conglomerate is greenish grey and consists of pebbles, cobbles, and boulders of silicic volcanic rocks with minor amounts of basic volcanic rock, clastic sediments and, rarely, granitic rocks.

The Simms Ridge Formation (map-unit 12C) has a measured thickness of 2,340 feet along the south shore of Sops Arm (Heyl, 1937b). It consists of grey to pale green, fine- to medium-grained arkosic sandstone at the base (ca. 300 feet thick), which is overlain by varicoloured shales. According to Heyl, the shale units are commonly "spotted" owing to the presence of numerous euhedral metacrysts of siderite. Limy beds, rare in the northern exposures, are commonly intercalated with the shales in the southern part of the sequence.

Heyl (1937b) reported probable crinoid stems from both the Giles Cove and Simms Ridge Formations and tentatively interpreted both formations as Ordovician on the basis of lithology and relationship to overlying Silurian rocks. Lithologically these formations partly resemble unit 11 and differ from the known Ordovician rocks of the area. The Simms Ridge Formation grades conformably upward into fossiliferous Middle Silurian rocks so that unit 11 probably is, at least in part, of Silurian age as suggested by Betz (1948, p. 8).

Silurian

Natlins Cove Formation (Map-unit 13)

This formation was named for Natlins Cove on the south shore of Sops Arm (Heyl, 1937a, b). It consists mainly of fine- to medium-grained, grey and greyish brown feldspathic and argillaceous sandstone with interbeds of limestone and limy siltstone and rare beds of conglomerate. Coarse arkosic sandstone and cobble-conglomerate are relatively common in the northern exposures, particularly between Jackson's Arm and Frenchman's Cove. Clastic fragments in the conglomerate consist chiefly of silicic volcanic rocks and quartz-feldspar porphyry, but include important amounts of fine- to medium-grained massive granite and also shale and siltstone that may have been derived by erosion from unit 12.

Heyl mapped 1,675 feet of rhyolitic and andesitic volcanic rocks as a middle member of this formation. These rocks, which extend southwestward from the east shore of Sops Island, are closely associated with intrusive quartz-feldspar porphyry and are included in unit 16 on the accompanying map.

Amygdaloidal andesite and basalt flows are exposed along the coast immediately south of Frenchman's Cove where they are intercalated with shale, sandstone, and conglomerate beds.

Well-developed cleavage, which grades, locally, into schistosity is common in rocks of the Natlins Cove Formation. Near Jackson's Arm, it is recognizable as axial plane cleavage.

A thickness of 10,700 feet is reported by Heyl (1937a,b) along the south shore of Sops Arm. However, our reconnaissance work in this region suggests that the formation is thinner owing to the possibility of repetition of section by folds and/or faults in this region.

There are several fossil localities in the Natlins Cove Formation and the following early Middle Silurian forms, collected by Heyl, have been identified by W.H. Twenhofel (Heyl, 1937a,b).

Favosites gothlandicus
Favosites hisingeri
Clathrodictyon vesiculosum
?*Cladopora* species
Heliolites ?interstincta
?*Pentamerus*
Indeterminate "*Orthoceras*"

In addition, L.M. Cumming has collected the brachiopod *Dayia* sp.

Map-unit 14

Southwest of Southwest Arm, Green Bay, in the east-central part of the map-area, Silurian fossils occur in thin beds of limestone that are intercalated with volcanic rocks. The volcanic rocks, which include both flow and pyroclastic rocks, range in composition from rhyolite to basalt. Slightly more than half of these fall into the rhyolite-dacite classification. The flow rocks in this category are massive to slightly schistose, pale red, grey and greenish grey, and commonly porphyritic with quartz and feldspar phenocrysts. The basic flow rocks range from schistose pillowed andesites in the southwestern exposures to fresh, massive, amygdaloidal purplish grey basalts in the eastern part of the outcrop area. Apart from the limestone beds, the only sedimentary rocks of this unit are scattered occurrences of thinly layered grey chert.

Unit 14 differs from nearby Ordovician rocks, from which it is at least partly separated by faults, in its abundance of silicic volcanic rocks and its generally lower grade of metamorphism. The southwestern exposures were tentatively referred to the Ordovician Roberts Arm Formation by Kalliokoski (1953). However, the eastern exposures were included in the Springdale Group by MacLean (1947). The fossil evidence favours MacLean's correlation, but it is possible that some of the schistose pillowed lavas to the southwest are Ordovician as suggested by Kalliokoski, for there is some slight structural evidence to favour this interpretation.

Fossils in limestone at several localities near the south end of Silver Pond (also known as South Catcher Pond) were first discovered by geologists of British Newfoundland Exploration Limited in 1959. Collections identified by L.M. Cumming include the following Middle Silurian (Guelph) assemblage:

Prionopeltis archiaci (Barrande)
cf. *Prolucina* (*Ilionia*) *galtensis* Whiteaves cf. *Reticularia septentrionalis* Whiteaves
Triplesia sp.

Silurian and (?) Later

Springdale Group (Map-unit 15)

The term "Springdale Formation" was first used by Espenshade (1937) to refer to red beds exposed around Springdale village and also on Pilley's Island, east of this map-area. Subsequently, MacLean (1947) mapped volcanic units intercalated with the red beds and referred to the sequence as the "Springdale Group". Later mapping by Kalliokoski (1953, 1955) has shown that the group consists dominantly of volcanic rocks with, at most, 15 per cent sedimentary members. Kalliokoski has distinguished twelve mappable units, most of which could have formational status. It was not possible to show them all on the map accompanying this report, owing to the scale, nor was it possible to project them into unmapped regions by reconnaissance methods. However, the broad lithological division presented here adequately shows the major aspects of stratigraphy and structure.

The lowermost unit of the Springdale Group in this area is red arkosic sandstone with thin conglomerate interbeds (map-unit 15c) exposed along and near the valley of South Brook, a few miles west of Gull Pond. According to Kalliokoski (1955), it consists largely of granitic debris, much of which resembles granitic rocks that outcrop 5 miles east of the map-area. Kalliokoski did not describe the relationship of this sedimentary unit to the granitic and dioritic rocks, but his legend suggests that it could be younger than some of the dioritic rocks although older than and intruded by the granitic rocks.

