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RECONNAISSANCE GEOLOGY OF SHELBURNE MAP-AREA, QUEENS, SHELBURNE, AND YARMOUTH COUNTIES, NOVA SCOTIA

F. C. Taylor

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RECONNAISSANCE GEOLOGY OF SHELBURNE MAP-AREA, QUEENS, SHELBURNE, AND YARMOUTH COUNTIES, NOVA SCOTIA

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By
F. C. Taylor

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PREFACE

Geological investigations in southwestern Nova Scotia have been carried on for more than 125 years, but the present survey is the first systematic geological mapping of Shelburne map-area to be undertaken in this century.

This study disclosed the existence, in the Yarmouth district, of a thick section of rocks of the White Rock Formation, and many others of volcanic origin. It also enabled the author to establish metamorphic zones within the areas of layered rocks.

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

OTTAWA, April 27, 1964

MEMOIR 349 — Rekognoszierungs-Geologie des Kartenbereichs von Shelburne: Queens, Shelburne und Yarmouth Counties (Neuschottland).

Von F. C. Taylor

Beschreibt die paläozoische Geologie eines etwa 3 600 qkm grossen Gebiets im südwestlichen Teil von Neuschottland. Ein Grossteil dieses Gebietes ist von nach dem Nordosten streichenden gefalteten Metasedimenten der Meguma-Gruppe unterlagert. Grosse Massen von devonischem Granit sind als Intrusivkörper in diese Metasedimente eingedrungen.

ТРУД 349 — Рекогносцировочная геология Шелбурнского листа геологической карты, районы Куинс, Шелбурн и Ярмоус, Новая Шотландия.

Ф. К. Тейлор

Описывается палеозойськая геология 1400 квадратных миль юго-западной Новой Шотландии. Большая часть района подстилается метаморфизованными отложениями Мегумского комплекса смятыми в складки северо-восточного направления. Крупные интрузивные тела девонских гранитов внедряются в эти метаморфизованные отложения.

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RECONNAISSANCE GEOLOGY OF SHELBURNE MAP-AREA, QUEENS, SHELBURNE, AND YARMOUTH COUNTIES, NOVA SCOTIA

Abstract

Shelburne map-area covers about 1,400 square miles of the Southern Upland of southwestern Nova Scotia.

The largest part of the area is underlain by rocks of the Meguma Group, which is divided into two formations. The lower, the Goldenville Formation, consists predominantly of light to medium grey, medium-grained greywacke with small amounts of slate, schist, and conglomerate. These rocks are conformably overlain by thinly laminated, dark to light grey, rarely black slates of the Halifax Formation of Early Ordovician age. Both these formations are commonly metamorphosed to schists with staurolite, andalusite, and rarely cordierite.

In the Yarmouth syncline, rocks of the White Rock Formation (post-Lower Ordovician and pre-Upper Silurian) consisting of slate, quartzite, conglomerate, and mafic and acidic volcanic rocks conformably overlie the Halifax Formation. There the White Rock Formation is more than 15,500 feet thick.

During the Devonian Period, the layered rocks were intruded by several plutons of granodiorite, granite, and quartz diorite. Basic intrusions, both pre- and post-granitic rocks, occur locally.

Regional metamorphism has left the eastern two-thirds of the area in the almandine amphibolite facies and the remainder in the greenschist facies. Locally, contact metamorphism has taken place.

During the Acadian orogeny the layered rocks were folded into north- to northeast-trending folds. Few faults are known.

Glacial ice moved south-southeastward during the Pleistocene Epoch. Recent sea encroachment has drowned well-established forests at many places along the coast.

Building stone quarrying is the sole economic mineral activity.

Résumé

La région de Shelburne comprend une surface d'environ 1,400 milles carrés des hautes terres du sud-ouest de la Nouvelle-Écosse.

La plus grande partie de la région repose sur des roches du groupe de Meguma qui se divise en deux formations. La formation de Goldenville, qui est la moins élevée, consiste surtout de grauwacke à grain moyen, variant du gris clair au gris moyen, et d'un peu d'ardoise, de schiste et de conglomérat. Ces roches sont recouvertes en concordance des ardoises mincement laminées, de couleur allant du gris foncé au gris clair, rarement noires, de la formation d'Halifax qui date du début de l'Ordovicien. Ces deux formations se métamorphosent souvent en schistes contenant de la staurolite, de l'andalousite et, rarement, de la cordiérite.

Dans le synclinal de Yarmouth, des roches de la formation de White Rock (après l'Ordovicien inférieur et avant le Silurien supérieur) constituées d'ardoise, de quartzite, de conglomérat et de roches volcaniques acides et ferromagnésiennes, recouvrent en concordance la formation d'Halifax. A cet endroit, la formation de White Rock a plus de 15,500 pieds d'épaisseur.

Pendant le Dévonien, plusieurs plutons de granodiorite, du granite et de la diorite quartzifère ont pénétré les roches en couches. On trouve sur les lieux des intrusions de base, des roches prégranitiques et prostgranitiques.

Le métamorphisme régional a laissé, aux deux tiers du côté est de la région, un faciès d'amphibole à almandine, et au reste un faciès à schiste vert. Il y a eu métamorphisme de contact dans la région.

Les roches en couches ont subi, au cours de l'orogenèse acadienne, des plissements orientés vers le nord et le nord-est.

Les glaciers se sont déplacés vers le sud—sud-est durant le Pléistocène. L'ingression récente de la mer a noyé des forêts bien établies le long de la côte.

L'extraction de la pierre de construction est la seule activité économique minérale.

Chapter I

INTRODUCTION

Shelburne map-area, Queens, Shelburne, and Yarmouth counties, Nova Scotia, encompasses the entire southwestern part of the province south of latitude 44°00′N. This area occupies about 1,400 square miles.

Field work commenced in 1959 and finished the following year. Particular attention was directed toward the following objectives: (1) division of the Meguma Group into its constituent formations, and (2) delineation of synclines, anticlines, and domes within the Meguma Group. A preliminary map was published earlier on a scale of 1 inch to 4 miles (Taylor, 1961a).

The region is readily accessible by road, as Highway 3 from Halifax to Yarmouth follows the coast across the area. North from Yarmouth, Highway 1 extends north along the west and northwest side of the province. Roughly parallel with these highways are the Canadian National Railways and Dominion Atlantic Railway (C.P.R.) lines, both of which link Yarmouth to Halifax. Air Canada makes regularly scheduled flights into Yarmouth Airport from Boston, Saint John, and Halifax. Canadian National steamships provide a regular car ferry service between Bar Harbour, Maine, and Yarmouth.

Within the map-area, roads cover most of Yarmouth county and all the coastal areas. Much of the interior of Queens and Shelburne counties has been opened by logging roads and, except during wet periods, most of these roads are passable by truck. Most streams are too shallow for canoeing except upstream from dam sites.

Whereas fishing is the principal means of livelihood for many of the inhabitants, lumbering and pulpwood provide a source of income for many others. Agriculture, except on a very small scale, is limited to a small area surrounding Yarmouth where a few prosperous mixed farms are present. Much land previously cleared has now returned to bush and in places has been cut for pulpwood. Efforts are being made to increase the number of tourists visiting this part of Nova Scotia and in the future this industry will probably provide added revenue for the inhabitants. The climate is temperate and humid, with few temperature extremes. The mean annual precipitation is 46.43 inches at Yarmouth, consisting of 80.0 inches of snow and 38.43 of rain. Mean annual temperature for the year is 44°F. Temperatures in the interior are probably somewhat more extreme than those in the coastal areas.

Ms. received 6 January, 1964.

Yarmouth, the largest town in the area, with a population of 8,095, is primarily a fishing and lumbering centre, but also has a few small industries. Shelburne, population 2,337, once a thriving ship-building town, is now a centre for small manufacturing and stone works as well as for fish and wood.

The writer was assisted during the 1959 season by J. F. Donovan, D. R. Grant, W. K. MacDonald, and for a short period by R. L. Tedrick, and during the 1960 season by H. H. Bostock, R. H. Henley, and M. J. Quayle.

Previous Geological Work

Geological investigations in southwestern Nova Scotia started in 1828 with a brief description of the south coast by Jackson and Alger (1829).

Gesner (1836) made brief mention of the south coast and later (1843) published a map of the entire province. Although no systematic mapping was undertaken until near the end of the 19th century many geologists visited the area, among the most prominent of whom were Dawson (1855), Selwyn (1872), and Honeyman (1881).

Bailey (1898) was the first to map the area systematically. He divided the sedimentary rocks into three units consisting of a quartzite division, a banded argillite division, and a black slate division. Bailey's map was the only geological map of the entire map-area until the present survey. Faribault (1915, 1918, 1920) spent several seasons in various parts of the map-area, but was primarily concerned with mineral showings and structure. Powers (1915) mapped part of Shelburne county.

In recent years, Garland (1953) made a gravity survey of southern Nova Scotia and the Geological Survey of Canada issued aeromagnetic maps (Geol. Surv. Can., 1957, a to i) of the map-area. Boyle, *et al.* (1958) carried out a geochemical survey of water and sediments of streams, rivers, and lakes. Fairbairn, *et al.* (1960) sampled granite bodies for isotopic age dates.

Physiography

The map-area forms part of the Southern Upland (Goldthwait, 1924) of the larger Atlantic Uplands. The surface of this upland within the map-area increases in elevation from sea-level to 350 feet, although elsewhere in central Nova Scotia it attains 800 feet. Typically, this upland surface consists of low rounded hills with the areas between them filled with small lakes, swamps, or sluggish streams. Local relief is less than 100 feet.

The coast-line is typical of a submerged coast, with numerous bays, peninsulas, and islands. Spits, bars, and tombolos occur in many places.

Drainage

The main drainage in the area is toward the south and in general follows the same trend as the glacial advance. The largest stream is Tusket River, which flows in a southerly or southwesterly direction for most of its course. This is the only river large enough to be navigable by canoe without undue hardship, and even it contains many areas of low water or rapids.

In the east half of the area, Roseway and Jordan Rivers are the chief drainage channels. They are similar in that they occupy fairly wide valleys but, except during periods of excessive rainfall, are shallow. Most streams commonly meander through swampy areas or old beaver meadows and at these places are generally deepest. All the streams have their headwaters in the interior in a region marked by small lakes or swamps. The major streams are probably consequent throughout most of their courses, as it is only locally that courses follow the structure.

Numerous dams have been built throughout the map-area for sawmills and log ponds. Most of these are no longer in use and many have fallen into a state of disrepair.

In Yarmouth county, salt marshes occur along part of Tusket River and much of the Chebogue and Little Rivers. In the past these have been used for hay, but at present are put to little use.

Chapter II

GENERAL GEOLOGY

The oldest rocks in the area are greywackes, schists, and slates of the Meguma Group. The ages of these rocks have, until recently, been in doubt, but it is now established that the Halifax Formation, the uppermost of the two formations comprising the group, is Early Ordovician. These rocks are overlain conformably by quartzites, slates, and volcanic rocks of the White Rock Formation of silurian(?) age.

During the Devonian Period, all these rocks were folded and intruded by granitic rocks. At that time much of the Meguma Group was metamorphosed to staurolite-andalusite schists and quartz-feldspar paragneiss. Basic dyke rocks of several ages are present, the longest and thickest of which is a post-granitic diabase.

During the Pleistocene Epoch, an ice-sheet covered the area, which upon retreat left large areas covered with bouldery till and rare drumlins. More recently, encroachment of the sea has resulted in drowned trees at several localities along the coast.

Meguma Group

The rocks of the Meguma Group have a long history of exploration because of their accessibility, their widespread occurrence, and their association with gold. Occupying most of the southern half of Nova Scotia they were mapped by the earliest geologists (Gesner, 1836; Jackson and Alger, 1829) in the province. The Meguma Group was first separated from the later rocks, especially the Silurian and Devonian, by Sir William Dawson (1855, 1868). The division of the Meguma Group into an upper argillaceous part and a lower arenaceous part was recognized by Campbell (1863), while working in the eastern part of the province. However in the southwest part of the province, Bailey (1898) made a threefold subdivision: a lower quartzite division, a middle banded argillite division, and an upper black slate division. Not until 1900 was a formal name proposed for any of the rock units. At that time Ami (1900, p. 195) proposed the term "Guysborough Formation" for the quartzite group and the term "Halifax Formation" for the 'slate group'. Subse-

Table of Formations

Era	Period or Epoch	Group	Formation	Lithology
Cenozoic	Recent			Tidal alluvium, stream alluvium, peat, beach sands and gravels, dunes
	Pleistocene			Drift, drumlins, eskers, kames, outwash
		Unconformity		
Palaeozoic				Quartz diabase, biotite diorite, olivine diabase, hornblende-quartz diorite, basalt, diorite
		Intrusive contact		
	Devonian			Granite, granodiorite, quartz diorite, minor hornblende diorite and pegmatite
		Intrusive contact		
				Gabbro, diorite
		Intrusive contact		
	Silurian		White Rock	Andesite, actinolitic gneisses and schists, mafic tuff, slate, quartzite, conglomerate, rhyolite, rhyolite tuff and breccia, minor argillaceous quartzite, greywacke and schists of sedimentary origin
			Conformable	
	Early Ordovician	Meguma	Halifax	Slate, siltstone, minor argillite; in part recrystallized to schists and gneisses characterized by andalusite, staurolite, cordierite, and sillimanite
			Conformable	
	Early Ordovician or earlier, possibly Late Cambrian		Goldenville	Greywacke, minor slate, argillite, conglomerate; in part recrystallized to schists and gneisses characterized by andalusite, staurolite, sillimanite and cordierite

quently, Woodman (1904a) chose the name Meguma[1] Series for the unit as a whole, and renamed the quartzite part of the Meguma the Goldenville Formation, after a mining locality of that name in which the quartzites are well exposed. He rejected the term Guysborough as not suitable because the locality did not typify the formation. Woodman refrained from naming Bailey's intermediate division, pointing out that in the eastern part of the province it is not separable. An intermediate mappable division does not exist in the present map-area.

All subsequent workers have used the terms suggested by Woodman until recently, when Stevenson (1959) changed the name Meguma Series to the rock-unit term Meguma Group. Andalusite and staurolite schists (map-units 2 and 4) belonging to the Meguma Group are described later (p. 17).

Goldenville Formation

Distribution

The Goldenville Formation underlies most of the eastern third and a large part of the western third of Shelburne map-area. Excellent exposures of these rocks occur along the coast at Western Head, Lockeport, and Green Harbour. Inland exposures are small, widely spaced, and lichen-covered. Only rare outcrops are present in the area north of the Tusket Islands.

Thickness

The exact thickness of the Goldenville Formation is unknown as the base is nowhere exposed. Woodman (1904b) reported 17,670 feet of Goldenville Formation in the centre of an anticline at Moose River. The lowest known Goldenville strata were reported by Faribault (1914) along the shore of Liverpool Bay, Queens county, which is 3 miles north of the eastern edge of Shelburne map-area. There, 18,348 feet of Goldenville Formation rocks are reported, which is the greatest thickness recorded for the formation.

Within the map-area, several thickness estimates are possible. In the Broad River valley 15,500 feet of Goldenville strata are exposed between the Halifax Formation and granite on the coast. About 10,250 feet occur in almost continuous exposure. At Lockeport, there are 13,000–16,000 feet of greywacke measured from the centre of the Lockeport syncline to the crest of the anticline along Green Harbour. At Pubnico Harbour 10,000 feet of greywacke and paragneiss are exposed between the lowermost schists and the Barrington Passage quartz diorite pluton.

Measurement from the Halifax Formation contact at Chebogue Point eastward to the crest of the anticline through the Tusket Islands indicates 30,000 feet of sediment. This figure is probably unreliable, however, because outcrop is widely spaced in this area and steep dips are common so that the other undefined folds are probably present.

Unless a better locality exists elsewhere in the province, Faribault's 18,348 feet

[1] Meguma is from a Micmac word, the root of the native term for their own tribe.

along Liverpool Bay is the most acceptable figure available on the maximum thickness of the formation.

Lithology

The Goldenville Formation consists mainly of greywacke, with small amounts of conglomerate, slate, and argillite. In most places, the argillaceous parts of the formation have been metamorphosed and are now slate or schist.

The commonest rock type is a light to medium grey, medium-grained biotite greywacke. Characteristically, this rock is well bedded with beds ranging in thickness from a fraction of an inch to 20 feet. Most beds are 1 foot to 2 feet thick. Many show graded bedding; this feature is commonly marked by the transformation of the finer grained upper part of the beds to a muscovite- or biotite-quartz schist. Individual beds maintain a uniform thickness along strike for tens of feet at least. Exposures are such that rarely are beds exposed for great distances. Crossbedding occurs sporadically and chiefly on a small scale so that in part these structures may be of scour and fill origin. Forty-nine crossbedding and bedding attitudes were measured in the eastern two-thirds of the map-area. Ten of these readings are in schists of map-unit 4 and may be part of the Halifax Formation. The crossbedding readings were rotated to correct the deformation of the Goldenville beds. The results are shown on Figure 1, expressed in dip azimuth directions in 30 degree classes on the basis of number frequency per cent. Current and oscillation ripple-marks are extremely rare and were recognized in only seven poorly exposed localities. Current ripples range from a ½- to 1-inch amplitude and a wave length of 2 to 3 inches.

In several places along the shore where exposures are large, breccia consisting of large angular blocks of greywacke in a similar matrix is present. Near Johnson Pond, fragments as large as 30 by 20 feet show good bedding similar to that in the greywacke. Bedding planes within the block are disconformable with the surrounding strata. These blocks were probably formed by slumpage. A common feature of the massive and thick greywacke beds is the presence of pyrite cubes up to 2 inches thick but averaging about 1 inch. Rocks of the formation are cut by numerous joints normal or nearly normal to the bedding planes. These have not been studied systematically.

Throughout the eastern part of the map-area many exposures contain spherical, elliptical, or elongate bodies of garnet, hornblende, or biotite and quartz. The spherical and elliptical bodies, ranging from 4 to 12 inches in greatest dimension, upon cursory examination look like boulders or cobbles. However, this is not the case and they are probably derived from calcareous concretions. At Round Bay, a single bed 2 inches thick showing scour and fill structure is mineralogically and lithologically similar to the concretions. This bed was probably derived from a calcareous sediment.

Conglomerate in the formation consists of three types, a quartz- and quartzite-pebble conglomerate, a greywacke boulder conglomerate, and an intraformational conglomerate.

The pebble-conglomerate occurs chiefly at Western Head, near Lockeport, and

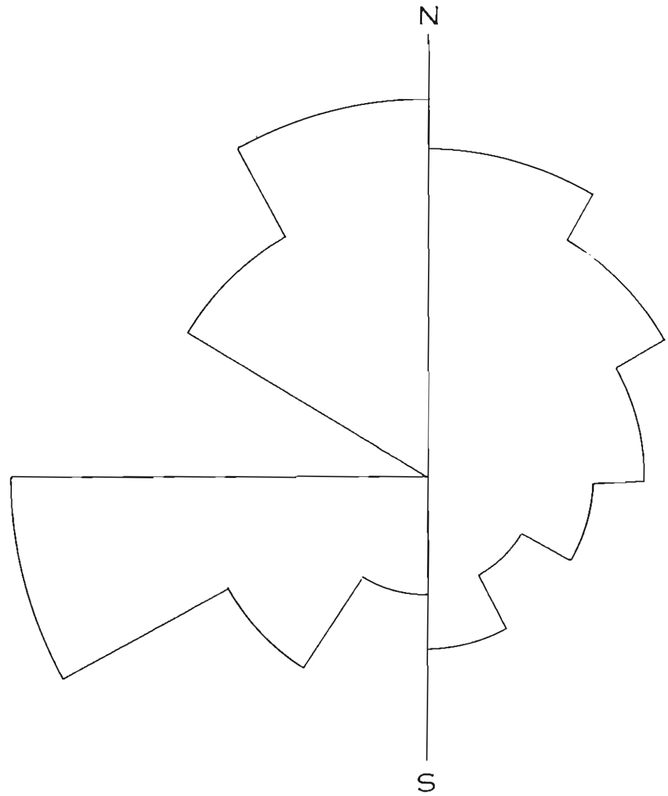


FIGURE 1. Rose diagram showing current directions (tilt corrected dip azimuth of crossbeds) for 49 cross-bedding readings in the Goldenville Formation.

on Locke and Gooseberry Islands. A small amount is also present on the west coast just south of Green Cove, where it shows excellent grain gradation to a fine-grained top.

At Western Head, the pebble-conglomerate occurs as discontinuous bands, up to 3 feet thick, in a zone 50 feet thick. Most of the conglomerate is confined to one bed in this zone. The greywacke in this area is predominantly massive.

On Locke Island, conglomerate forms a single bed 2 inches thick. On Gooseberry Island, pebble-conglomerate forms a bed up to 2 feet thick, and there a few larger pebbles, the largest 3 inches long, occur sporadically. In all localities the pebbles consist of subangular to rounded quartz and quartzite ranging from one-eighth to one-quarter inch in diameter.

The second type, greywacke boulder conglomerate, is widely distributed although quantitatively unimportant. Most of it occurs in large outcrops along the coast. Subrounded to rounded fragments, up to 10 inches in diameter, are lithologically similar to the greywacke matrix and are probably derived from the Goldenville Formation itself. Commonly, only a few cobbles or boulders are present at any one locality and are, so far as known, confined to one bed at each locality.

The intraformational conglomerate is present only along the west coast northward from Cranberry Point in a zone of interbedded greywacke and slate. It consists of greywacke matrix with light grey fragments of argillite up to 7 inches long. These are elongate in outline, angular for the most part, but in part rounded. In some places, the elongate fragments lie normal or nearly so to the bedding plane; elsewhere they are parallel with it. In general, the fragments lie in beds less than 3 inches thick.

The slate and argillite (map-units 1a, 1b) of the Goldenville Formation are confined to the upper part of the formation where they are interbedded with greywacke. Slate (1b) also occurs in two mappable units in the Goldenville Formation near Red Head. Nowhere else in the map-area were these two slate members recognized, even though one is about 2,700 feet thick. This particular member is evidently persistent, because it extends north of the map-area and is prominent along the coast near Salmon River and also outcrops along the Sissiboo River; both localities are in Digby county (Taylor, 1961b, 1962). The other band is only 180 feet thick and probably dies out along strike. These rocks are indistinguishable from slates and argillites in the Halifax Formation.

Fifteen specimens of Goldenville Formation from widely spaced localities were examined in thin section. Only four of these display well-preserved, microscopic sedimentary features, and they are from the western part of the map-area where metamorphic grade is low.

In these four specimens detrital quartz forms 12 to 19 per cent of the rock. Detrital quartz grains are chiefly subangular to rounded, with a few grains distinctly angular. These grains range from 0.02 to 1.2 mm in diameter, and average between 0.1 and 0.4 mm. Only rarely are original grain outlines preserved, because sericite and chlorite grains penetrate grain outlines. Detrital feldspar grains are similar in shape to the quartz, but in general are smaller. The feldspar is sodic plagioclase, in part untwinned. Many plagioclase grains are sericitic or cloudy; others are clear and show no signs of alteration. Rock fragments consist of quartzite and extremely rare quartz-feldspar grains. The quartzite grains fall chiefly in the range of larger grain sizes and the largest, in rare pebble-conglomerate, are as much as 5 mm in diameter. With disintegration to smaller grain sizes the rock grains break up into individual minerals. Lens-shaped patches of quartz grains, enveloped by chlorite and sericite in some thin sections, may be rock fragments or the product of the break-up of single quartz grains. These were considered to be rock fragments during grain counts. Rare angular grains of epidote are also present. The matrix, less than 0.02 mm, consists of quartz, plagioclase, sericite, biotite, and chlorite. The last three minerals are probably all authigenic. Rare angular grains of epidote are also present, and tourmaline and apatite are common accessories. A plot of volume per cent of the four thin section specimens (Fig. 2) shows these rocks to be lithic greywacke. As these samples are all from near the top of the Goldenville Formation and were laid down just prior to the slates of the Halifax Formation, they are probably richer in clayey matrix than most of the Goldenville Formation. However, it is assumed that the bulk of the Goldenville Formation consists of the same rock type lithic greywacke.

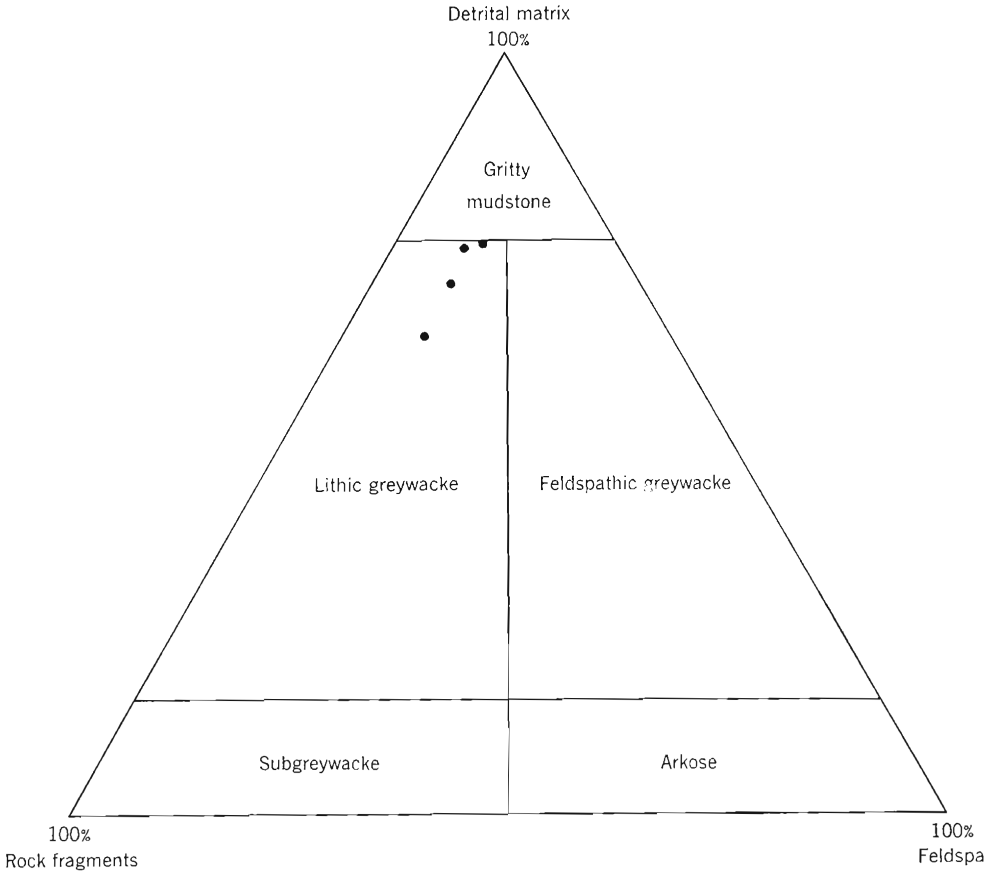


FIGURE 2. Plot of compositions (volume per cent) of 4 specimens of the Goldenville Formation in which grain boundaries are preserved (after Pettijohn, 1957).

In the central and eastern part of the map-area, typical Goldenville Formation rocks consist of an equigranular mosaic of recrystallized quartz and plagioclase with intergranular biotite and muscovite. A plot of compositions of eleven specimens of these rocks is shown on Figure 3. For this figure, all minerals other than quartz and feldspar are assumed to have been derived from recrystallization of the matrix. Undoubtedly some quartz and feldspar have also been derived from the matrix, so that the diagram as shown does not indicate a high enough percentage of matrix. The specimen with the highest quartz content is from an outcrop on Highway 3, just west of the bridge across Broad River, which is obviously more siliceous than any other Goldenville Formation strata and is an atypical specimen.

Biotite is present in all but two specimens, and in each it is reddish brown to pale brown, with ragged outlines. The largest grains, as much as 0.6 mm, are in part poikiloblastic with inclusions of quartz and feldspar. Most grains range from 0.1 to 0.2 mm. Pleochroic haloes are present in some grains. All the biotite is the product of recrystallization.

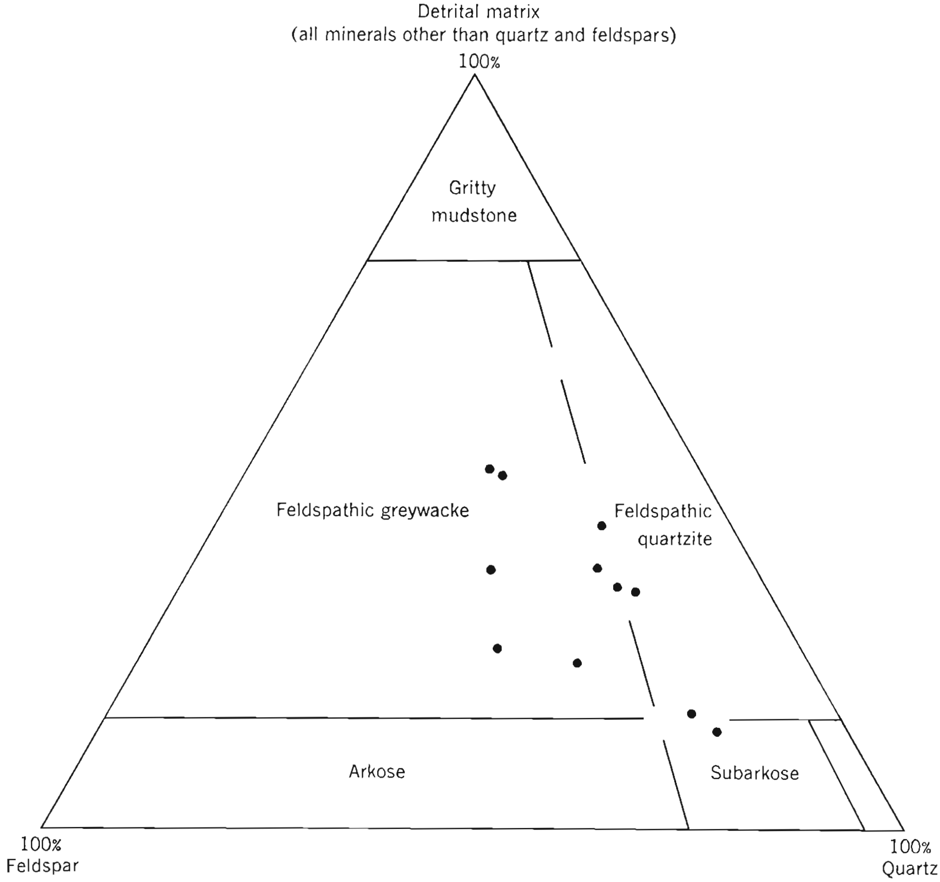


FIGURE 3. Plot of compositions (volume per cent) of 11 specimens of recrystallized Goldenville Formation (after Pettijohn, 1957).

Muscovite is similar in habit to biotite but most grains are smaller, up to 0.1 mm, with rare, large poikiloblastic grains of anhedral outline up to 0.5 mm. A few large (0.3 to 0.5 mm) grains of muscovite may be detrital. These are bent and show fractures normal to the cleavage, possibly induced by compaction.

Opaque and accessory minerals together form less than 3 per cent of the rock. The accessory minerals consist of sphene, zircon, apatite, tourmaline, and potash feldspar. Tourmaline and apatite are the most widespread, one or both occurring in every thin section examined. The tourmaline is colourless to grey-green to dusty blue-green. Apatite is primarily anhedral and shows rounded corners whereas tourmaline is subhedral to euhedral.

Opaque minerals are rod-like to irregularly shaped, and rarely euhedral. Magnetite is probably the commonest, although ilmenite (recognized by a leucoxene coating) is present in some samples. Pyrite, in part altered to limonite, is euhedral although rare in the thin sections examined. Few grains of potash feldspar were seen in any of the thin sections.

Structural Relationships

The bottom of the Goldenville Formation is not exposed anywhere, and uniformity of the lithology in most of the formation makes it nearly impossible to recognize the stratigraphic position within the formation of the rocks in any individual outcrop. Only near the top of the unit are there recognizable beds whose positions can be established and traced from one outcrop to another. The top of the Goldenville shows a variety of relationships with the overlying formation. For this reason a review of Halifax–Goldenville contact relationships (as known elsewhere in Nova Scotia) is desirable to ensure a better understanding of the relationships in Shelburne map-area.