Overlying this thin sedimentary unit is approximately 10,000 feet of silicic (map-unit 15b) and basic (map-unit 15a) volcanic rocks with minor amounts of intercalated sandstone and conglomerate. The silicic flow rocks include pale red and, rarely, pale grey rhyolite, quartz latite, and trachyte, all of which commonly exhibit flow layering and spherulitic structure. Also included in map-unit 15b is quartz-feldspar porphyry, which Kalliokoski (1955) interpreted partly as a flow rock, partly as a crystal tuff. This rock resembles that of map-unit 15a and may be at least in part of intrusive origin. Silicic tuff and agglomerate consist chiefly of fragments of volcanic rock with rare fragments of granitic and metasedimentary rocks. Silicic breccias in places, e.g. Goodyear Cove of Halls Bay, cut flanking tuff beds and flows and apparently represent extrusive vents. The basic flow rocks are chiefly dark purplish grey, black, and reddish grey massive basalts and lesser greenish grey andesite. Amygdular varieties are common and the vesicle fillings include chlorite, serpentine, calcite, quartz, chalcedony, prehnite, zoisite, and epidote (MacLean, 1947). The only pillows noted occur east of King's Point road in thin basaltic flows that are intercalated with clastic sediments.

Red conglomerate, arkosic sandstone, limy siltstone, and shale (map-unit 15c) in the region west of Halls Bay overlie the thick volcanic section and represent the uppermost beds of the Springdale Group in this map-area. Minor amounts of rhyolite and amygdaloidal basalt and sheet-like bodies of quartz-feldspar porphyry are locally intercalated with these sediments. Fragments in the conglomerates consist mostly of fresh-looking volcanic rocks and quartz-feldspar porphyry, but also include altered volcanic rocks and massive, medium-grained granitic rocks. These sediments are highly indurated and fracture planes cut through fragments and matrix alike. This feature has commonly been overlooked because of the apparently friable aspect of the easily decomposed, limonite-cemented red beds in rubbly road-cuts. Crossbedding, scour-and-fill structures, and current-ripple marks suggest a fluviatile origin for most of these beds.

At the head of Southwest Arm, approximately 4,500 feet of red clastic sediments (map-unit 15d) is included in the Springdale Group. On the east side of the Arm the basal part of the section consists of red arkosic conglomerate and sandstone, which are overlain by maroon and greenish grey shale and siltstone with limy nodules and thin, pale grey, limestone interbeds. The upper 2,000 feet of the sequence, chiefly concealed beneath the waters of the Arm, is represented by a few outcrops of arkosic sandstone and conglomerate on the west side of the Arm and by red sandstone that is faulted against Ordovician metavolcanic rocks along the southeast shore of the Arm. This sequence, together with a few outcrops near the mouth of Rattling Brook on the west shore of the Arm, was originally referred to the "Springdale Group" by MacLean (1947). His correlation was disputed by Neale, Nash, and Innes (1960) because these rocks appeared much less indurated than typical Springdale sediments. However, preliminary paleomagnetic studies carried out by R.F. Black in 1961 show that, although the Southwest Arm sediments differ in polarity from the typical Springdale sediments and volcanic rocks, there is little difference in mean directions of magnetization. It is, hence, tentatively concluded that the sediments at Southwest Arm differ only slightly in age from the Springdale sediments west of Halls Bay.

The only fossils known from the Springdale Group are unidentifiable plant fragments collected by Heward Peters (personal communication) at Southwest Arm and on Pilley's Island, east of this map-area. Originally the Springdale Group was interpreted as younger than the nearby granitic rocks (map-unit 18)—a reasonable conclusion as it is largely unmetamorphosed and contains granite fragments. However, Kalliokoski's maps (1953, 1955) and Nash's study show that rocks of this group are intruded and locally metamorphosed by granite.

The Springdale Group has been correlated with the Botwood Group in the adjacent area to the east (Twenhofel, 1947) and has been assigned a possible Devonian age on the basis of fossiliferous Silurian fragments within conglomerates of the Botwood Group. However, the recent work of Williams (1962) has shown that shaly interbeds of the Botwood conglomerates also contain Silurian fossils and, hence, that the Botwood Group is of Silurian age. This, together with the similarity of the Springdale rocks to some of the known Silurian rocks near King's Point road (Neale, Nash, and Innes, 1960) suggests that the group is Silurian in age.

Porphyry and Associated Volcanic Rocks (Map-unit 16)

Quartz-feldspar porphyry, commonly associated with silicic volcanic rocks, is widely distributed in the northern half of the map-area. It also occurs in the southern half of the map-area as sills, which were not mapped separately, in rocks of the Springdale Group and map-unit 11.

The porphyry is commonly pale reddish grey or pale brown and weathers to buff or pale yellowish brown. It consists of phenocrysts of quartz and/or feldspar, which average 1/4 inch but range up to 3/4 inch in maximum dimension, set in a fine-grained to aphanitic felsic groundmass. The quartz phenocrysts are commonly rounded and embayed by the groundmass. The feldspar phenocrysts include both euhedral perthitic K-feldspar and/or sodic plagioclase. The groundmass consists of quartz and feldspar with small amounts of finely divided biotite and magnetite. Evidence of sericitization is common. Compositionally, most of these rocks range from soda rhyolite to trachyte. In a few places, thin porphyry dykes, which consist almost wholly of albite and quartz, are best classified as quartz keratophyre.

Some of the porphyry (map-unit 16a) is definitely intrusive in origin, as for example in the northwestern corner of the map-area where porphyry, originally called the "Cap Brule granite" by Baird (1951), cuts Ordovician rocks (map-unit 7); and also in the region between Burlington village and Flatwater Pond (Neale, 1958), where a partial ring dyke of porphyry cuts granodiorite (map-unit 10).

West of the headward part of White Bay, quartz and quartz-feldspar porphyry outcrops as a sheet-like body between granitic rocks and Silurian sediments (Betz, 1948). Northward, this sheet-like body extends to Sops Island (Heyl, 1937b). Nash's study of this northern region suggests that the 'intrusive' sheet is disrupted by numerous faults and that the porphyry is intimately intermingled with flow-layered silicic volcanic rocks, tuffs, and agglomerates. Westward, near the head of Sops Arm, similar co-mingling of porphyry and extrusive rocks is apparent.