In Guysborough and Halifax counties Faribault (1887, p. 146) described the contact as follows: "The black slate group is separated from the quartzite group by a few layers of greenish, soft, smooth slate which becomes darker as it approaches it and insensibly passes into it." But Woodman (1904b), primarily concerned with the eastern part of the province, wrote:

> The contact between the two divisions of the series is always sharp where actually observable. It is usually marked by a striking change in colour of the strata, from the greenish and grayish of the lower rocks to the black, or less often light green, of the upper.

Woodman considered that Faribault's greenish slate at the contact was absent in many areas and that it corresponded to Bailey's (1898) 'banded argillite division'. He further commented that although Bailey's 'banded argillite division' separates the quartzite from the slate in places, it was not shown on Bailey's map.

In Kings county Faribault (1909a, p. 151) found that ". . . line of division between it (the quartzite) and the overlying slate . . . form(s) . . . (a) well defined horizon markers(s)." In the same area, Crosby (1962) was unable to recognize a clear division between the Halifax and Goldenville Formations, although he recognized an increase in silica content toward that part called Goldenville by Faribault. Perhaps Crosby was unable to recognize Faribault's contact phenomena because of the concealing of certain critical outcrops through the damming of Black River for power some years before Crosby mapped in Kings county.

Faribault (1909b) showed several beds of limestone near the base of the Halifax Formation on the east side of Halifax Harbour. On the west side of the harbour, King (1935) located four beds of limestone within the Goldenville Formation close to the contact. King described the Halifax Formation near the contact as consisting of a uniform carbonaceous slate with a distinct cleavage. At the contact, this slate changes abruptly to a series of alternating beds of slate and quartzite showing prominent crossbedding.

On a series of one-mile map-sheets, Faribault, *et al.* (1938a, b) placed the contact between the two formations at the highest exposed bed of greywacke (called quartzite by Faribault). This position for the contact has been used in this report. Stevenson (1959, p. 9) reported that the boundary between the Halifax Formation and the Goldenville Formation in the Shubenacadie–Kennetcook area is rarely well defined.

Within the map-area, the contact between the Goldenville and Halifax Formations is exposed at four localities: along the Broad River; at Pubnico Harbour; at Chebogue Point; and along the west coast. Metamorphism, in part, obscured the primary relationships of the two formations, but some features are well preserved and general conclusions can be drawn.

The best exposure of the contact occurs along the west side of Chebogue Point, where outcrop is continuous along the beach for about 1½ miles. The Goldenville Formation, of which 315 feet are there exposed, consists of grey fine-grained greywacke with thin interbeds of grey slate ranging from half a foot to 3 feet thick. The greywacke beds range from 1½ to 25 feet in thickness with most in the 8- to 10-foot range. About 330 feet from the top of the formation, the greywacke beds thin, with the thickest about 2 feet but most about half a foot. Here, too, the slate beds show a green shade as well as grey. A few of the greywacke beds are argillaceous. The top 200 feet are chiefly green slate with rare 1- to 10-foot-thick beds of fine-grained, grey-green argillaceous greywacke. The contact is drawn at the top of the stratigraphically highest arenaceous bed.

Along the west coast near Cranberry Point, the Goldenville Formation consists of grey greywacke in beds one-half foot to 4 feet thick with thin-bedded grey slate bands up to 1 foot thick. The slate forms less than 5 per cent of the rock up to the contact with the overlying Halifax Formation, which near Cranberry Point consists of light greenish grey weakly cleaved argillite to slate.

Farther north, northwest of Sandford, the greywacke is grey with beds one-half to 1 foot thick, which are commonly separated by grey slate. The Halifax Formation there consists of greenish grey thin-bedded slate immediately above the contact.

At Pubnico Harbour, meta-greywacke is well bedded, in 1-foot-thick beds, to within about 200 feet of the base of the Halifax Formation which consists of staurolite-andalusite schists. In this upper 200 feet of the Goldenville Formation there are only rare greywacke beds up to 1 foot thick.

Along Broad River, slate is rare up to the contact, and bedding in the Goldenville Formation is generally much thinner than elsewhere, for it ranges from one-twentieth inch to 2 feet in thickness.

Thus, within the map-area the contact between the Goldenville and Halifax Formations is of two types: (1) an abrupt change stratigraphically upward from well-bedded greywacke (as shown along Broad River) to pelitic rocks; and (2) a gradational change from greywacke to slate through the addition of slate beds in the greywacke. The colour variation (greys and greens) probably is not significant except where carbonaceous matter is concerned, as whether the slate and greywacke have or have not green hues depends on their chlorite content. In the more highly metamorphosed eastern part of the map-area, chlorite is scarce and hence green rocks are uncommon.

Nowhere within the map-area are limestone beds known. Near Tusket, deeply pitted greywacke may contain some carbonate, but nowhere does carbonate form distinct beds.

Age

Identifiable fossils are unknown in the Goldenville Formation. Bailey (1898, p. 55) found a form on the southern end of Locke Island that he called *Asteropolithon*. The writer re-examined this fossil location and identified the form as *Scolithus*. The tube portion is about one-half inch in diameter and is separated from the matrix of the rock by a thin layer of muscovite, which lies normal to the bedding plane. Inside the tube is rock indistinguishable from that without. Each *Scolithus* stands out on the surface of the bed so that the surface is now a series of small circular hummocks, the largest 8 inches in diameter. Similar forms occur on islands in Green Harbour and near Sodom Lake, along Jordan Bay, and along the coast between Chegoggin Point and Green Cove. In every place the tubes are normal to the bedding plane and at Locke Island they lie on the top of the bed.

These *Scolithus* forms, unfortunately, are of no use in dating the Goldenville Formation. However, as this formation is conformably overlain by, and grades into, the Halifax Formation, which is of Tremadoc age or earliest Ordovician (Crosby, 1962), the Goldenville Formation is probably Late Cambrian.

Halifax Formation

Distribution

Slates typical of the Halifax Formation occur at the following five places in the map-area: along the west coast north of Chegoggin Point, where in part this formation forms the west limb of a syncline about Yarmouth Harbour; on the east limb of the same fold; north of Pubnico peninsula; north of Beech Hill Lake; and in the core of a syncline northwest of Port Mouton. Aluminous schists, which comprise a large area from Baccaro Point north-northwest to near the north boundary, part of Pubnico peninsula, and small areas elsewhere, are probably part of the Halifax Formation. Some of the rocks shown as paragneiss (map-unit 5) were possibly also derived from this formation.

Thickness

The thickness of the Halifax Formation was determined by Faribault (1909a) to be 11,700 feet along the Black River in the Wolfville area. More recent work by Crosby (1962) suggested that it may be more than 12,000 feet, as some beds regarded as Goldenville Formation by Faribault may be part of the Halifax Formation. To the southwest, Smitheringale (1960) reported about 10,000 feet along the South Annapolis River, although the structure is not well enough known to ensure the accuracy of this figure.

The only place in the map-area in which both the top and bottom of the Halifax Formation are exposed is along the west side of Chebogue Point. There, the thickness is 1,500 ± 50 feet. A fault of unknown displacement 740 feet above the base of the formation may have shortened the slate exposure so that this figure must be regarded as a minimum thickness. North of Arcadia, at least 1,700 feet of slate occur in intermittent outcrops in the same slate horizon.

On the west limb of the Yarmouth syncline at Cranberry Point, 1,800 feet of slate are exposed along the coast and a gap of 2,500 occurs between this slate and the lowest exposed White Rock Formation. Thus, the Halifax Formation there has a minimum thickness of 1,800 feet and a maximum of 4,300.

At Pubnico Harbour, 9,300 feet of slate and schist are present between the top of the Goldenville Formation on the east side of the Pubnico syncline and the most westerly slate outcrops. These slate outcrops are greenish grey, a colour of slate known only in the lower 600 feet of the Halifax Formation, which suggests that they are near its base. Therefore, the maximum thickness of slate and schist present in the Pubnico syncline is in the order of 9,900 feet, with a minimum thickness of Halifax rocks of 4,950 feet. This figure may be somewhat high because dragfolding and faulting were not considered.

North of Jordan Falls, a rough estimate shows that 5,000 feet of schist are present in a syncline. In the Broad River syncline, 3,250 feet of slate and schist are present between the Goldenville Formation and the centre of the syncline.

Thus, within the map-area, the thickness of the Halifax Formation ranges from a minimum of 1,500 feet to a maximum of 4,950. From a comparison with thicknesses of the formation in areas to the northeast, as described by Crosby (1962) and Smitheringale (1960), the formation evidently thins toward the southwest, particularly along the east limb of the Yarmouth syncline where the most reliable thickness was ascertained.

Lithology

The Halifax Formation consists predominantly of thinly laminated, dark to light grey, rarely black slate. Strata range from microscopic to three-quarters of an inch in thickness and are commonly traceable only for short distances. Laminae also pinch and swell. In many places, strong cleavage has destroyed the bedding; in other places, cleavage and bedding are parallel or almost so. In part, weathered surfaces are masked by rust derived from weathering of pyrite, which is common, particularly in darker carbonaceous slates.

At Chebogue Point, the lowermost 480 feet of the Halifax Formation consist of greenish grey weathering, light greenish grey to dark greenish grey, moderately cleaved slate with bedding strata ranging from one-sixteenth to 1 inch thick and averaging one-eighth inch. Pyrite crystals in some of the slate are locally as much as half an inch in diameter. A few, fine-grained, greenish greywacke beds up to 2 inches thick are present also.

These green slates grade upward into grey and dark grey slate through a 250-foot zone of alternating green and grey slates in which the grey strata increase in number upwards within the green strata until the rock is entirely grey. The rest of the formation consists of typical light to dark grey slates except for a single 4-inch bed of thinly laminated, medium light grey quartzite. Locally, thin skins of pyrrhotite are present along cleavage planes.

At Cranberry Point, cleavage in many places is poorly developed and the rock is an argillite. Bedding is not as well developed there and rare quartz grains are present. Pyrite and arsenopyrite crystals occur in the lowermost 1,000 feet. In the upper part, a few white laminae consisting entirely of quartz are present and green bands are absent. The slate near the base of the outcrop area shows generally paler shades than that in the upper part. Rock from near the contact with the Goldenville Formation is slightly siltier than that higher up in the Halifax Formation.

On the other hand, on the coast west of Sandford, slates show green tints as the contact with the Goldenville Formation is approached. Bedding is not clearly defined and ranges from one-eighth to one-quarter inch in thickness. There, a few lenses and pebble-shaped nodules of quartz, garnet, carbonate, and chlorite up to 2 inches in diameter and one-half inch thick are present. Locally, these coalesce to form a thin bed that pinches and swells but is rarely more than one-half inch thick. It is parallel with the bedding in the slates. The nodules on the other hand may lie either parallel with or normal to the bedding. Similar nodules and beds occur in the Halifax Formation northeast of Broad River, but there they lack carbonate. E. Schiller (personal communication) has observed similar nodules, to which he applies the term 'cotiqule', in the Halifax Formation in the Guysborough area of northeastern Nova Scotia. His study shows the garnet to be rich in the spessartite molecule, and the 'cotiqules' were probably derived from manganese nodules.

Although scour and fill structure, crossbedding, and ripple-marks have been reported from the Halifax Formation elsewhere in Nova Scotia, no primary structures other than bedding have been seen within the map-area.

Secondary structures consist of cleavage, joints, and drag-folds. Cleavage is the most prominent and in many places masks the bedding. Joints occur ubiquitously but were not studied. Drag-folds are locally common; most of them are related to the major folds of the Acadian orogeny, but some can be related to local later faulting in the slates.

Microscopically typical slate consists of subangular to subrounded, silt-sized and smaller grains of quartz and feldspar. Quartz is commoner than in the greywacke of the Goldenville Formation. A few grains of epidote and larger than average muscovite grains may be detrital. Quartz grains are rarely as large as 0.1 mm. Apatite and tourmaline are accessory minerals in most specimens.

The matrix now consists of chlorite and muscovite in the green slates from the lower parts of the formation whereas higher up in the formation, depending upon the degree of metamorphism, the matrix consists of one or more of the following minerals: chlorite, sericite, biotite, garnet, andalusite, cordierite, and staurolite.

Magnetite and ilmenite are present in strings of grains, anhedral grains, and, more rarely, well-formed crystals; graphite occurs as tiny dust-like particles and rod-shaped laths.

Structural Relationships

The contact between the Halifax Formation and the overlying White Rock Formation is exposed only along the west side of Chebogue Point. There, slates typical of the Halifax Formation are indistinguishable from those considered to be part of the White Rock Formation. However, intercalated with the White Rock slates are thin beds of volcanic rocks, probably tuffs. The contact is arbitrarily placed at the base of the stratigraphically lowest volcanic horizon. The contact between the White Rock and Halifax Formations in the map-area, like the Halifax–Goldenville contact, is conformable.

Age

Until recently the age of the Halifax Formation has been in doubt. It is now regarded as Early Ordovician on the basis of fossil determinations in Wolfville map-area (Crosby, 1962). Similar fossils have been found by Smitheringale (1959, 1960) in the Nictaux–Torbrook and Digby areas. None are known in Shelburne map-area.

Andalusite and Staurolite Schists (Map-units 2 and 4)

Both the Goldenville Formation (map-unit 1) and the Halifax Formation (map-unit 3) have been extensively metamorphosed to schists characterized by the presence of andalusite, staurolite, cordierite, garnet, and biotite. These schists are correlated with the Goldenville Formation where they are interbedded with, or stratigraphically underlie, greywacke beds. Where the schists are free from greywacke interbeds or are stratigraphically above greywacke, they are assigned to the Halifax Formation. In places where outcrop is scarce or where the stratigraphy is poorly defined, some schists assigned to the Goldenville Formation may actually be part of the Halifax Formation. For example, some of the schists shown as map-unit 2 in the centre of the syncline extending from Port La Tour to Shelburne Bay may in fact belong to the Halifax Formation, and map-unit 4.

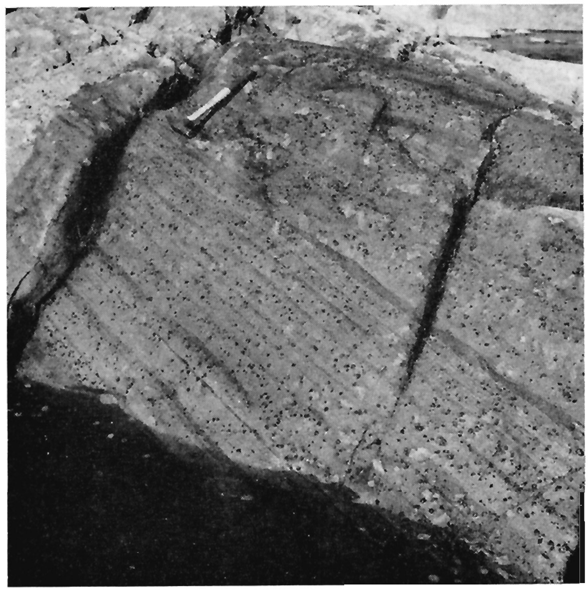
These rocks, which were first mapped by Bailey (1898), are most prominent in the area north of Jordan Falls, along the upper parts of the Clyde River, and extending eastward to the Jordan River valley, and in a belt extending from Baccaro Point to near Shelburne. They are also well developed along the west side of Pubnico Harbour and to the north of Pubnico. A zone of the same schists crosses Broad River about a mile upstream from Highway 3. Smaller areas of these schists occur elsewhere in the eastern half of the map-area.

These schists (map-units 2 and 4) range from dark grey to yellowish grey to greenish and brownish grey. They are commonly porphyroblastic with andalusite, staurolite, biotite, garnet, and rare cordierite forming metacrysts. Some of the andalusite metacrysts are 6 inches long; staurolite and cordierite are rarely more than an inch in length. These large metacrysts show excellent sieve structure and contain biotite, quartz, muscovite, feldspar, and graphite. In many places the metacrysts consist of more than 75 per cent inclusions. In part the schists are knotted, and andalusite, in particular, is poorly developed. Inclusions show no preferred orientation except where carbon occurs in chiastolite, a variety of andalusite.

Whereas in most outcrops the metacrysts in these schists show no preferred orientation, in a few places andalusite lies in well-defined planes. At the bridge across the Roseway River on the road to John Lake, 6-inch andalusite (chiastolite) crystals lie parallel with the bedding planes in 2-inch beds. Smaller crystals in the same outcrop show no preferential orientation.