The largest bodies of porphyry and associated volcanic rocks occur in the northeastern quarter of the area, between Baie Verte road and Southwest Arm of Green Bay. There the porphyry appears to grade, in places, into subporphyritic syenite and massive red granite (map-unit 18a). On the shore of Middle Arm, dykes of quartz-feldspar porphyry, syenite, and red granite intrude granodioritic rocks (map-unit 10). Silicic agglomerate, tuff, and flow rocks (map-unit 16b) associated with the porphyry are in places intruded by the porphyry. In other places, however, relationships are gradational and suggest that porphyry sills served as feeders to the flow rocks (cf. MacLean, 1947, p. 7).

The simplest explanation of the relationships is that the silicic volcanic rocks are older than the granitic rocks and that the porphyry is genetically related to the granitic rocks (some of which are radiometrically dated as Devonian). This is the interpretation of most workers in this and adjacent areas. According to this interpretation, the gradational porphyry-volcanic relationships are explained by lithological similarity of volcanic feeder sills to the main mass of later (Devonian) porphyry.

However, a contrasting hypothesis merits consideration, namely that emplacement of most of the porphyry was related to Silurian volcanism. Favouring this hypothesis is the fact that most of the porphyry is associated with sedimentary and volcanic rocks of Silurian or presumed Silurian age (units 11-15). The only exceptions are apophyses of a large porphyry body that extends into rocks of the Baie Verte Group (Neale, 1958; Baird and Neale, 1958) and a few thin dykes in the Lush's Bight and Fleur de Lys Groups. Further, much of the conglomerate (11c, 12B, 13, and 15c,d) associated with the porphyry contains pebbles of similar porphyry. Also, in places, e.g. north of the head of Sops Arm, rounded cobbles and boulders occur within a 'matrix' of quartz porphyry, which suggests that the porphyry may have been intruded into unconsolidated gravels. If the porphyry is chiefly related to Silurian volcanism, then either the red syenitic and granitic rocks west and southwest of Green Bay (map-unit 18a) that in places appear to grade into it, must also be Silurian and, hence, not directly related to the 373 m.y. radiometric age of biotite at Middle Arm; or the syenite and granite are later (Devonian?) than most of the porphyry and have porphyritic marginal facies that cannot be distinguished from the main mass of porphyry. The latter is more likely as there are several examples of granite and associated quartz-feldspar porphyry that cut silicic flow rocks on the highland west of Southwest Arm.

Evaluation of these hypotheses will require detailed mapping and petrographic and chemical studies of the porphyry and related rocks.

Pre-Carboniferous Intrusive Rocks

Intermediate and Basic Intrusive Rocks (Map-unit 17)

These rocks outcrop most commonly in the southeastern quarter of the map-area where they have been mapped and briefly described by Hayes (1951a,b) and Kalliokoski (1953, 1955). They range from quartz diorite to gabbro. The texture is commonly hypidiomorphic and equigranular. Hornblende is the chief mafic mineral in the diorite and gabbro, hornblende and biotite in the quartz diorite. Angular inclusions of metasedimentary and metavolcanic rocks are common. Kalliokoski (1955) noted that, near South Pond, quartz diorite grades eastward into gabbro at the contact with basic volcanic rocks (map-unit 6C). He also suggested that the intermediate and basic rocks, in part at least, represent a marginal phase of the granitic rocks.

In the central part of the map-area, a few miles south-east of Mic Mac Lake, the presence of a body of mafic syenite (map-unit 17a) within granitic rocks (map-unit 10) is reflected in relatively high aeromagnetic readings. It is typically a greyish red, medium-grained rock containing about 30 per cent hornblende. In places it grades into hornblende diorite and leucogabbro.

Quartz diorite, diorite, and gabbro also occur as three small bodies in the west-central part of the map-area. Northeast of the north end of Sandy Lake these rocks are characterized by a weak foliation. The two bodies east of White Bay are weakly foliated to massive and show evidence of rather intense saussuritization of the plagioclase and chloritization of the mafic constituents.

Granitic Rocks (Map-unit 18)

Slightly more than a third of the map-area is underlain by red granitic rocks, which chiefly range in composition from granite to granodiorite but, in places, include important amounts of syenite and quartz syenite.

Syenite, quartz syenite, and leucocratic granite (map-unit 18a) outcrop at and west of Southwest and Middle Arms of Green Bay and also as a body that extends from the northeast corner of Sheffield Lake northward to the Baie Verte road. Syenite that occurs with a wide variety of granitic rocks south and east of Indian Pond is mapped as undivided unit 18. The syenite is typically greyish red and pale reddish brown, contains accessory hornblende and, less commonly, biotite, and is generally medium grained and equigranular. However, near some of its contacts with silicic volcanic rocks, e.g. southwest of Middle Arm and south of the Trans-Canada Highway, it appears to grade through a sub-porphyritic phase into feldspar and quartz-feldspar porphyry. The syenite grades elsewhere into moderate reddish orange, leucocratic quartz syenite and granite. Leucocratic granite, which forms most of a small pluton on the west shore of Southwest Arm, is intrusive into nearby silicic volcanic rocks (map-unit 16b), apparently gradational into quartz-feldspar porphyry (unit 16a), and contains inclusions of syenite similar to the syenite with which, elsewhere, it exhibits gradational relationships.

Porphyritic biotite granite (map-unit 18b) exposed west of Baie Verte road is pinkish grey, contains 5 to 10 per cent biotite, and has K-feldspar phenocrysts more than 1 inch long. In places, gneissosity is imparted by aligned clots, wisps, and foliae of biotite, muscovite, and, rarely, hornblende. This rock grades, especially near its contacts, into hybrid gneiss and schist that are characterized by large K-feldspar porphyroblasts.

Two granitic bodies (map-unit 18c) west of White Bay are lithologically somewhat similar to uncontaminated facies of the porphyritic biotite granite (map-unit 18b) and may be genetically related. The granite of these bodies is pale to medium red, white weathered, very coarse grained, and equigranular to sub-porphyritic. The most abundant mineral is microcline, in crystals up to 2 inches long. Albite and quartz, the other major constituents, occur in approximately equal amounts. Accessories include about 5 per cent chloritized biotite and small quantities of muscovite. The larger of these two bodies intruded the Silurian(?) Giles Cove Formation. Fine-grained quartz-monzonite dykes that may be related to this granite (Heyl, 1937b) cut known Silurian rocks on Sops Island and along the shores of Sops Arm. However, these dyke rocks (undifferentiated map-unit 18) could conceivably be related to Silurian volcanism rather than to the main granitic intrusive activity. The smaller, northern, granite body west of Sops Arm cuts Precambrian rocks (map-unit 1) and is faulted against Palaeozoic rocks (map-unit 4). If Palaeozoic in age, as suggested by its lithological similarity to the southern body (Heyl, 1937b; Betz, 1948), it is the only known Palaeozoic intrusion within the Precambrian rocks of the Northern Peninsula of Newfoundland.

A granitic complex (map-unit 18d) in the southern part of the map-area has been called the "Topsails granite" by Baird (1959) in the adjacent area to the west. This complex consists chiefly of granite and quartz monzonite with lesser granodiorite. These rocks are mainly pale red to pale brown, less commonly shades of grey. Generally they are equigranular and medium to fine grained, although coarse-grained and porphyritic types are known. Partly chloritized hornblende is commonly the sole or dominant mafic mineral, but biotite-hornblende granite and biotite granite are known, particularly in the easternmost exposures (Kalliokoski, 1955). There are rare occurrences of muscovite-biotite granite in the northwesternmost exposures.

Granitic rocks of map-unit 18 intrude most of the probable Silurian units in the map-area, e.g. map-units 10, 12A, and 15. Relationships with the fossil-dated Middle Silurian units (13 and 14) are obscure. However, these units are cut by quartz-feldspar porphyry bodies, which may, as stated above, be related to some of the granitic rocks. K/Ar dates suggest Devonian ages of 358 m.y. for biotite in porphyritic granite at the south end of Wild Cove Pond and 373 m.y. for biotite in Ordovician(?) granodiorite at Middle Arm. The date from Middle Arm is probably the age of recrystallization associated with intrusion of red syenitic and granitic rocks (map-unit 18a) and, possibly, associated porphyry dykes.

Most of the Palaeozoic granitic rocks of the Canadian Appalachian region have been assigned a Devonian age (Weeks, 1957) and this has generally been substantiated by radiometric dates (Fairbairn et al., 1960; Lowdon, 1960, 1961). Tentatively, then, map-unit 18 is interpreted as chiefly Devonian. However, a recent K/Ar determination of 484 m.y. (Lowdon, 1962), suggestive of an Early Ordovician age, was obtained on muscovite from the 'Topsails granite' south of Sandy Lake. With present sparse information, this date could be explained in several ways, but the fact that present work has already shown the presence of a probable Ordovician granite (i.e. map-unit 10) within the area suggests strongly that an unknown amount of such early granite may be included in map-unit 18.

Mississippian

Anguille Group (Map-unit 19)

This group outcrops on the west shore of White Bay southwestward from Sops Arm. Previously it was named the "Spear Point Formation" (Heyl, 1937b) but, as the name "Anguille Group" is used to refer to similar Lower Mississippian rocks in the adjacent area to the west (Baird, 1959) and elsewhere in western Newfoundland (Bell, 1948), it is used here in lieu of the original name.

The group consists chiefly of a steeply dipping, fault-bounded, red and grey clastic sequence with an estimated maximum thickness of 8,000 feet (Heyl, 1937b). The siltstone, sandstone, and conglomerate are mainly pale to medium grey, less commonly shades of red, and generally of arkosic composition. Muscovite flakes parallel to bedding planes are abundant in the grey sandstone and siltstone. Clastic fragments include quartz, both feldspars, sandstone, shale, silicic porphyry, and volcanic rock and, rarely, granitic rocks. Rounding is prevalent in boulders of the coarse conglomerates but rare in the finer clastic materials. Ripple-marks and crossbedding are abundant in some of the grey and practically all of the red sandstone and conglomerate. Shaly interbeds are commonly black or dark grey, less commonly red or green. The shales contain abundant mud-cracks; dark varieties contain plant debris. Limy beds are rare in the section. Betz (1948) noted dolomitic interbeds on the island near the head of White Bay and grey limestone at a few localities south of White Bay. A measured section of part of the group in the southern reaches of White Bay shows that red beds form a third of the group (Betz, 1948). The present study shows that this is the approximate proportion of red beds elsewhere in the outcrop area, and the authors agree with Betz that Heyl (1937b) minimized the significance of red beds in the type section of Sops Arm.

Plant fragments that occur in black shale near the northern limit of outcrop suggest Early Mississippian age and correlation with those of the Horton Group in Nova Scotia (Heyl, 1937b). Immediately west of the map-area, on Birchy Ridge, abundant plant remains in grey shale (Baird, 1959) strengthen this correlation.

Possible Windsor Group Equivalents (Map-unit 20)

Red sandstone and conglomerate that outcrop immediately beyond the western boundary of the map-area, west of White Bay, may extend a few hundred feet into the area. Baird (1959) has tentatively correlated these rocks with those of the Upper Mississippian Windsor Group of Nova Scotia.

Pennsylvanian

Red and grey, micaceous and arkosic conglomerate, sandstone, and siltstone that outcrop near the southeast shore of Sandy Lake are on strike with coal-bearing beds to the southwest that contain Early Pennsylvanian spores (Hacquebard, Barss, and Donaldson, 1960). It is possible that some of the rocks included in map-unit 21 underlie the coal-bearing beds and are of Late Mississippian age.

STRUCTURAL GEOLOGY

The rocks of the map-area are characterized by a north-northeast to northeast structural grain. This is equally true of the oldest gneisses and schists (map-units 1, 2), which appear to be parts of great north-northeast-striking anticlinoria, and of the youngest sediments (map-units 19-21), which are partly bounded by northeast- and north-northeast-striking faults and whose site and mode of deposition were probably related to movement along these faults.