Relict bedding is preserved in many places. At Jordan Falls, for example, bedding in staurolite-andalusite schist ranges from 2 to 8 inches in thickness and in places shows small-scale crossbeds (*see* Pl. I). Pinkish grey weathering andalusite

PLATE I
Staurolite-andalusite schist at Jordan Falls. Note preservation of the bedding planes and the large andalusite crystals ending sharply against the bedding planes in many places.



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metacrysts, as much as 4 inches long in many beds, are much more abundant and larger near the tops than at the bottoms of the beds. In many beds, andalusite metacrysts stop abruptly at the bottom of the overlying bed; this is undoubtedly a reflection of the change in grain size and composition from the top of one bed to the bottom of the overlying bed. This reverse textural gradation due to metamorphism was used for top determinations wherever possible in these schists. On the other hand, in some places schistosity is strongly developed and primary structures have been destroyed.

Andalusite weathers pinkish grey to light grey and commonly is distinguishable only on the weathered surface. On fresh surfaces it is the same colour as the matrix and contains so many inclusions it is unrecognizable. Staurolite is dark yellowish brown, commonly euhedral, and saw-horse twinning is plentiful. Cordierite is light grey on weathered surfaces and medium dark grey on fresh surfaces. It contains, in general, fewer and smaller inclusions than either andalusite or staurolite.

Locally, as on Greenwood Lake, andalusite is altered to chlorite so that the rock shows large green spots wherever andalusite occurs. Garnet is reddish brown and rarely more than one-sixteenth inch in diameter. Biotite is reddish brown and locally, as along Negro Harbour, forms metacrysts as much as one-quarter inch in diameter. Muscovite occurs both in the matrix and as large porphyroblastic plates. Tourmaline, apatite, magnetite, graphite, and ilmenite occur as accessory minerals. Mineral relationship and petrogenesis of these schists are described and discussed later in this report under the heading 'Metamorphism'.

Paragneiss and Migmatite (Map-units 5 and 5a)

Some of the Meguma Group, in part close to granite plutons, has been extensively metamorphosed and/or impregnated with granite and pegmatite so as to form paragneiss and migmatite. These rocks occur chiefly in the area of Quinan and Barren Lakes, Great Pubnico Lake, along parts of the valley of Bloody Creek, and around the perimeter of the large granitic pluton in the Barrington Passage area. A few outcrops of similar rocks are present west of West Birchtown Lake, east of Harper Lake, and within the batholith west of Shelburne. Similar rocks possibly underlie much of the area between Bloody Creek and the road to Upper Clyde River and the region between Barren Lake and Upper Wood Harbour. Paragneiss and migmatite are also present in the Port Mouton, Wedgeport, and Brenton areas but in amounts too small to map.

Gneisses in the Bloody Creek, Quinan Lake, Great Pubnico Lake, and Madashack Lake areas are chiefly medium- to coarse-grained, although locally fine-grained, light to dark grey speckled rocks. Dark biotite and greyish red porphyroblasts of feldspar give rise to the speckled appearance. In most places, the gneissosity is well developed, but where biotite and muscovite, or both, are plentiful the rocks are schistose. Gneissosity primarily parallels the original bedding wherever the relationship could be determined, such as at those localities where biotite meta-greywacke contains elongate metamorphosed limy concretions that elsewhere in the map-area are known to lie in the plane of the bedding. Locally at Great Pubnico Lake, bands of gneiss 1 inch to 2 inches thick are intercalated with biotite meta-greywacke beds 2 to 4 feet thick.

Layers in the gneiss range from 1 mm to 5 cm thick and relict bedding is as much as 3 feet thick with fine laminae throughout. For the most part gneissosity is consistent to attitude for several tens of feet, but in part is highly contorted and crenulated. Large patches of gneiss in places show a uniform attitude within areas of contorted gneiss.

Much of the gneiss in these areas contains sills, dykes, and irregularly shaped bodies of biotite granite, biotite-muscovite granite, and pegmatite. Sills are by far the commonest form and range from a few millimetres to a few feet in thickness. Dykes are relatively rare, most of them less than 2 feet thick, but one as much as 20 feet thick is present at Quinan Lake. Inclusions of gneiss, some of which have been rotated, are common in the larger granite masses and in some outcrops the gneiss is distinctly granitic in appearance close to granite contacts. Although gneissosity is well developed in the paragneiss, the granite never shows this fabric in the area under discussion. On the whole, granite forms less than 10 per cent of the rocks in the areas mapped as unit 5. Muscovite granite and pegmatite are younger than the biotite granite.

The paragneiss in these areas is a medium- to coarse-grained, light to dark grey speckled rock consisting of granular biotite, quartz, and feldspar, with lesser amounts of garnet, muscovite, sillimanite, and cordierite. The amount of biotite, quartz, and feldspar is variable, but in general feldspar is more abundant than quartz, and quartz more abundant than biotite. Feldspar is chiefly oligoclase with small amounts of potash feldspar. Quartz is commonly strained. Biotite is reddish brown and generally contains pleochroic haloes.

Sillimanite occurs sporadically as long thin crystals lying parallel with the foliation, and is most abundant along Bloody Creek. Garnet is most abundant along the southeast side of Quinan Lake, where individual crystals are as much as 1 inch in diameter and many of them have partial haloes of sillimanite. The eccentricity of the thickness of these enveloping haloes suggests that they are not an alteration product of the garnet, but rather that the garnet provided a resistant mass that allowed a void to be filled on either side of the garnet. As seen in thin section, the sillimanite occurs as a fibrous aggregate roughly normal to the garnet; many fibres, however, are parallel with or oblique to the garnet outline. In the same area, garnet clusters up to 1 foot in diameter are present both in the gneiss and lying athwart gneiss-granite contacts. Garnets are also present in granite where inclusions are abundant. Muscovite where present is commonly poikiloblastic and in flakes that are about twice the size of those of accompanying biotite. It is locally as much as 1 inch long. Cordierite is granular and less common than either muscovite, sillimanite, or garnet.

On Cape Sable Island, north and east of Barrington Bay, and in the vicinity of Upper Wood Harbour, biotite-feldspar-quartz gneiss and biotite-quartz gneiss, locally with garnet and muscovite, is intimately mixed with quartz diorite and muscovite pegmatite. Granitic rocks are more abundant on Cape Sable Island than elsewhere, and there form up to 80 per cent of the rock; south of Villagedale on the east side of Barrington Bay, only a few veinlets of biotite-muscovite granite are present. Inclusions of biotite meta-greywacke are common within the granite. Bedding and gneissosity are parallel in most places, but show a divergence of up to 20 degrees in some outcrops. In other places the rocks show intense deformation and swirled foliation with no indication of whether or not the foliation follows bedding.

The granite occurs chiefly as sills, less than 2 feet thick, and even where it forms the major part of an outcrop appears to follow the gneissosity of the paragneiss. Muscovite pegmatite forms the most irregular bodies of the granitic rocks. Grey, medium-grained biotite-quartz diorite is the chief rock type amongst the granitic rocks, but biotite-muscovite granite and muscovite pegmatite together are probably as abundant. Muscovite pegmatite commonly shows plumose quartz-muscovite structures, which are well displayed in the outcrop west of Baker Inlet on Cape Sable Island. A few tourmaline grains occur in many pegmatites and veins of chlorite are present in some.

At Barrington, some of the migmatite contains a pale pink, medium-grained, equigranular muscovite granite of a type not present elsewhere. Bright pink potash feldspar provides the colour and only rare biotite phenocrysts are present. The paragneiss commonly shows more feldspar than is present in less metamorphosed Meguma Group rocks.

The northernmost outcrops of paragneiss along Bloody Creek consist of fine- to medium-grained, grey, well-foliated muscovite-biotite-quartz-feldspar gneiss and muscovite-biotite-feldspar-quartz gneiss. Metamorphosed limy concretions, up to 1 foot long and now consisting of biotite, garnet, and quartz, lie parallel with relict bedding planes, which at least in part parallel the gneissosity. Although the gneissosity is in a uniform direction throughout most of these outcrops, there too, in places, it is highly contorted. A few layers are composed entirely of feldspar. Locally, narrow granite dykes intrude these rocks.

The paragneiss west of West Birchtown Lake is a dark brown, garnet-biotite-quartz gneiss and biotite-quartz gneiss. Granite is associated with some of the biotite-quartz-gneiss, where it forms up to 50 per cent of the rock (map-unit 5a). Similar migmatite is present within the granite west of Shelburne.

Origin of the Meguma Group

The source of the sediment composing the Meguma Group is not known. The presence of abundant plagioclase and quartz points towards a source rock of granodiorite composition. The rare quartzite pebbles in the Goldenville Formation are from a metamorphic terrain and therefore it is possible that the source area was a metamorphic region consisting dominantly of rocks of granodiorite composition with some quartzite beds.

Current direction during sedimentation is little known even though current indicators such as ripple-marks and crossbedding have been reported from many localities, particularly in the Halifax Formation (Woodman, 1904b; Stevenson, 1959; Smitheringale, 1960; Crosby, 1962). As yet no comprehensive study of current indicators has been undertaken. Current direction as determined from rare crossbedding in the Goldenville Formation is predominantly toward the west and north (Fig. 1). Phinney (1961) found current direction in the Meguma Group to be eastward in a few outcrops examined in a small area along the coast, 65 miles east-northeast of Halifax. This aspect of the origin of the Meguma Group requires more study, but present knowledge favours a generally northwestward-trending current during the deposition of the Goldenville Formation.

The deposition of the Goldenville Formation has generally been considered to have taken place in a marine, slowly subsiding geosynclinal environment. According to Woodman (1904b), the formation was deposited in moderately shallow water, upon a floor essentially flat and influenced by somewhat violent currents and waves, constantly shifting their relations. Woodman alone considered the Goldenville Formation strata to be non-persistent and to show rapid thinning where he examined the formation at Moose River and West Waverly. Malcolm (1929) was of the opinion that grain-size variation was the result of a combination of causes, such as long periods of heavy precipitation alternating with shorter periods of drought, changes in direction or velocity of shore currents, and variation in the rate of subsidence.

Woodman (1904b) thought the Halifax Formation was deposited in deeper water than the Goldenville, either farther from the land mass or from a land mass worn much lower. The alternating fine and coarse layers in the Halifax have been ascribed to seasonal deposition by Douglas, *et al.* (1938). Crosby (1962) also considered seasonal deposition a possibility and concluded that the Halifax Formation was deposited in fairly shallow and muddy water in a marine geosynclinal basin.

The characteristic features of the Goldenville Formation, such as graded bedding, uniform thickness of beds, slump breccia, scarcity of crossbeds and ripple-marks, are similar to those occurring in strata formed by turbidity currents of high density (Kuenen and Migliorini, 1950; Dott and Howard, 1962). Phinney (1961) recently suggested, after a brief examination, that the entire Meguma Group was possibly a turbidity current product. However, it is doubtful that turbidity currents were responsible for the deposition of the Halifax Formation, for its beds are rarely graded and are discontinuous. In other areas (Stevenson, 1959; Smitheringale, 1960; Crosby, 1962), Halifax rocks show truncated lenses, cross-laminations, scour and fill, and ripple-marks, structures that are not characteristic of turbidites. From the evidence presently available, Crosby's (1962) conclusion as to the origin of the Halifax Formation is probably correct. The existence of diverse contact relationships between the two formations is probably a reflection of changing conditions at the end of the Goldenville depositional period.

The following sequence of events is consistent with the characteristics of the Meguma Group. Erosion of a mountainous terrain, probably dominantly of metamorphic rocks, resulted in deposition of sediment on a shelf platform. Subsequent turbidity currents redistributed the sediment on the sea floor to a thickness, eventually, of more than 18,000 feet. The depositional basin may have received sediment from more than one direction. Palaeocurrents, in part at least, trended northwesterly but the source area or areas are unknown. With the filling of a large part of the depositional basin, the water level was reduced and a transition occurred from a turbidite deposit, the Goldenville Formation, to one associated with shallower water, the Halifax Formation. During the turbidite depositional period the source area would have been greatly reduced with regard to relief, and so, with the commencement of the Halifax deposition, only the finer sedimentary detritus would be carried to the depositional basin. With the advent of the deposition of the Halifax Formation, compaction of the Goldenville and subsidence of the basin itself kept pace with the deposition of sediment so that at least 12,000 feet of sediment accumulated.

White Rock Formation (map-units 6, 7, 8, and 9)

The first reference to rocks of this formation was by Faribault (1909a) in Gaspereau map-area. These he called 'Whiterock quartzite'.

Faribault (1920) was also the first to recognize the existence of similar, although more metamorphosed rocks at Chegoggin Point in Shelburne map-area. Crosby (1962) remapped Faribault's original area and changed the name to White Rock Formation because the unit commonly contains more slate than quartzite, and the locality wherein the name is derived is White Rock Mills rather than Whiterock. Crosby (1951) precisely defined the formation as follows:

> The White Rock Formation . . . . . . is essentially two massive quartzite beds with slate between them. The top of the upper quartzite bed and the base of the lower quartzite beds are the limits of the formation.

The slate of this formation is indistinguishable from that of the Halifax Formation so that the only distinctive member is the massive quartzite.

Smitheringale (1959, 1960) was able to extend the White Rock Formation to the southwest as far as Digby map-area, although he could not maintain Crosby's definition. In the Nictaux–Torbrook area, he found that bedded argillaceous quartzites, quartzites, and volcanic rocks underlie the base of the lowermost white quartzite that comprises the base of the formation in Crosby's map-area. As these rocks are dissimilar to any in the Halifax Formation, Smitheringale included them in the White Rock Formation and placed the contact ". . . either at the bottom of the lowest quartzite or volcanic member, or at the top of the thinly interlaminated, light and dark grey 'Halifax type' slates, whichever location is stratigraphically lowest" (Smitheringale, 1960, p. 15). Hence the White Rock Formation includes volcanic rocks not known in the type area.

Farther southwest in Digby map-area, however, there are no volcanic rocks and typical massive quartzite is relatively rare. There, the contact with the Halifax Formation is gradational along Bear River between typical Halifax rocks and a dark grey 'featureless' arenaceous siltstone (Smitheringale, 1959, p. 5) that comprises the largest part of the formation in this area.

Typical White Rock Formation quartzite is present near Doucetteville and volcanic rocks are present along Sissiboo River (Taylor, 1962). Both the quartzite and volcanic rocks overlying the Halifax Formation at Cape St. Mary (Taylor, 1961b) are part of the White Rock.

Thus, the presence of the White Rock Formation has been established in several districts along the northwest side of Nova Scotia from Wolfville map-area to Shelburne map-area, despite the existence of later granitic intrusions and extensive overburden. Also, the White Rock Formation is not primarily a simple rock-unit consisting of quartzite and slate as it is known in Wolfville map-area, but a complex rock-unit composed of diverse rock types with little stratigraphic continuity, and the only rock type that can be considered characteristic of the formation is a massive quartzite that is commonly white or light coloured.

The stratigraphy of the White Rock Formation and other Silurian strata of southwestern Nova Scotia and the Silurian–Ordovician relationships have been described by Taylor (1965).

Distribution

Within the map-area, the White Rock Formation is confined to the centre of a syncline extending from Yarmouth Sound to Lake George. It consists predominantly of volcanic rocks with lesser amounts of slate, argillaceous quartzite, conglomerate, greywacke, and typical White Rock Formation massive quartzite. The quartzite outcrops on both limbs of the syncline at approximately the same stratigraphic horizon, and also west of Overton stratigraphically much higher in the sequence. Argillaceous quartzite and slate are present chiefly on the west limb north of Chegoggin Point and near Overton.

Slate is also present near the core of the syncline through Yarmouth Harbour and on the coast north of Chebogue Point. Volcanic rocks, chiefly basic types, are well exposed about Yarmouth Sound and northward to South Ohio. Scattered outcrops of volcanic rocks occur throughout most of the area shown as White Rock Formation on the geological map, and on the whole this formation, especially the volcanic rocks, is the best exposed rock-unit in the map-area.

Thickness

The maximum thickness of the White Rock Formation cannot be determined as there are no overlying rocks. However, it is much thicker in this map-area than elsewhere in Nova Scotia (*see* Table I).