The major faults of the area are parts of a fault system that extends from the southwestern tip of Newfoundland to the vicinity of Sandy Lake, from whence branches extend to White Bay, Baie Verte, Southwest Arm, and, possibly, to Halls Bay (Betz, 1943; Baird, 1954). There is evidence that some of these faults were active in Early Palaeozoic time and also that latest movement along some of them was in Carboniferous or post-Carboniferous time. Northwest- and east-striking transverse faults are, in places, known to cut the north-easterly faults. In most parts of the area, lack of stratigraphic details and reliable bedding attitudes makes it difficult to delineate fold axes. The available data suggest that Ordovician and Silurian rocks may have been subjected to only one, post-Silurian (probably Acadian) period of folding in the White Bay region. In the eastern part of the map-area, complex close folds in the Ordovician rocks, in contrast to relatively simple open folds in nearby Silurian(?) rocks, suggests two ages of deformation.

Faults

The major faults, which are related to the trans-Newfoundland fault system, include the north-northeast faults that bound the Mississippian rocks (map-unit 19) of White Bay, the fault zones associated with the ultrabasic rocks that extend from Birchy Lake to Baie Verte, the fault zone that extends from Birchy Lake to Southwest Arm, and the Lobster Cove fault (Espenshade, 1937), which extends southwestward from Springdale on Halls Bay and which may be a branch of the Southwest Arm fault.

The faults that bound the Mississippian rocks of White Bay separate them from Silurian sediments and Devonian granitic rocks on the west and from Precambrian (?) gneisses on the east. Southwestward, these faults lie entirely within Carboniferous rocks (Baird, 1959). The western fault is marked by a linear valley along much of its length and, at the coast, by contortion in the rocks on both sides of it. Subsidiary faults within the Mississippian rocks dip moderately to steeply eastward; drag effects suggest that latest movement in the vertical plane was east side up relative to west side (Heyl, 1937b, pp. 19-20). Evidence for the eastern boundary fault consists of shear zones and distortion in the Mississippian rocks near the fault and the juxtaposition of these unmetamorphosed rocks to the schists and gneisses of the Fleur de Lys Group.

A parallel fault, possibly related to the faults that bound the Mississippian rocks, is located at the base of the Precambrian upland in the northwestern corner of the area. It is characterized by a linear valley, slickensides, and contortion, and in the valley of Doucers Brook by a steep, east-dipping gouge zone about 4 feet thick (Heyl, 1937b). Southward, it lies entirely in Ordovician marble and apparently dies out immediately beyond the limits of the map-area (Baird, 1959). Latest activity on this fault occurred after the intrusion of Devonian (?) granitic rocks.

A steeply dipping fault zone and a linear belt of ultrabasic rocks mark much of the contact between the Fleur de Lys gneisses and the Ordovician (?) and Silurian (?) volcanic and sedimentary rocks to the east. Movement along the fault zone has been west side upward relative to east side. North-northeasterly striking faults bound most of the individual plutons of the ultrabasic belt. The ultrabasic rocks were probably intruded along a major fault zone and were further faulted following emplacement. A parallel, possible subsidiary fault that extends north-northeastward from Flatwater Pond partly separates Ordovician (?) rocks from granitic rocks.

The major northeast-striking fault between Birchy Lake and Southwest Arm lies chiefly along drift-filled valleys. Near Birchy Lake it separates Fleur de Lys gneisses and associated granitic rocks from rocks of map-unit 11. Silurian(?) rocks north of Sheffield Lake appear to have undergone right-hand lateral displacement along the fault. The fact that sedimentary members of this unit (11c) are common on the north side of the fault and lacking on the south side, may imply a significant vertical component of movement. Near Shoal Pond the fault separates granitic rocks from Silurian volcanic rocks. Northward, where identical flow and intrusive rocks (map-unit 16) appear on either side of the fault, rocks along the fault-line scarp are characterized by steep, southeast-dipping shear zones. The fault-line scarp, near Rattling Brook village, separates Ordovician flow rocks and Silurian(?) sediments from porphyry and silicic volcanic rocks (map-unit 16).

A major, steeply-north-dipping fault, known as the "Lobster Cove fault" (Espenshade, 1937), separates the Ordovician Lush's Bight Group from the Silurian Springdale Group west of Springdale village. The Springdale rocks, commonly gently dipping in this region, are overturned, sheared, and brecciated along the fault zone. This fault either merges with or is offset by a fault that extends through Davis Pond, parallel to the Little Bay road, and which may join southwestward with the Birchy Lake - Southwest Arm fault. Offsetting of the Lobster Cove fault along the Davis Pond fault, originally suggested by MacLean (1947), appears the most logical explanation for the outcrop pattern of the Springdale Group. If correct, it necessitates a 2 1/2-mile, right-hand, lateral displacement along the Davis Pond fault.

Small northeast and north-northeast longitudinal faults have been mapped in the southeastern quarter of the map-area (Kalliokoski, 1953, 1955) where they are, in several localities, associated with mineral deposits.

East-striking transverse faults are also mapped in the southeastern quarter of the map-area. In most of these, movement has been north side up and eastward (i.e. right-handed). An easterly-striking fault at Middle Arm, Green Bay, displays evidence of brecciation and mylonitization of associated granite and volcanic rocks exposed in the valley of Middle Arm Brook. It may be subsidiary to the Southwest Arm fault.

Northwest-striking transverse faults are mapped within the Springdale Group and within the ultrabasic rocks and surrounding rocks (map-units 2, 7, 11 and 18). Those within the Springdale Group are projections of faults mapped by Kalliokoski (1953) and by company geologists. These or similar faults are required to explain the map pattern of the synclinal structure that Kalliokoski's stratigraphic sequence suggests in this area. The northwest faults associated with the ultrabasic rocks are chiefly characterized by left-hand lateral displacement. A significant vertical component of movement is associated with at least some of them, e.g. the northwest fault near Black Lake, which cuts off the outcrop belt of the Baie Verte Group. Where relationships are discernible, latest movement along these transverse faults appears to postdate latest movement along the major northeast faults.

Folds

The earliest period of folding in this area took place in Precambrian time and involved the schists and gneisses (map-unit 1) that unconformably underlie basal Cambrian quartzite in the northwestern corner of the map-area (Heyl, 1937b). Farther north, radiometric ages ranging around 950 m.y. on granites (Clifford and Baird, 1962; Lowdon, 1962) suggest that intrusion and initial folding of the Precambrian rocks was related to climactic orogeny in the Grenville province. If the granite west of the head of Sops Arm is Palaeozoic, as suspected on lithological grounds (Heyl, 1937b), then the Precambrian rocks in the map-area may also have been subjected to Palaeozoic deformation.

Foliation and most of the rare bedding trends in the Fleur de Lys Group suggest that it constitutes a northeast-trending anticlinorium as suggested by Baird (1951). The present writers suggest that part of the west flank and possibly part of the east flank of this anticlinorium consist of Palaeozoic rocks. North of the map-area, rocks along the east flank are structurally conformable with metavolcanic rocks of the Ordovician (?) Baie Verte Group (Neale, 1959). It is possible that the rocks in the core of the anticlinorium were first folded during Precambrian time but, if so, Devonian metamorphism, intrusion, and folding have obscured their relationships to the flanking rocks.

The Palaeozoic rocks along the west shore of White Bay are apparently a structurally conformable, east-dipping sequence (Heyl, 1937a, b), as shown by the regional distribution of map-units 3, 4, 12 and 13. However, because of deformation, detailed evidence of structural conformity is lacking. The present study has outlined a major, north-northeast-striking, south-plunging, synclinal axis that extends from Frenchman's Cove to Jackson's Cove and beyond. A syncline in the Silurian rocks between Spear Cove and Little Spear Cove, on the south shore of Sops Arm (Heyl, 1937b) could, conceivably, be an extension of the Frenchman's Cove syncline. Murray (Murray and Howley, 1881, p. 18) originally suggested that the Palaeozoic rocks of this area occupied a huge syncline and that strata on the west side of the bay were, in part, repeated on the east side of the bay. This interpretation was disputed by Betz (1948). However, the discovery on Granby Island of west-facing clastic beds resembling those of the Natlins Cove Formation, and the similarity of marble beds (map-unit 2b) on the east shore of White Bay to those of the Doucers Formation on the west side, tend to support Murray's interpretation. This hypothetical synclinal axis could coincide with the Frenchman's Cove syncline or it may lie farther east. The axial zone of the syncline was later disrupted by the White Bay faults described above.

In the northeastern corner of the map-area, a northeast-plunging anticline in the Ordovician(?) Baie Verte Group was intruded by granodiorite (map-unit 10) along its axial region. This anticline is flanked on the east by a probable syncline south of Ming's Bight and on the west by a syncline (not shown on the map) west of Baie Verte. Southwestward, outcrops are few and folds are difficult to recognize. However, west of the southern part of Mic Mac Lake, there is some indication that northeast-striking fold axes in the Baie Verte Group are truncated along the north-trending, faulted contact with adjacent Silurian(?) rocks (map-unit 11).

The Ordovician-aged Lush's Bight Group occupies a complex synclinorium whose axis trends roughly northeastward through Davis Pond. Northwest of Davis Pond, top determinations from pillow lavas suggest that the rocks are closely folded with some tendency for the folds to be overturned toward the southeast. Southeast of Davis Pond, flows and tuff beds face northwest and there is little evidence of tight folding. The axial zone of this synclinorium is the locus of the Davis Pond fault described above.

Kalliokoski (1955) has suggested that the Ordovician rocks in the southeastern quarter of the map-area are situated on the west limb of a northerly plunging anticlinorium. This anticlinorium could be the counterpart of the synclinorium in the Lush's Bight Group to the west.

Rocks of the Springdale Group occupy a broad, open, gently-northeast-plunging syncline. The configuration of map-units 15a, b, and c in the northern and southern parts of this fold has been worked out in detail by Kalliokoski (1953, 1955). In the present study, an attempt has been made to extrapolate these units through the intervening area which, unfortunately, contains few outcrops. Anomalous bedding attitudes and contortion in several localities suggest that the syncline may be disrupted by many more transverse faults than are shown on the map.

Tectonic History

The map-area is located at the northern extremity of the Appalachian orogenic system and many attempts have been made to compare and contrast its history with that of the more southerly and better-known parts of the system.

There is general agreement (Neale et al., 1961; Clifford and Baird, 1962) that the Long Range complex is part of the Grenville craton, which was folded, metamorphosed, and intruded in Precambrian time, approximately 950 m.y. ago. Some parts of the Fleur de Lys Group may also be part of the Grenville craton and, hence, may have been subjected to Precambrian folding and metamorphism. If so, the evidence has been obscured by Palaeozoic metamorphism and intrusion. Watson (1947) and Baird (1951) have suggested that the metamorphic grade (chiefly amphibolite facies) of the Fleur de Lys Group implies a more complex history than that of the adjacent Ordovician greenstones. However, Neale (1959) has reported two localities where the Baie Verte and Fleur de Lys Groups are in other than faulted contact and the metamorphic histories of both groups are similar.

Indirect evidence for folding, metamorphism, and intrusion during Taconic (Ordovician) and Acadian (Devonian) orogenies has been cited by workers in several parts of the map-area (e.g. MacLean, 1947; Watson, 1947). In contrast, Heyl (1936, 1937a, b) from work in the White Bay region and also to the east of the present map-area, stated that there is no evidence of Taconic orogeny and that the major pre-Carboniferous tectonic event was a Caledonian (Silurian) orogeny. He gave the following three lines of evidence for his interpretation. (1) The presence of gently folded Devonian rocks unconformably overlying Lower Palaeozoic rocks on Groais Island and Cape Rouge Peninsula, north of this map-area. Subsequent work (Baird, 1957) has shown that the gently folded rocks are Carboniferous rather than Devonian. (2) The structural conformity of Ordovician and Silurian strata in the White Bay region and to the east in the New Bay area of Notre Dame Bay. This conformable relationship is now well established in some places in the Notre Dame Bay region (Williams, 1962). (3) The absence of Devonian rocks in northern Newfoundland. Twenhofel (1947) and Kalliokoski (1953, 1955) suggested that the

Springdale and Botwood Groups are probably Devonian, but more recent evidence (Neale, Nash, and Innes, 1960; Williams 1962) favours a Silurian age.

However, the structural conformity of Ordovician and Silurian rocks cited by Heyl (1936, 1937a, b) for some parts of the area does not eliminate the possibility that deformation related to Taconic orogeny may have occurred in other parts of the map-area. Also, the fact that the strata above the Groais Island unconformity are now known to be Carboniferous rather than Devonian raises the upper time-limit of deformation of the Silurian rocks so that this deformation could as well be related to Acadian as to Caledonian orogeny.