Table I

Thickness of the White Rock Formation

Area	Thickness in feet	Reference
Wolfville	100 – 500±	Crosby, 1962
Nictaux–Torbrook	200± – 2,000±	Smitheringale, 1960
Digby	3,500±[1] (shown as 1,500 in report)	Smitheringale, 1959
Shelburne	+ 13,500 – 15,500[2]	This report

[1] White Rock–Kentville equivalent. White Rock Formation probably not less than 2,000 feet.
[2] Top unknown.

From its base at Pembroke Cove to the centre of the Yarmouth syncline near Milton Lake (if one disregards possible thickening due to folding or faulting), the White Rock Formation shows a maximum of 15,500 feet to a minimum of 13,500 feet depending upon where the Halifax–White Rock contact is drawn. This thickness is composed of about 4,500 feet of sedimentary rocks with the remainder volcanic. On the east side of the syncline, although the Halifax–White Rock contact is not as well defined, the thickness is of the same order. A thickening from the type area to the southwest is evident, in part due to the presence of volcanic rocks.

Sedimentary Rocks

Sedimentary rocks in the White Rock Formation cover a wide range of lithologies from conglomerate to slate. For mapping purposes they are divided into two units: the argillaceous rocks (map-unit 9); and all the rest, consisting of quartzite, conglomerate, greywacke, and argillaceous quartzite (map-unit 6). This division is entirely lithological and has no stratigraphic significance.

White Rock Quartzite (Map-unit 6a)

The typical quartzite of the White Rock Formation is present at several localities on both limbs of the Yarmouth syncline.

At Chegoggin Point, the quartzite forms several bands ranging in thickness from 12 to at least 80 feet; the thickest of these bands was once quarried for silica rock. Individual beds measure 2 inches to 4 feet in thickness. Also at Chegoggin Point, irregular and lens-shaped bodies of quartzite up to 3 feet thick are present in amphibolite of volcanic origin. These lenses show a banding parallel with the walls, but no distinct bedding. They possibly represent beds broken up during volcanism and incorporated in the volcanic rock.

West of Overton, a 21-foot-thick section of quartzite is present in a sequence of argillaceous quartzite and slate. There the massive quartzite occurs in beds half a foot to 2 feet thick.

The only other outcrop of this rock on the west limb of the Yarmouth syncline is along the road on the west side of Lake George, where several small outcrops are poorly exposed. If one assumes a north-northeast strike, the quartzite there could be 100 feet thick. No structure is visible at this locality.

On the east limb, half a mile east-northeast of Sandbeach, the quartzite is predominantly light grey and medium grained. Banding is well displayed in a few boulders nearby, but in outcrop is poorly defined. Much of the quartzite there contains biotite and is gneissic, but at the north end of the outcrop area it is almost entirely quartz and typical of the quartzite of this formation.

Farther north, a quarter mile southwest of Brooklyn, a single outcrop of white weathering, light grey, massive, medium-grained quartzite containing pink garnets represents the White Rock quartzite in this area. The quartzite half a mile east of Brazil Lake crossroads displays good bedding as shown by white to light brown banding. Probably more than one bed is present in this area, as individual outcrops are not aligned along strike.

The distribution of the quartzite in this map-area establishes the existence of more than two quartzite beds within the formation and also the existence of similar quartzite higher in the stratigraphic section as exposed at Overton.

Although the quartzite is widely distributed along the northwest side of the province, the persistence of any individual bed of quartzite is unlikely. At Cape St. Mary (Taylor, 1961b), two exposures of quartzite beds separated by about 1 mile show marked differences from one another in thickness and stratigraphic position.

The stratigraphic position of the lowermost quartzite bed shows considerable variation from the Wolfville area, where it forms the base of the formation, to the Shelburne area, where it occurs between 4,300 and 5,400 feet above the base along the west limb of the Yarmouth syncline. On the east limb, although its position cannot be established with accuracy, it also occurs about 5,000 feet above the base of the formation.

This distinctive member of the White Rock Formation is a fine-grained quartzite, chiefly white or light grey but in part mottled brown, yellow, dark grey, or red, depending upon the amount and type of impurities. This quartzite forms beds ranging from one-quarter inch to 4 feet in thickness, although inland where exposures are poor no structure is discernible in some outcrops. The thin beds are marked by colour banding. Where it borders slate, this quartzite is commonly argillaceous and darker grey than normal.

In thin section, the quartzite is seen to be a fine-grained mosaic of recrystallized quartz averaging 0.15 mm grain size, with rare grains up to 1 mm long. White specimens consist entirely of quartz with typical analyses showing more than 97 per cent silica (Collings, 1956).

The only detrital minerals are tourmaline, apatite, and epidote(?), all of which are subrounded with grains as long as 0.1 mm. Small amounts of secondary sericite, chlorite, magnetite, garnet, biotite, and cummingtonite are present locally.

Conglomerate (Map-unit 6b)

Although conglomerate at Cape Fourchu (West Cape) early attracted the attention of geologists, it has not been described fully. Selwyn (1872) first reported it and noted the flattening and elongation of the pebbles in the direction of the cleavage. Later Bailey (1898) visited the Cape but only mentioned the conglomerate in his report and attempted to correlate it with rocks at Pubnico Harbour.

Conglomerate is confined to the west side of the Yarmouth syncline southwest of Overton and approximately on strike at Cape Fourchu (West Cape). Scattered cobbles are present in volcanic rocks southwest of Yarmouth Bar in line with the above exposures. A quarter mile north of Yarmouth Bar, 5 feet of conglomerate lying east of the main conglomerate zone forms an entirely separate band. Conglomerate is not known north of Overton and is assumed to be of limited lateral extent in those places where it is present.

At Cape Fourchu (West Cape), conglomerate outcrops in two areas separated by 200 feet of cobble beach. Stratigraphically, more than 100 feet of conglomerate is exposed with a maximum thickness of about 250 feet. Southwest of Overton along the coast, it forms a bed at least 39 feet thick with neither top nor bottom exposed.

Fragments range from pebbles to boulders up to 2 feet in greatest dimension. Most fragments are of cobble size, however, and many are deformed (Pl. II). Many quartzite and basic volcanic rock cobbles are about 1½ feet long and only 3 or 4 inches in diameter (*see* Pls. III and IV). Fragments of rhyolite are more resistant to stretching so that they probably show their original outline more closely than the basic volcanic rocks, and are well rounded. Conglomerates close to the overlying and underlying volcanic rocks do not show stretching as much as those in the central part of the conglomerate horizon.

In the most eastern exposure of conglomerate at Cape Fourchu (West Cape), some of the basic volcanic pebbles up to 2 inches long are angular to subangular, although quartzite, biotite quartzite, and rhyolite pebbles up to 5 inches long in the same stratum are well rounded.

About 70 per cent of the fragments (boulders, cobbles, and pebbles) consist of fine- to medium-grained, recrystallized, medium grey, massive biotite-muscovite quartzite. Some fragments show bedding and a few others are themselves a con-

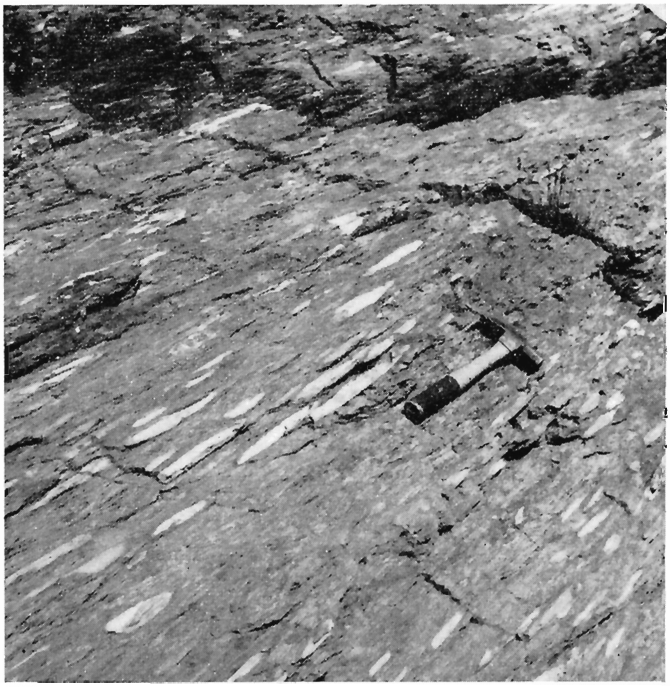
F.C.T. 5-2-60

PLATE II
Conglomerate of the White Rock Formation at Cape Fourchu. Hammer head is on a cobble of rhyolite (map-unit 8).

F.C.T. 5-660

PLATE III
Stretched cobbles in the conglomerate of the White Rock Formation at Cape Fourchu.

glomerate containing well-rounded quartz pebbles up to one-half inch. Basic volcanic rocks are estimated to comprise 25 per cent of the fragments. They are similar in composition to the White Rock basic volcanic rocks (map-unit 7), and were without doubt derived from them. Rare cobbles and pebbles of the distinctive White Rock Formation quartzite (map-unit 6a) and White Rock rhyolite (map-unit 8) are



F.C.T. 5-12-60

PLATE IV
Stretched quartzite cobbles in the conglomerate of the White Rock Formation at Cape Fourchu.

scattered throughout the conglomerate. Some horizons in the conglomerate contain more fragments of one rock type than is generally present. For example, in the most eastern conglomerate outcrop at Cape Fourchu (West Cape), biotite-muscovite quartzite forms more than 90 per cent of the fragments. Rare quartz pebbles are present throughout the conglomerate but are commonest in the eastern exposures at Cape Fourchu (West Cape).

The matrix shows considerable variation in composition. In general, quartz fragments dominate in the eastern parts of the conglomerate zone. There, much of the rock is medium-grained, yellowish grey greywacke in which conglomerate forms bands one-half inch to 3 feet thick. Farther westward, although a quartz-rich matrix is common in many places, much of the matrix consists of fine- to medium-grained plagioclase, biotite, and hornblende and fragments of volcanic rock. Lenses of quartzite to greywacke, 6 to 8 inches thick, are also present in the west part of the outcrop area. Some of these pinch out within 20 to 30 feet along strike and down dip.

In general, the matrix is composed of the same minerals that form the fragments. Where sedimentary rocks form most of the fragments, the matrix is chiefly composed of minerals occurring in the sedimentary fragments; on the other hand, where the fragments are dominantly volcanic, the matrix is composed of minerals derived from volcanic rocks.

The matrix of the conglomerate southwest of Overton is similar to some of that at Cape Fourchu (West Cape), consisting chiefly of volcanic rock debris with small amounts of quartz and, locally, plagioclase grains up to one-quarter inch long. The fragments, chiefly of cobble size and up to 8 inches long, are dominantly basic volcanic rocks with scattered rhyolite quartzite and quartz, the latter pebble-sized. Rare cobbles of well-rounded porphyritic rhyolite are present in the basic volcanic rocks in the Cape Fourchu area. One such cobble of rhyolite, 8 inches in diameter, is well displayed on the southeast side of the road to Markland one-quarter mile beyond the causeway from Yarmouth Bar, where it occurs in amygdaloidal andesite.

At Cape Fourchu (West Cape), the east or upper contact, exposed only at low tide, shows poorly interbedded conglomerate and greywacke grading into the overlying massive andesite over a width of 4 inches. Slight embayments occur but the contact is structurally conformable.

The lower contact consists of an extremely complex zone, 40 feet thick, of conglomerate, medium bluish grey greywacke, hornblende gneiss, and intrusive porphyritic rhyolite. The rhyolite forms lenses in the hornblende gneiss as much as 4 feet long by 2 feet wide, whereas in other places irregularly shaped patches of gneiss are present in the rhyolite. The rhyolite crosses the structure for about 30 feet, so that in part this zone is almost entirely rhyolite. The strike of the conglomerate is parallel with that of well-developed flows to the west of the rhyolite, and although the dip is shallower, this may be due to the intrusion of the rhyolite. Inland, southwest of Overton, conglomerate grades into hornblende gneiss at the lower contact. At the contact, the fragments are entirely volcanic whereas stratigraphically higher fragments are predominantly quartzite. The upper contact is not exposed.

The 5 feet of conglomerate north of Yarmouth Bar is intercalated with basic tuff and the matrix of the conglomerate is primarily tuff, although the fragments are quartzite up to 6 inches long. As the conglomerate is structurally conformable with the overlying rocks and nearly so with the underlying rocks, the conglomerate is considered to be an integral part of the White Rock Formation in this map-area.

Greywacke (Map-unit 6c)

Greywacke forms only a small part of the White Rock Formation. It is present at Sunday Point, the east side of Yarmouth Sound, and northwest of Ships Stern. At Sunday Point greywacke occurs at two places: near the southern tip of the point; and four-fifths mile north along the west coast of the point. At the first locality, 15 feet of greywacke are exposed but die out along strike. At the second location, a similar thickness is exposed by the sea. At both places the greywacke is medium grey, chiefly medium grained, and well bedded, although in part massive at the northern locality. Also at the north end of Sunday Point, pyrite cubes up to three-eighths inch commonly occur.

One-quarter mile northwest of Ships Stern, bands of fine-grained greywacke, up to 2 inches thick are intercalated with similar sized bands of dark green hornblende gneiss possibly of tuffaceous origin. Subangular fragments of greywacke as large as 6 inches by 1½ inches, are present in coarse-grained hornblende gneiss underlying the banded zone. This gneiss may have been derived from a sill that incorporated some of the overlying rock. Less than a foot of greywacke is present in the whole exposure.

On the east side of Yarmouth Sound, a single bed of medium-grained greywacke is present in basic volcanic rocks.

Argillaceous Quartzite (Map-unit 6d)

Argillaceous quartzite forms a zone 490 feet thick near the base of the White Rock Formation south of Pembroke Cove, where it consists of light grey, medium-grained, well- and thin-bedded biotite quartzite. Beds range from one-eighth to one-half inch in thickness with rare cleaner quartzite interbeds up to 2 inches. A cleavage is present parallel with the bedding. Locally, the feldspar content is sufficient for the rock to actually be a feldspathic quartzite.

Similar argillaceous quartzites occur west of Overton in four sections ranging from 4 to more than 33 feet in thickness. In the thickest section, rare quartzite beds up to 1 foot thick are present. These argillaceous quartzites commonly grade into slates.

Argillaceous quartzite is interbedded with slate west of Overton, in beds that are as much as 4 feet thick, but which are mostly about 1 foot thick. Many of these beds are elongate lenses and the thickest of them commonly terminate within 100 feet along strike. Contacts with the slate are generally abrupt.

On the east limb of the Yarmouth syncline similar arenaceous sediments are scarce, possibly because of the dearth of outcrop. Schistose feldspathic quartzite occurs at Brooklyn and small amounts are associated with garnet-andalusite schists on the road to the south-southwest.

Slate (Map-unit 9)

Slate forms the largest part of the White Rock sedimentary rocks in Shelburne map-area. On the west side of the syncline, nearly 900 feet of slate lie beneath the White Rock quartzite north of Chegoggin Point. There the slate is light grey to grey, thinly laminated, and strongly cleaved to schistose. Numerous small folds are present and thickening is probable. Garnet is present in much of this slate and chloritoid crystals up to one-half inch long are locally common. Thin diorite sills are common in its upper part. West of Overton, several slate bands are present which range in thickness from 10 to 220 feet. Most of this slate is similar to that north of Chegoggin Point, but some of it is greyish green, particularly in the thin stratigraphically highest layers. Bedding is well developed, with individual beds 1 inch thick or less. Cleavage is only weakly developed. Some of the slate layers contain interbedded quartzite and argillaceous quartzite beds that form up to 30 per cent of the rock but average about 10 per cent.

On the east side of the Yarmouth syncline, the rocks are not as well exposed, but slate occurs in the contact area with the Halifax Formation north of Chebogue Point. There they are dark grey, thinly laminated, and indistinguishable from the Halifax Formation rocks. East of Brazil Lake crossroads, staurolite-andalusite schists (map-unit 9a) were probably derived from slate of the White Rock Formation, as they are close to typical White Rock quartzite. Garnet-mica schist (map-unit 9a) near the Yarmouth airport was probably derived from these slates also.