To the writers, the bulk of the evidence favours deformation during both the Taconic and the Acadian orogenies. The Taconic orogeny did not greatly affect the Palaeozoic rocks of the White Bay region. This region, and possibly the whole Northern Peninsula of Newfoundland, was part of a stable shelf on which carbonate sediments (e.g. map-units 2b and 4) accumulated in Cambro-Ordovician time. This shelf zone may have extended eastward as far as the present eastern margin of the Fleur de Lys Group. Farther east the character of the Ordovician rocks (map-units 5, 6, and 7) suggests deposition by turbidity currents in deep marine troughs that were the sites of extensive submarine volcanism. The Ordovician turbidites and volcanic rocks were folded and intruded during the Taconic orogeny. Evidence of this deformation in the central and eastern parts of the map-area has been cited above and includes differences in metamorphism and style of deformation between Ordovician and Silurian rocks. Intrusion of ultrabasic rocks took place chiefly along a fault system that may have coincided with the hinge line between the western carbonate shelf and the eastern trough zone. Where Taconic ultrabasic rocks are known to cut rocks younger than Ordovician, evidence of later (Acadian) re-activation is present (Neale, 1957). Some of the granitic rocks (e.g. map-unit 10) may have been emplaced late in this Taconic intrusive stage. The evidence of conformable Ordovician-Silurian contacts in some places east of the carbonate shelf zone (Heyl, 1936; Williams, 1962) is to be expected if this region is considered one of predominant subsidence in Ordovician and Silurian time with large but localized upwarps associated with Middle and/or Late Ordovician orogeny. Cady (1960, p. 563) has described the same phenomenon in a discussion of the effects of the Taconic orogeny in Vermont and Quebec.

The Taconic upwarping in Sandy Lake (east half) map-area may have been followed by the thrusting or gravity sliding of large masses of Ordovician turbidites and submarine volcanic rocks westward over the carbonate shelf zone. The anomalous position of turbidites and volcanic rocks on the west coast of Newfoundland, west of the carbonate shelf zone, might be explained in this fashion (Rodgers and Neale, 1962).

The second episode of Palaeozoic orogeny involved Silurian and older rocks. This was probably related to the climactic Acadian orogeny of Middle or Late Devonian time. The nearest known Devonian rocks that were folded and intruded by granite at this time are located about 100 miles to the southwest (Cooper, 1954). However, most of the radiogenic age determinations that date final metamorphism and intrusion in this area and elsewhere in Newfoundland (Lowdon, 1960, 1961) coincide with fossil-controlled Devonian ages obtained in other parts of the Canadian Appalachian region.

The third and final deformation of Palaeozoic rocks involved the Carboniferous rocks (map-units 19-21). The pre-Carboniferous rocks reacted to this latest deformation mainly by faulting. Tilting and folding of the Carboniferous rocks appear to be related to the type and amount of movement along their bounding faults. The nature of the coarse clastic Carboniferous sequences in Newfoundland suggests that, in part, fault movements took place during sedimentation. Final movements could have taken place in either Late Carboniferous or post-Carboniferous time.

ECONOMIC GEOLOGY

Large parts of the map-area are now under concession to Advocate Mines Limited and to British Newfoundland Exploration Limited. Both these companies and the M. J. Boylen Engineering Offices are engaged in continuing exploration programs and in development work on both old and recently discovered mineral deposits.

Within the map-area are numerous gold and base-metal prospects, and a few old mines that were worked before or shortly after the turn of the century. The old base-metal prospects are chiefly within the Ordovician volcanic-greywacke sequences (map-units 5-7); the gold prospects are in both the Ordovician sequences and in the Silurian (?) Simms Ridge Formation where they are closely associated with silicic intrusive rocks (map-unit 16a). Most of the gold prospects have been described by Snelgrove (1935), and the copper deposits by Douglas, Rove, and Williams (1940). In addition, detailed mapping of many of the prospects has been carried out by Heyl (1937b), Watson (1947), MacLean (1947), and Betz (1948), and a summary of their data is given by Snelgrove and Baird (1953). Marble and limestone deposits in the White Bay region have been described by Bain (1937), Betz (1948), and McKillop (1962). No further description of these old prospects is given here. The following is a brief account of recent work in the area.

Copper

The most recent copper discovery is at the southeastern tip of Whales Back Pond, between Halls Bay and Southwest Arm on the eastern boundary of the map-area. This is the site of an old prospect shaft (MacLean, 1947, p. 36) and the recent discovery resulted from geological and geophysical work carried out in 1960 field season by Stanley Roderick for British Newfoundland Exploration Limited. Pyrite and chalcopyrite are associated with a linear 'chlorite zone' that trends about N65°E from the southeastern tip of the pond. The 'chlorite zone' is bounded by pillowed andesitic and basaltic flow rocks of the Lush's Bight Group and appears to terminate northeastward against a lineament that strikes N40°E, and is probably a fault zone. Geologists on the property do not agree on whether or not the 'chlorite zone' represents a shear (i.e. a feather fault) subsidiary to the N40°E lineament or a stratigraphic unit. Chlorite schist is the dominant rock of the 'chlorite zone', and the fact that it is intercalated with small amounts of slightly schistose to massive dacite, andesite and basalt flow rocks favours the interpretation that it is a stratigraphic unit—probably consisting of basic tuff and ash beds that were more amenable to shearing than the adjacent and intercalated flow rocks. Sills and dykes of dacite, plagioclase porphyry, and amphibole-plagioclase porphyry cut the chlorite schist. The chlorite schist carries most of the ore values although mineralized zones are also common in the flow rocks; mineralized zones are rare or absent in the dyke rocks. An intensive drilling program has been completed on the chlorite zone and its extension beneath the waters of Whales Back Pond. Further exploration will be carried out from an underground shaft. Geological, geochemical and geophysical exploration has been concentrated along the north shores and beneath the waters of Deer Pond in an attempt to find an extension of the Whales Back Pond deposit. An attractive feature of the deposit is that it is only 2 1/2 miles from a producing copper mine and ore-shipping facilities at the village of Little Bay.