Slate of the White Rock Formation also occurs along the east side of Yarmouth Harbour and extends north as far as Dayton. The thickness of this section is unknown, but probably does not exceed 700 feet. These rocks are greenish grey to dark greenish grey, chiefly strongly cleaved and poorly bedded. Characteristically, these rocks are peppered with black vitreous crystals of chloritoid up to one-sixteenth inch in diameter. In thin section, many of the chloritoid grains are seen to be oriented parallel with the cleavage traces, but others show no preferred orientation. The matrix appears to flow around many of the chloritoid grains, especially those normal or at acute angles to the cleavage traces. Secondary quartz commonly lies along the edges of the chloritoid grains in their "shadows". The chloritoid is pleochroic, yellowish grey to bluish grey, with rare inclusions of graphite and even rarer quartz. The matrix consists of fine-grained chlorite, sericite, quartz, and scattered laths of graphite.

Dark to medium grey, thinly laminated slate forms a band 20 feet thick on the east side of Yarmouth Sound in basic volcanic rocks. Within the slate band, three quartzite beds 4 to 6 inches thick are present. All contacts are conformable at this locality.

Volcanic Rocks

Volcanic rocks comprise the largest part of the White Rock Formation in Shelburne map-area. They are divided into two units, one consisting of mafic volcanic rocks that include flows, tuffs, and probable associated sills, and the second consisting of rhyolite, rhyolite tuffs, and some rhyolite intrusive rocks.

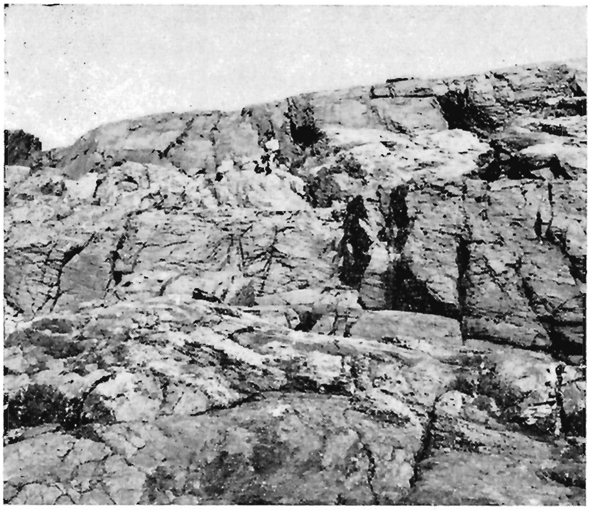
Mafic Volcanic Rocks (Map-unit 7)

The first record of mafic rocks is by Dawson (1855, p. 350), who wrote: "Near the town of Yarmouth there are hornblende and chorite slates . . . ". Later, Selwyn (1872, p. 272) recognized ". . . hornblendic, chloritic, epidotic, and micaceous strata, with dark greenish and black slates; also massive crystalline epidote diorites, with large enclosed patches of epidote rock" near Markland and Yarmouth. Bailey (1898, pp. 68–71) also noted the hornblende-bearing rocks in the Yarmouth district but erroneously correlated them with metamorphic rocks of the Meguma Group occurring at Pubnico.

These rocks are well exposed from both sides of Yarmouth Sound to as far north as South Ohio and form prominent hills along the west side of Milton and Doctor Lakes. North of South Ohio, outcrop is scattered with exposures abundant only near Brazil Lake. Mafic volcanic rocks probably underlie most of the area extending from Lake George to Yarmouth Sound.

All but about 600 feet of the 9,000 to 11,000 feet of volcanic rocks in the White Rock Formation are mafic rocks.

Although many of the mafic volcanic rocks have been metamorphosed to schists and gneisses, primary structures have been preserved locally and flows and tuffs can be distinguished. The best exposures of flow rocks are on the west side of Cape Fourchu (West Cape) (*see* Pl. V). There three flows, each about 40 feet thick, can



F.C.T. 6-8-60

PLATE V
Three flows of andesite on cliff face on the west side of Cape Fourchu. Tops of the flows are marked by the light coloured bands. Figure sitting on the top of the second flow.

be distinguished in a cliff face. Typically these flows show, from the top downward, a breccia and scoriaceous zone, an amygdaloidal zone, and a massive zone. The upper zone, which ranges from 20 to 60 feet in thickness, consists of grey to pale purple, scoriaceous flow-top breccia. The lowest flow shows a well-laminated 1-foot-thick bed overlying the breccia. The laminae, which are as much as one-quarter inch thick, in thin section are seen to be composed of various proportions of medium-grained actinolite, fine-grained epidote, untwinned plagioclase, rare quartz, and magnetite, producing a banded rock. This laminated bed is probably of tuffaceous origin. The breccia zone grades into the amygdaloidal zone. In the latter, amygdules consist primarily of quartz, but locally epidote is common. In the lowest flow, these amygdules, which are as long as $1\frac{1}{2}$ inches, lie normal to the top of the flow. The amygdaloidal zone grades into the massive lower part of the flows, which consists of well-jointed andesite. The joints are characteristically normal to the flow surface. The contact between flows is clearly defined, as the dark green massive andesite of the base contrasts sharply with the grey to pale purple flow breccia of the underlying flow.

North-northeast of Bunker Lake, at least three flows are present in a stratigraphic thickness of 400 feet separated by fragmental flow tops with fragments as large as 6 inches by 2 inches. In these flows, grain size ranges from fine to coarse, and in places weakly developed mineral banding is present parallel with the flow surface. West of Doctor Lake, three thin breccia beds 2 to 3 feet thick separate flows 15 to 20 feet thick.

The thickest flow observed to date occurs on Cape Fourchu (West Cape) east of the conglomerate. There, 40 feet of amygdaloidal breccia overlie 110 feet of fine-grained massive andesite. The thinnest flows occur on the west side of the same cape and range from 1 foot to 4 feet in thickness.

Primary structures in the flow rocks consist of fragmental and vesicular tops, amygdules, pillows, rare inclusions of country rocks, and possible flow lines. Fragmental flow tops probably do not exceed 50 feet in thickness. They are generally fine grained with fragments less than 1 inch long. In many places, they are only readily identifiable on weathered surfaces. Locally, northwest of Bunker Lake, fragments as large as 2 feet by one-half foot contain subhedral to euhedral plagioclase phenocrysts up to three-quarters inch long and averaging one-third inch. Similar phenocrysts also occur in the matrix, but are poorly formed although in the same size range. In many places flow tops are scoriaceous as well as fragmental.

Amygdules are probably the most common structure in the flow rocks and are particularly well developed about half a mile south of Chegoggin village. There amygdules of quartz and, in some places, epidote are as much as 8 inches long. In plan they are elliptical with the major axis up to 5 inches long but in general about 1 inch. Some are gourd-shaped in section with the bulbous part at the base. A few are only partly filled and have well-formed quartz crystals lining them. Others show an epidote rim with a quartz core. Hornblende is a rare constituent. Elsewhere a few amygdules are formed of calcite.

The thickest amygdaloidal zone is on Cape Fourchu (West Cape) where about 40 feet of amygdaloidal rock are present. Although amygdules in general lie in a plane parallel with flow surfaces, they are not in themselves suitable for top determinations.

Pillow structures are rare and where present are poorly developed. The best example is near Ships Stern, where lens-shaped pillows, ranging from 1 foot by one-half foot to 4 feet by $1\frac{1}{2}$ feet, and mattress-shaped pillows, 8 feet by 1 foot, occur. Selvedges are as wide as 4 inches and consist of needles of hornblende in very fine grained plagioclase. Nowhere are pillows suitable for top determinations.

A few boulders of country rock, chiefly rhyolite, are present in andesite in the Cape Fourchu area. None are useful for top determinations. Narrow wispy lines in some outcrops have been interpreted as flow lines, but as their direction invariably corresponds with any gneissosity developed they may be a metamorphic phenomenon.

These mafic rocks are chiefly dark greenish grey, but are also light greenish grey, bluish grey, and greenish black. Although chiefly gneissic to schistose they are also aphanitic and porphyritic. Feather amphibolite is characteristic of many of the gneissic rocks. Grain size ranges from fine to coarse, and phenocrysts of plagioclase and amphibole metacrysts commonly attain a length of one-half inch.

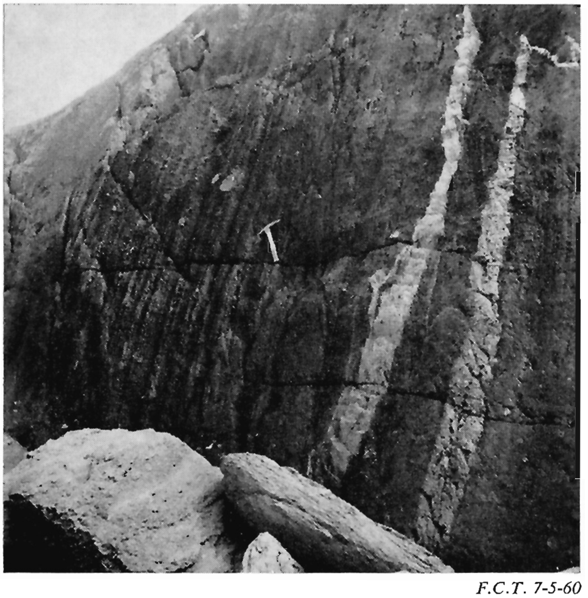
As seen microscopically, the mafic rocks are composed predominantly of actinolite, epidote, plagioclase, and chlorite, with small amounts of quartz, biotite, apatite, sphene, calcite, magnetite, and ilmenite. The ratio of the essential constituents to one another varies greatly from place to place but, in general, actinolite and epidote are more common than chlorite or plagioclase. Plagioclase occurs in two forms. The phenocrysts in the porphyritic rocks show an anorthite content as high as 30 per cent. These crystals are cloudy with inclusions of actinolite, chlorite, epidote, and calcite.

In the matrix of the porphyritic rocks and elsewhere, however, the plagioclase occurs as small untwinned anhedral grains.

Mafic Tuffs (Map-unit 7a)

Tuffs occur erratically throughout the volcanic rocks, but form a fairly continuous band from Cape Fourchu (East Cape) north along the west side of Milton and Doctor Lakes as far as Bunker Lake. Another band is present on the west side of Cape Fourchu. Tuffs on Green Island may be an extension of this band. These are all on the west limb of the Yarmouth syncline. Thin tuff bands are present at the tops of some flows, such as those previously described at Cape Fourchu.

Typically mafic tuffs are greenish grey, fine to coarse grained, well bedded, and commonly contain rock fragments (Pls. VI and VII). Bedding ranges from one-



F.C.T. 7-5-60

PLATE VI
Well-bedded mafic tuffs just north of the lighthouse on Cape Fourchu. Two rhyolite dykes on the right and bombs to the left of the hammer.

eighth inch to 8 inches in thickness. Rock fragments may be as much as 2 inches in diameter, but most commonly are less than 1 inch. In many places the fragments are oriented parallel with cleavage or schistosity. Plagioclase phenocrysts, up to one-quarter inch long, are common locally and the rocks were probably crystal tuffs originally. North of Yarmouth lighthouse, bedding is particularly well displayed and locally graded bedding is evident. There too, volcanic bombs, up to 10 inches long, have fallen into soft unconsolidated bedded ash so as to transect the uppermost laminae and bend downward those below. Later laminae arch over the bombs. Similar tuffs with bombs are present on Green Island. Graded bedding and bomb sag were both used for top determinations.

Microscopically, the mafic tuffs were seen to consist of corroded albite phenocrysts in a fine-grained recrystallized matrix of albite, actinolite, chlorite, epidote, ilmenite, rare magnetite, and quartz. The phenocrysts are cloudy and extensively altered to sericite, actinolite, epidote, and probably calcite. No shards or other microscopic characteristics have been preserved.

F.C.T. 7-4-60

PLATE VII
Detail of the volcanic bombs in Plate VI, showing the depression of the beds due to impact. Tops of the tuff to the left.

In a few places within the mafic volcanic rocks are massive diorites that are probably sills. The most prominent of these is a dark greenish grey, medium-grained, equigranular, granitoid, well-jointed rock, which outcrops along the east side of Cape Fourchu (West Cape). This rock locally shows weak mineral banding parallel with the regional trend, with alternating plagioclase and actinolite bands one-half inch thick. Irregularly shaped patches of epidote, as large as 2 feet by 1 foot, which grade into the diorite, are common throughout the length of the outcrop. Similar smaller and less well-defined diorites occur elsewhere in the mafic volcanic rocks.

These rocks are more massive and coarser grained than the flow rocks and lack any extrusive characteristics. Therefore, they are considered to be sills that were probably derived from the same magma as the volcanic rocks and may be contemporaneous with them. They are possibly related to the diorite sills (map-unit 10b) common in the sedimentary rocks. Some of them may, however, be parts of thick, slowly cooled flows.

Rhyolite (Map-unit 8)

Rhyolite forms only a small part of the White Rock Formation in Shelburne map-area. The only references to these rocks are by Selwyn (1872, p. 272) and Bailey (1898, p. 69), both of whom noted the presence of a white quartz or feldspathic rock within the town of Yarmouth. Bailey also discovered the same rock southwest of Overton and noted the similarity of the two occurrences. However, neither recognized the extrusive character of these rocks.

In addition to the two occurrences mentioned above, rhyolite is also present at

Cape Fourchu (West Cape), at Sunday Point, south-southwest of Brooklyn, and east of Sandbeach. Rhyolite is not known north of Hebron.

The total thickness of rhyolite probably does not exceed 600 feet and in many places it is absent. Individual bands do not exceed 250 feet in thickness and most are thinner. Rhyolite shows diverse gross lithological and structural relationships with the adjacent rocks throughout the Yarmouth district (*see* Pl. VIII). Near

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PLATE VIII
Porphyritic rhyolite (map-unit 8) cutting greywacke (map-unit 6c) at Sunday Point. A dark coloured lamprophyre dyke occurs in the foreground with the greywacke to the right of the hammer head. Yarmouth lighthouse in the background.

Overton, the rhyolite is conformable with basic volcanic rocks and is present as a single well-defined band. In part the outcrop is vesicular, and the rhyolite there is probably of extrusive origin.

At Cape Fourchu, however, the rhyolite lies between the base of the conglomerate and the underlying basic flows. The lower 25 feet form a complex zone in which the rhyolite occurs as lenses in hornblende gneiss as large as 4 feet by 2 feet in some places, whereas in others irregularly shaped patches of hornblende gneiss occur in the rhyolite. At one point, rhyolite cuts across the structural trend for about 50 feet so that intrusive relationships are apparent. This complex zone in some places consists almost entirely of rhyolite whereas in other places it consists almost entirely of hornblende gneiss.

About 120 feet of rhyolite occur as lens-shaped white, grey, or pale brown masses, as large as 4 feet by 12 feet. Within this 120 feet, epidote and quartz occur sporadically in patches and lenses as large as 30 feet by 10 feet.

The lower contact between the rhyolite and basic flow rocks is abrupt and in part hairline, and parallel with banding in the underlying rock. Locally, inclusions of fine-grained basic volcanic rocks are present in the rhyolite. Lenses of rhyolite, quartz, epidote, and minor chlorite, as large as 3 feet by 2 feet, are present in the basic volcanic rocks at the contact. The lack of flow features and the presence of intrusive characteristics suggests that the rhyolite at Cape Fourchu is intrusive.

At the southwest tip of Sunday Point, 168 feet of rhyolite are present and the lower contact is exposed. Part of this rhyolite is in contact with hornblende gneiss, and part of it with greywacke. The tongue of rhyolite clearly cuts the bedding of the greywacke. The contact with the hornblende gneiss is parallel with the foliation in the gneiss. At this locality, a few irregular, thin, dark green mica lamprophyre dykes are present in the rhyolite and along the contact with greywacke. The upper rhyolite contact is not exposed, but a few inclusions of metasedimentary rocks are present. Good intrusive evidence at the base of the rhyolite indicates that it is probably an intrusive rock at this place. Here, too, no extrusive characteristics are evident in the rhyolite.

Southwest of Sandbeach on the shore of Yarmouth Sound, angular to rounded, locally lens-shaped inclusions of andesite are present in rhyolite that is an extension of the above band. These are as long as 6 inches. Possible flow lines are present at this locality.

The rhyolite band southwest of Sandbeach may join with the band that extends northward from Yarmouth to east of Dayton. At the latter place the rhyolite is brecciated and consists of fractured feldspar and quartz grains, in a matrix of biotite, quartz, and feldspar. Some of the largest fragments consist of fractured feldspar in a quartz matrix. This breccia is probably of flow or tuff origin. Other outcrops along this horizon are well foliated, but otherwise show no structure.

On the west side of Sunday Point, elongate lenses and bands of rhyolite occur in hornblende gneiss that is characterized by abundant feldspar phenocrysts. Contacts are poorly defined, and whether or not the rhyolite is intrusive there is not known. However, no extrusive features have been observed. On the east side of Sunday Point, rhyolite in places shows a weak lamination that may be a relict flow structure.

South-southwest of Sandbeach, well-foliated rhyolite contains inclusions of fine-grained, thin-bedded pure quartzite as large as 3 feet by 0.5 foot. Scoriaceous rhyolite that may belong to this same band contains fractured feldspar crystals on the eastern edge of the outcrop at northeast Yarmouth, which suggests an extrusive origin at this locality.

The most easterly rhyolite is a well-foliated rock, which, south-southwest of Brooklyn, is well laminated in the western part of the outcrop area, suggestive of a tuff. However, shearing is common in this area and the laminae may be a secondary feature.

The rhyolites are pale pinkish grey to dark grey, and are commonly light grey to white on weathered surfaces. Texturally they are fine to medium grained, commonly porphyritic, locally gneissic or schistose, and rarely aphanitic. Well-formed feldspar phenocrysts, up to one-half inch long, project above weathered surfaces in many places, particularly in outcrops along the coast.

In thin section, the rhyolites are seen to be composed of albite, quartz, and less commonly potash feldspar phenocrysts, in a fine-grained matrix of the same minerals. The phenocrysts are corroded and fractured. A few show micrographic intergrowths of quartz and potash feldspar. Perthite occurs locally. Inclusions of biotite, chlorite, muscovite, quartz, apatite, epidote, and magnetite are present in some feldspars.

A specimen from the southern tip of Sunday Point shows sunbursts of epidote in albite. The ratio of potash feldspar, albite, and quartz to one another shows a wide range. In some specimens, potash feldspar forms a very small percentage of the rhyolite but elsewhere it forms up to 25 per cent. Some specimens show quartz exceeding 50 per cent whereas others contain less than 10 per cent. In general, however, albite is dominant. Potash feldspar is more prominent in the matrix.

In the matrix, preferential orientation of biotite, which forms up to 15 per cent, imparts a gneissic fabric. Feldspar and quartz tend to be equigranular. Muscovite, chlorite, sphene, magnetite, apatite, and hornblende are present in small amounts.

West of Overton, at the north end of the outcrop along the coast, an amygdaloidal rhyolite sill ranging in thickness from 18 to 30 feet, intrudes White Rock Formation slate. It is exposed for 700 feet along strike, and although conformable throughout most of its length, crosses the bedding of the slate on its north end. The amygdules, one-half inch in diameter, lie in rows parallel with the walls. Most of them are calcite, but some smaller ones are quartz.

The rhyolite is fine grained, medium grey, and consists of equal amounts of granular quartz and albite (An_{10}). Reddish brown and green biotite forms about 5 per cent and small amounts of epidote and calcite are also present.

Rhyolite dykes are also present at Cape Fourchu (West Cape) in well-bedded tuff. These randomly oriented dykes are as much as 2 feet thick, although most are between 2 and 6 inches. One shows a ring-like structure whereas another contains concentric layers of quartz amygdules parallel with the walls. These dykes vary from dark grey green to light grey, and are fine grained, although they commonly show phenocrysts of hornblende along with rare pyrite.

Age

No fossil evidence is available within Shelburne map-area to date these rocks. The only fossils ever located in the White Rock Formation occur near Inglisville (Smitheringale, 1960, p. 16) and are unidentifiable.

In Nictaux–Torbrook map-area, the White Rock Formation is conformably overlain by the Kentville Formation of Late Silurian (Ludlovian) age. Rocks correlative with the Kentville Formation can be recognized only in Digby map-area (Smitheringale, 1959) through the existence of Late Silurian fossils in the upper part of those rocks lying stratigraphically above the Halifax Formation and below the Devonian Torbrook Formation. Thus, some of the rocks in Shelburne map-area, here assigned to the White Rock Formation, may in fact be more properly correlated with the Kentville Formation. In particular, the chloritoid slates in the core of the Yarmouth syncline may be Kentville correlatives, for they overlie volcanic rocks that are unknown in the Kentville Formation.

In Wolfville map-area, Crosby (1962) mapped, named, and described the New Canaan Formation, which overlies the Kentville. The New Canaan Formation is fossiliferous and is of Silurian, probably Niagaran, age. It consists of breccias composed of volcanic detritus, beds of siltstone, slate, and probably limestone. Only one outcrop is present that may be part of a volcanic flow within Wolfville map-area. To the west of Wolfville map-area, three outcrops of basic volcanic flow rocks are present along the New Ross Road, Highway 12, south of South Alton and on strike with the New Canaan Formation. Therefore it is probable that flow rocks are present in the New Canaan Formation.

The presence of volcanic rocks in the New Canaan Formation brings up the possibility of a correlation of the part of the rocks mapped as White Rock Formation in Shelburne map-area with the New Canaan Formation, and, in fact, could embrace all the pre-Devonian formations recognized in western Nova Scotia.

The White Rock Formation as mapped in Shelburne map-area is post-Lower Ordovician and probably pre-Upper Silurian. However, the possibility exists that the upper sedimentary part is a correlative of the Kentville Formation and as such would be Upper Silurian.

Pre-granitic Basic Intrusive Rocks

Basic intrusive rocks are scarce in Shelburne map-area. The few present can be broadly divided on the basis of whether they pre-date or post-date the Devonian granitic intrusions. Pre-granitic intrusions are present at Murray Cove and many small intrusions along the west coast probably also belong to this unit.

Gabbro (Map-unit 10a)

At Murray Cove, on the north side of Barrington Passage, a gabbro dyke is exposed intermittently for half a mile along a northwest bearing. This dyke is about 150 feet thick and lies wholly within quartz diorite (map-unit 11c). Along Highway 3 and on the islands close to shore it is cut by the quartz diorite and several biotite pegmatite dykes up to 5 feet thick. The gabbro is also cut by a thin, irregular, porphyritic diorite dyke, which is also intruded by pegmatite. The contacts between the larger pegmatite dykes and the gabbro are poorly defined, but the narrower pegmatites show sharp contacts with the gabbro and contain angular fragments of it.

The gabbro is medium to coarse grained, and light olive grey to greenish black. It varies markedly in grain size and proportion of feldspar to mafic minerals from place to place. In part the weathered surface shows a spheroidal weathering pattern in individual joint blocks. The gabbro consists of 10 to 20 per cent augite and/or uralite, the former chiefly the commonest. The plagioclase is in the labradorite range and fresh. Small amounts of chlorite, biotite, apatite, magnetite, and quartz occur interstitially.

As the porphyritic diorite cuts the gabbro and both rocks are cut by Devonian granitic rocks (map-unit 11), then these dykes are pre-granitic rocks. Their relationship to other pre-granitic rocks is unknown.

Diorite and Related Rocks (Map-unit 10b)

Many small basic intrusive rocks are present along the west coast from Chebogue peninsula to near the north boundary of the map-area. Most of them occur as thin tabular or lens-shaped sills with a maximum thickness of 70 feet.

Along Chebogue peninsula several of these lens-shaped diorite sills are present in dark grey Halifax Formation slates and a few also are present in the White Rock Formation slate. Characteristically, in this area the sills are perfectly conformable and one, the thickest at 60 feet, can be traced for 250 feet along strike. Most sills are thinner and shorter than this, however, and some are less than one-half foot thick and only 6 feet long. In the larger sills, flow lines are parallel with the contacts and commonly shearing is also present in the same position. One sill in the White Rock Formation tails out into a quartz vein. Slate bordering the sills is bleached pale yellow or light grey up to as much as 10 feet around the largest sill. Bleaching around the smaller sills is proportionately less. The sills form less than 5 per cent of the rock mass along Chebogue peninsula.

These diorites are light to dark greenish grey to mottled light grey and dark greenish-grey, fine- to medium-grained, granular to weakly ophitic rocks. The content of plagioclase ($An_{32\text{-}40}$) in these diorites ranges from 40 to 70 per cent, so that some are much darker than others. Actinolite, in part altered to chlorite, is the chief mafic mineral, although locally epidote forms as much as 20 per cent of the rock. The epidote in part is an alteration product of the plagioclase. Chlorite is present in most specimens, chiefly as an alteration product of the amphibole. Small amounts of apatite, magnetite, hematite, pyrite, and locally calcite and quartz form the accessory minerals.

On the coast west of Overton, four sills of meta-diorite, 1 foot to 5 feet thick, some of which are tabular and others lensoid, are present in White Rock sedimentary rocks. One of these is schistose in the contact zone. They are similar to the diorites at Chebogue peninsula, but are weakly metamorphosed. In the same area, a coarse-grained, dark green, massive, slightly lens-shaped diorite sill, up to 68 feet thick, lies between slate and quartzite. Numerous small randomly oriented quartz veins cut this sill.

North of Chegoggin Point, diorite sills similar to those at Chebogue peninsula occur in both the White Rock and Halifax Formations. Most of them are less than 6 feet thick and a few show discordant relationships with the slates. In part they are coarse grained and gneissic, with plumose actinolite grains up to one-half inch long. Calcite is present interstitially in some sills. Bleaching of the slates along the contacts is a common feature. As at Chebogue, sills form less than 5 per cent of the rock.

Near Burns Point, two sills less than 5 feet thick intrude green slate of the Goldenville Formation (map-unit 1b). Locally these sills intersect the bedding planes and contain slate inclusions. Both trend northeasterly and dip southeast at 60 degrees.

These rocks are dark greenish grey, fine grained, and slightly schistose, and are characterized by abundant calcite, which forms up to 50 per cent of the rock. Chlorite is the only other major mineral and forms up to 50 per cent also. Small amounts of quartz, indeterminate feldspar, epidote, sphene, and muscovite are present along with about 2 per cent magnetite.

Although these diorite sills are not known to be intruded by the Devonian granitic rocks, they probably pre-date the granites as they are folded with their pre-granitic host rocks. Smitheringale (1960) reported that similar mafic rocks in Nictaux–Torbrook map-area intrude the Lower Devonian Torbrook Formation and are themselves intruded by granite. Therefore, some if not all of these dioritic rocks are post-Lower Devonian and pre-granitic rocks.

All the diorites from Chebogue peninsula to near the north boundary of the map-area are similar in lithology to the White Rock basic volcanic rocks (map-unit 7) and may be related to them. They probably escaped laterally from feeders during the period of volcanism. The carbonate-rich sills at Burns Point are probably also related to the volcanic rocks of map-unit 7, because many of the latter contain carbonates, although in much smaller amounts.

Granitic Rocks

Granitic rocks underlie most of the south-central and southern part of the map-area, extending from Barrington Passage northward to near Gull Lake. Smaller plutons of granitic rocks occur at or near Port Joli, Shelburne, Beech Hill Lake, Deception Lake, Wedgeport, Brenton, and on Seal and Mud Islands. On the whole, granitic rocks are poorly exposed and the upland areas typically consist of vast fields of large boulders, up to 20 feet in diameter, with rare outcrops. Along the coast, outcrop is common only near Barrington Passage, Hart Point, on the islands in Port Mouton, and on Seal and Mud Islands. The area near Rushy Lake is strewn with granitic boulders and although no outcrop is known, this area is probably underlain by granitic rocks (Pl. IX).

Throughout the map-area, the granitic rocks show considerable variations in texture and composition, but almost everywhere they are grey with biotite and smaller amounts of muscovite.

Port Joli Pluton

The granitic rocks in the Port Joli area are predominantly equigranular, medium- to locally coarse-grained, very light grey to more rarely pinkish grey biotite granodiorite. On the weathered surface they commonly are slightly pink. Microcline forms the largest grains, which attain one-half inch in length near the golf course at White Point. Contacts with sedimentary rocks are chiefly sharp, but in part consist of a mixed zone of biotite quartzite and granodiorite up to 70 feet wide. Although chiefly massive, in places such as along the east side of Port Joli bay, biotite imparts a distinct foliation and sedimentary inclusions show a preferred orientation. Inclusions as long as 4 feet are abundant in the peripheral zone of this pluton.

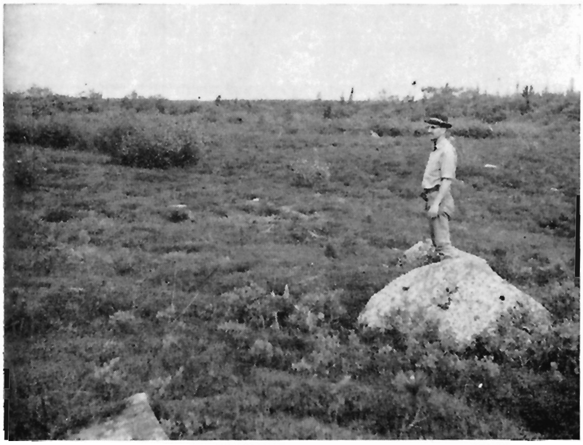

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PLATE IX
Typical view of the country underlain by granitic rocks with few trees and large granitic boulders. North of Rushy Lake.

Pegmatitic veins, up to 10 feet thick, are common, but none show any consistency as to width and length, and many show gradational boundaries with the granodiorite. They are particularly common along the west side of Mouton Island. A few well-defined pegmatite dykes, up to 1 foot thick, are present throughout much of this granite area. Muscovite is common, with rare garnet, tourmaline, and rarer beryl. Some of the quartz is slightly smoky.

Joints are poorly developed for the most part and only locally show any consistency in attitude.

Dykes of white, equigranular, medium-grained, muscovite granite up to 10 feet thick occur sporadically cutting both the Goldenville Formation and the biotite granodiorite, and in a few places contain inclusions of one or the other. Thus, these muscovite granite dykes post-date the main granodiorite intrusion, although probably they are only a late phase of the same intrusive period.

In thin section, the granodiorite is seen to consist of anhedral potash feldspar, plagioclase ranging from An_4 to An_{15}, and fine-grained intergranular quartz. The plagioclase is commonly cloudy and contains scattered muscovite grains. Some of it is untwinned. Much of the potash feldspar shows microcline twinning, but some of it is massive. Quartz occurs in tiny veins in many places and elsewhere the larger grains show strain shadows. Reddish brown biotite occurs both interstitially and enclosed by feldspar. Pleochroic haloes are common. Interstitial muscovite is about twice the grain size of the biotite, is commonly bent, and, although chiefly subordinate in amount in comparison with the biotite, does locally form up to 16 per cent of the rock. Epidote and euhedral apatite occur sparingly throughout. Modes of 13 specimens for this and other plutons are shown on Figure 4.

Deception Lake Pluton

The small pluton west of Deception Lake consists of light grey, coarse-grained, porphyritic granite with white to light grey potash feldspar phenocrysts as much as

2 inches long. This rock is similar to much of the granite present in the batholith north of the map-area.

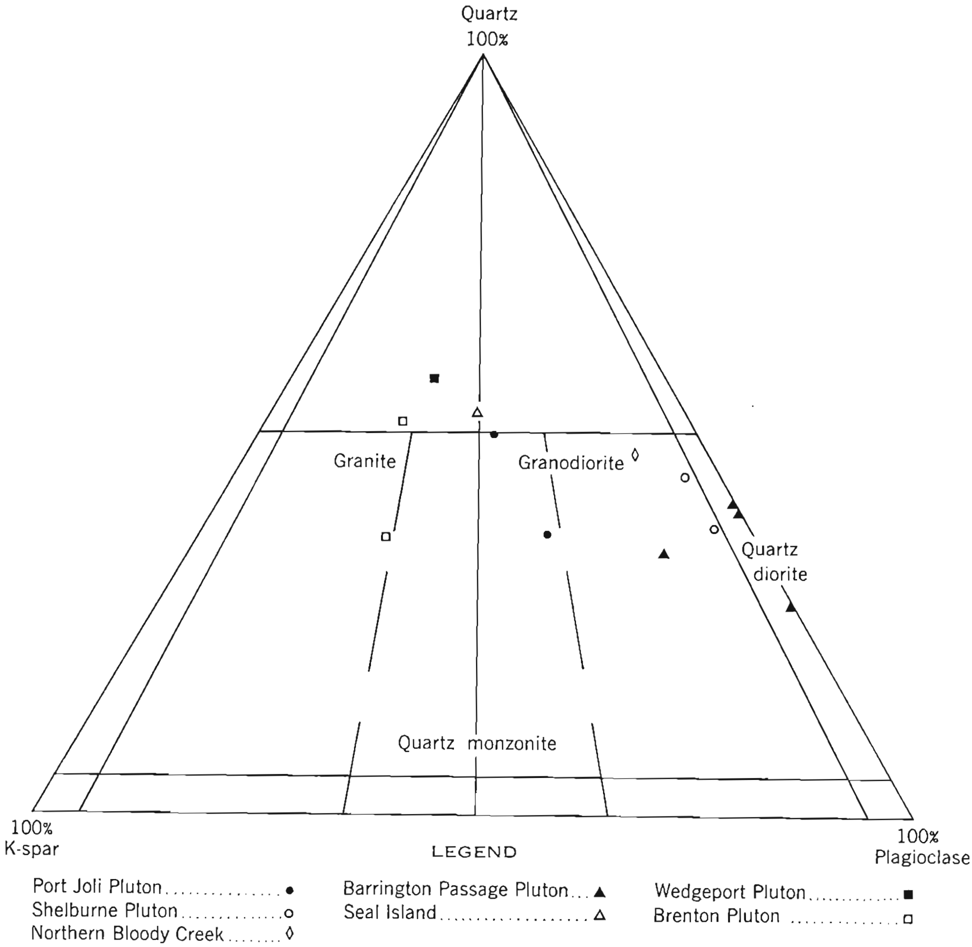

FIGURE 4. Plot of the mineralogical compositions (volume per cent) of the granitic rocks from Shelburne map-area.