Atlantic Coast Copper Limited, operators of the Little Bay mine, initiated a drilling program during 1961 near the Lady Pond mine (MacLean, 1947). This mine, a small producer during the last century, is 6,500 feet south of the north end of Davis Pond. The drill site is about 2,500 feet north-northeast of the old workings and is separated from them by a northeast-striking fault zone. Chalcopyrite, bornite, and pyrite occur in a zone of schistose tuffs and basic pillow lavas of the Lush's Bight Group. Dykes of fine-grained meta-diorite that cut across the volcanic rocks apparently postdate the schistosity. Trenching has shown that the zone is more than 200 feet wide at one locality.

A copper prospect, discovered by British Newfoundland Exploration geologists in 1960, is located near Muir Pond, midway between King's Point village and Shoal Pond. This region is underlain by quartz-feldspar porphyry and silicic volcanic rocks (map-unit 16) and the prospect is about 200 feet from a fault that separates these rocks from basic lavas of the Lush's Bight Group. Chalcopyrite and pyrite occur in silicified sericite schist within a tight anticlinal structure that plunges S20 to 30°W. The sericite schist, which was probably derived from rhyolitic tuffs, is intercalated with massive to slightly schistose rhyolitic flow rocks that contain pyrite. Similar rhyolitic flow and pyroclastic rocks west of Southwest Arm are known to contain abundant pyrite and traces of chalcopyrite (Neale, Nash, and Innes, 1960), particularly in exposures along the branches of Rattling Brook. Similar minerals also occur in silicic and basic volcanic rocks (map-unit 14) west of King's Point road. These occurrences are interesting as they are in Silurian or probable Silurian volcanic rocks that have generally been neglected by prospectors.

Copper minerals in glacial erratics near the Trans-Canada Highway, south of Indian Pond, have attracted the attention of British Newfoundland Exploration geologists for several years. Several attempts at boulder tracing have been made and, during the 1961 field season, a geophysical, geochemical, and trenching program was initiated in conjunction with the Boliden Mining Company of Sweden. The bedrock in this area of sparse outcrop consists chiefly of silicic and basic volcanic rocks cut by both basic dykes and quartz-feldspar porphyry dykes and surrounded by intrusive granitic rocks (map-unit 18). These rocks are tentatively mapped as unit 14 of Silurian age, although they may be related in whole or part to one of the Ordovician groups. In places, the silicic volcanic rocks contain abundant pyrite, and stripping operations have revealed minor chalcopyrite and bornite in chloritized shear zones within andesite and quartz-dacite flow rocks.

Gullbridge mine, located on Gull Pond immediately west of the Badger - Halls Bay road, is a copper deposit discovered in 1905 and presently controlled by Maritimes Mining Corporation Limited. It consists of two pyrite-pyrrhotite-chalcopyrite replacement lenses in cordierite schist of the Exploits Group (Douglas, Rove and Williams, 1940; Kalliokoski, 1955). A headframe and mining plant were constructed in 1956, after which development work was suspended, pending (apparently) an increase in the price of copper.

Gold

The Rambler Pond gold deposit, 6 miles southeast of Baie Verte, was discovered in 1905. Together with several adjacent prospects, it is being intensively explored by Consolidated Rambler Mines Limited, which is controlled by M.J. Boylen interests. The region is underlain by rhyolite and andesite flow rocks, meta-diorite sills, and minor metasedimentary rocks of the Baie Verte Group. The regional structure has been interpreted as synclinal (Neale, 1958) on the basis of a few scattered observations of bedding attitudes. Detailed work near Rambler Pond (O.A. Seeber, personal communication) shows that the major structure is anticlinal in this region. The "Mine Ore Body", which is currently undergoing underground development, is located close to the anticlinal axis and is essentially a pyritic replacement of a sericite schist that probably represents metamorphosed rhyolite tuff. The pyritized schist carries recoverable values in gold, silver, and copper, and minor amounts of lead and zinc. The original Rambler showing, known as the "South Pyrite Body", is 600 feet south of the "Mine Ore Body". It consists of pyrite, chalcopyrite, and small amounts of pyrrhotite and sphalerite in a chlorite schist zone that may be related to a fault along Rambler Brook.

Asbestos

A large deposit of asbestos was discovered east of Baie Verte in 1955 by prospectors Norman Peters and the late George MacNaughton, working under the direction of O.A. Seeber of M.J. Boylen Engineering Offices. Previously, asbestos occurrences had been reported in this general region by Watson (1947). The deposit has been explored by Advocate Mines Limited (under management control of Canadian Johns-Manville) and is scheduled for production of 5,000 tons per day in 1963. The deposit occurs near the north end of the Birchy Lake - Baie Verte ultrabasic belt in a roughly pseudo-stratified, serpentinized peridotite pluton, about 3 1/2 miles north of the town of Baie Verte. Information available in 1959, when the writers last visited this deposit, suggested that the pluton occupies a fault-disrupted, synclinal or basinal structure with steeply-dipping east and west limbs that tend to flatten out at depth. On its south and west margins the pluton is in contact with metavolcanic and meta-sedimentary rocks of the Baie Verte Group. On its east margin, meta-gabbro is interlayered with the peridotite and intervenes between it and rocks of the Baie Verte Group. Cross-fiber asbestos occurs in pale-greyish-brown-weathered peridotite at both the south end and in the north-central part of the pluton. The southern ore zone is parallel to the margins of the body and is underlain and overlain by a medium-brown-weathered, more highly pyroxenic peridotite that contains few asbestos seams. The northern ore zone may be a fault-disrupted extension of the southern zone. To date, reserves of approximately 43 million tons of 4D fiber have been established.

Advocate Mines Limited has also investigated cross-fiber asbestos deposits in a pluton about 2 miles south of the main orebody and also in the northern part of the Flatwater Pond pluton and at several localities between Mic Mac Lake and Gillards Lake. A chromite prospect associated with the Flatwater Pond pluton consists of a lens of chromite 8 feet long and 28 inches wide.

An aeromagnetic survey carried out for the Newfoundland Department of Natural Resources in 1950 shows that the northern part of Baie Verte is underlain by ultrabasic rocks. A search for asbestos deposits in these rocks has been undertaken by the M.J. Boylen Engineering Offices and has included detailed geophysical work and drilling from offshore and island sites within the bay.

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