Beech Hill Pluton

The stock near Beech Hill Lake is chiefly a grey, coarse-grained, muscovite-biotite granite, but to the northwest of West Beech Hill Lake it is porphyritic. There also it is weakly foliated owing to the alignment of 1-inch-long potash feldspar phenocrysts in a northwesterly direction.

Shelburne Pluton

The areal extent of the Shelburne pluton, which consists of granodiorite, is poorly defined except on the east side. It may extend west far enough to merge with the Barrington Passage quartz diorite pluton. However, a magnetic anomaly trending north from Negro Harbour to south of Morris Lake suggests that this area is underlain by sedimentary rocks. From Morris Lake northward, granitic rocks may be present so that the Barrington Passage and Shelburne plutons may possibly join.

Contact relationships between the Shelburne granodiorite and the Goldenville Formation are exposed only along the Roseway River just north of the town of Shelburne. There, the southern contact shows massive to weakly porphyritic granodiorite with numerous sedimentary inclusions. Pegmatite is common in both the granodiorite and sedimentary rocks so that the contact consists of a zone 30 to 40 feet wide of mixed pegmatite and biotite greywacke. The north contact shows concordant relationships between well-foliated, white weathering, coarse-grained, biotite-muscovite granodiorite and massive to well-bedded biotite greywacke. A few narrow dykes and sills up to 1 foot thick are present in the greywacke, and a few inclusions, in the granodiorite. Between the two contacts small dykes of pegmatite and muscovite granite occur sporadically.

The occurrence of migmatite in Harper Lake and West Birchtown Lake suggests that the contact in this area consists of a zone of considerable width rather than the relationships exposed along Roseway River.

The Shelburne pluton consists chiefly of fine- to medium-grained, equigranular, massive granodiorite. Although locally porphyritic, it is more uniform texturally than most of the granitic rocks in the map-area.

Megascopically, this rock is similar to the granodiorite of the Port Joli pluton, but in thin section several differences are apparent. Microcline is less common, for it probably nowhere exceeds 5 per cent of the rock, whereas it forms about 20 per cent in the Port Joli pluton. Much of the plagioclase in outcrops near Shelburne is zoned, although chiefly of similar composition (An_{13}) to that at Port Joli. Biotite forms about 6 per cent of the rock and is twice as abundant as muscovite.

Associated with the granodiorite of the Shelburne pluton (map-unit 11b) is hornblende diorite (map-unit 11g) which is quarried for building stone 1 mile west of Birchtown. This diorite is also reported to outcrop on the height of land two-fifths of a mile east of Morris Lake (Longard, 1948). In the Birchtown quarry, the contact between the diorite and grey biotite granodiorite is exposed at the northern edge of an unused and water-filled part of the quarry. There, the contact is hairline and reveals no information as to the relative ages of the two rocks. Several, randomly oriented, white pegmatite dykes up to 18 inches thick and chiefly with low dips intrude the diorite. By the hoist house an inclusion of biotite greywacke of the Goldenville Formation measuring 6 feet by 3 feet is present in the diorite.

Douglas (1943) reported that drill cores from the quarry show black granite (diorite) passing gradationally into grey granite at depths as shallow as 25 feet.

The diorite is a medium- to coarse-grained, greyish black to greenish black, massive rock, and shows considerable variation in colour and mineral content within a small area. Longard (1948) divided the diorite into four groups: rock with a high feldspar content; one with a high chorite content; one with a low chlorite content; and a porphyritic rock, which contained scattered biotite phenocrysts up to 1 inch long. A specimen from that part of the quarry currently in use (1960) consists of about 55 per cent fresh plagioclase (An_{45}), 20 per cent each of light brown and pale green hornblende, in a hypidiomorphic granular texture. Quartz forms 2 to 3 per cent and is present interstitially and in a micrographic intergrowth with the plagioclase. Small amounts of apatite, sphene, pyrite, and magnetite, in order of decreasing abundance, are also present.

The origin of the hornblende diorite has been considered by Douglas (1943) and Longard (1948). Douglas (1943) was of the opinion that the "... black granites of Shelburne represent a zone in which the early phases of the grey granite assimilated and metamorphosed large xenolithic masses of quartzite and possible slate". On the other hand, Longard (1948) believed "... the 'black granite' represents an intrusion of dioritic magma which was later followed by a much larger intrusion of granite".

Whether or not large masses of Meguma Group rocks were assimilated to form diorite near Birchtown warrants consideration. Elsewhere in the area, where assimilation has probably taken place, such as in the paragneiss and migmatite (map-units 5, 5a), there are no mafic rocks similar to the diorite. On the contrary, where xenoliths have been partly assimilated, they show conversion to silicic rather than mafic rocks. The addition of slate and greywacke to a granodiorite magma would not produce a rock of diorite composition. Magnesia and lime content would be too low and potash content would be too high. Therefore it is improbable that the diorite near Birchtown is the product of assimilation of Meguma Group rocks as proposed by Douglas.

The presence of xenoliths of greywacke in the diorite suggests that the diorite existed as a magma. If diorite magma was emplaced after the granodiorite, a chill contact within the diorite or assimilation of the granodiorite would be anticipated. However, such is not the case, for the contact between the two rock types is abrupt in part, with no chill zone in the diorite, and gradational in part. The abrupt contact can be explained by the emplacement of the granodiorite after the diorite had cooled sufficiently so that mixing along the interface was not possible. Then the abrupt contact may represent a sealed fault. The gradational contact, present in drill cores, is possibly the result of slower cooling of the diorite in that zone, but in any event indicates that the time lag between the emplacement of the diorite and the granodiorite was short so that mixing of the two magmas took place. The pegmatite dykes, which have close affinity with the granodiorite and are probably from the same source, cut the diorite, and show that the emplacement of the granodiorite post-dates the diorite. Therefore, Longard's (1948) conclusion that the diorite existed as a discrete magma, and was later followed by the emplacement of the granodiorite, is considered to be the most probable origin of this rock.

Barrington Passage Pluton

The Barrington Passage pluton (consisting of quartz diorite and granodiorite), occupies the largest part of the southern mainland and probably extends north of Great Pubnico Lake. Its westward limit is about a mile east of Pubnico

Harbour and as previously mentioned it may merge on the east with the granodiorite near Shelburne.

Contacts of the Barrington Passage pluton are characterized by a zone of migmatite ranging in width from half a mile to more than 2 miles. Rocks in this zone are considered under the heading "Paragneiss and Migmatite".

In the Barrington Passage area, the dominant rock type is a quartz diorite. Megascopically, this rock shows many variations in colour, texture, and percentage of micas. Although chiefly very light grey, it ranges from medium grey to greyish orange and locally greyish pink. Texturally, it is commonly medium grained and equigranular, but in places is fine or coarse grained and in part pegmatitic. In a few localities it is weakly porphyritic with plagioclase grains up to one-half inch long. Foliation, caused by the alignment and concentration in bands of biotite grains, inclusions of sedimentary rocks, and more rarely streaks of greyish orange plagioclase, is present more commonly in this pluton than elsewhere.

Inclusions of Goldenville Formation rocks, the largest 4 feet long, are elongate or lensoid. All degrees of assimiliation of inclusions are present, ranging from well-defined, readily recognizable biotite greywacke to faint shadows. In places, as at Murray Cove, angular blocks are shaped so that they could be fitted together.

Pegmatite is common on Cape Sable Island and on the islands in Barrington Passage. In part, it forms irregular dykes up to 4 feet thick, but much of it consists of small patches in the quartz diorite. The longest pegmatite, 30 feet long and 4 feet thick, occurs on the first large island west of the causeway to Cape Sable Island. There contacts with the quartz diorite are sharp, and angular fragments of quartz diorite are present in the pegmatite close to their point of origin in the walls. The centre of this dyke consists of white to smoky quartz with an area of muscovite and feldspar next to the walls. Muscovite, up to 1½ inches in diameter, exceeds feldspar in amount along the north wall, whereas on the south feldspar is more abundant. In general muscovite is more abundant in the pegmatites than biotite. Chlorite, black tourmaline, and garnet are minor constituents. Veins of quartz and feldspar occur in many places.

Pinkish grey aplite dykes, the largest 4 feet wide on Green Island west of Cape Sable Island, are widely scattered throughout the Barrington Passage quartz-diorite area. Micaceous minerals are rare in most of the aplites, but where present muscovite is more common than biotite.

Pegmatite follows the contact between the aplite and granite on Green Island, southwest of Clark's Harbour, but does not cut the aplite. Similar relationships are present elsewhere; for example, on Stoddart Island where pegmatite and aplite intersect, they intermingle, neither cutting the other. On the other hand, on Prospect Island, a dyke of garnet-bearing pegmatite has been intruded by aplite. The latter commonly occurs in the centre of the pegmatite dykes and in some dykes contains large muscovite grains surrounded by an envelope of coarse feldspar.

The plagioclase in the quartz-diorite ranges from An_{28} to An_{35}, is fresh, and in contrast with the Shelburne granodiorite body only rarely shows poorly developed zoning. Potash feldspar occurs only as tiny inclusions within the plagioclase, forming less than 1 per cent of the rock, and in some places is absent. Quartz occurs as grains much smaller than the plagioclase and is in part cataclastic. Muscovite occurs only sparingly, up to about 3 per cent, whereas biotite forms 8 to 15 per cent of the rock. Powers (1915) found 23 per cent biotite in his analysis. Apatite, sphene, and opaque iron oxides comprise the accessory minerals. Small amounts of chlorite are present replacing biotite.

West of Pig Yoke Lake and east of Gull Lake (northern Bloody Creek), this pluton consists of granodiorite with 8 to 10 per cent potash feldspar, some of which shows microcline twinning. The plagioclase ranges from An_{28} to An_{33}, so that in the central part of the map-area granitic rocks are dominated by oligoclase-andesine plagioclase. The rocks in the northern part of the Barrington Passage pluton are similar in composition to those in the main Nova Scotia granite mass to the north (Hickox, 1958). The quartz diorite is confined to the district about Barrington Passage.

Seal and Mud Islands Pluton

Seal and Mud Islands, the most southwesterly part of the map-area, are underlain by coarse-grained, massive porphyritic biotite granite. In part, the rock is well jointed, particularly on Seal Island. A few lenticular to rounded inclusions, up to 2 feet by 0.5 foot, contain feldspar porphyroblasts. Rare aplitic veins occur on Mud Island.

Potash feldspar, up to 2 inches long, shows Carlsbad twinning in many places. Biotite content ranges from about 3 to 10 per cent north of Crowell Cove on Seal Island. Tourmaline is common and forms between 1 and 2 per cent of the rock. This rock is not typical of the islands as it is richer also in quartz and muscovite than most of the rocks.

Wedgeport Pluton

A poorly exposed area of granite extends from the western part of the Tusket Islands to north of Wedgeport. Although exposures are rare, numerous large boulders of granite are common, particularly north of Comeau Hill to just south of Goose Lake. Numerous granite boulders are present at Wedge Point and granite may underlie this area also.

At Pinkney Point, the contact between the granite and the Goldenville Formation is exposed along the coast (*see* Pl. X). The granite shows no change in grain size until within half an inch of the contact, which is sharp. Much of the contact is concordant, but in places granite cuts across the bedding planes of the greywacke in a step-like pattern. A few 6-inch dykes of granite extend into the greywacke.

Locally jointing is well developed, such as along Pinkney Point, where joints in granite extend into the greywacke of the Goldenville Formation. Inclusions are rare except on Spectacle Islands, where a few, small, angular, randomly oriented inclusions are present.

This granite is medium to coarse grained, light grey to pinkish grey, massive to slightly porphyritic. Potash feldspar, chiefly microcline, is the dominant feldspar

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PLATE X
Sharp contact between the Goldenville Formation and granite at Pinkney Point. Hammer lies on the granite.

forming about 25 per cent. It replaces plagioclase (An_{14}–An_{17}) in some grains. Plagioclase, although fresh for the most part, is partly altered to fine-grained sericite. Biotite forms up to 7 per cent and is chloritized in most places. Muscovite is rare.

Brenton Pluton

Granite in the area east of South Ohio, Yarmouth county, is different from the other granite masses in that it shows foliation owing to the planar orientation of biotite throughout the area exposed. Outcrops of this granite are not known north of the Deerfield road, but the presence of staurolite schist outcrops along the Brazil Lake–Pleasant Valley road suggests the extension northward to this area. Granite boulders are common in the area near Chandler Lake, east of Brooklyn and this pluton probably extends at least that far south. The western limit of this body occurs along the Brooklyn Deerfield road 2 miles north of Brooklyn and there grey biotite quartz schist occurs along the contact. This is probably the western limit of granite in this map-area. Gravity measurements show a steep rise from negative to positive values in western Yarmouth county and the profile suggests that the contact is steep (Garland, 1953). Schistosity in the schist along the contact parallels gneissosity in the adjoining granite. Staurolite schist boulders along the South Deerfield road probably mark the eastern limit of this granite body northwest of Ellenwood Lake. A magnetic anomaly extending from Agard Lake to near Chandler Lake suggests that granite does not occur east of this line.

This rock is chiefly a coarse-grained cataclastic granite with augen-shaped feldspar phenocrysts up to one-quarter inch separated by envelopes of quartz, biotite, and muscovite. Although well-foliated for the most part, some outcrops do show minor amounts of massive rock. East of Hebron, near the contact the granite is in part fine grained and equigranular.

It is chiefly light grey to grey but in places is greyish orange-pink to slightly pinkish grey. The quartz has a slightly bluish cast in the outcrop along the Dominion Atlantic Railway (C.P.R.) east of South Ohio.

In thin section, the augen-shaped feldspars show distinct cataclastic texture with granular quartz in the interstices. Mica, which forms about 3 per cent of the rock is wrapped around the augen or lies in a plane parallel with it. Potash feldspar consists chiefly of microcline, is in part perthitic, and in some places replaces plagioclase. Plagioclase (An_0–An_4) is commonly untwinned.

Some augen-shaped parts of the rock consist of a mixture of feldspar and quartz separated from the adjacent quartz and feldspar by mica envelopes.

Summary

In summary, the granitic rocks show a variation in composition from granite to quartz diorite with a core of quartz diorite in the south-central area and a more potassic border to the northeast and west. The composition of the plagioclase shows a variation outward from $An_{28\text{-}35}$ in the central part of the map-area to albite-rich plagioclase in the Brenton, Wedgeport, Mud and Seal Islands, Shelburne, and Point Joli plutons. With the exception of the Brenton stock all are generally similar megascopically. On the basis of gravity measurements, Garland (1953) considered the individual scattered exposures of granite to be surface expressions of a much larger, connected, slab-like mass that underlies the Meguma Group. Outcrop distribution suggests that the Barrington Passage and Shelburne plutons grade into one another.

Age of Granitic Rocks

Granitic rocks from four localities within the map-area were dated by Fairbairn, *et al.* (1960). A sample of mica schist from near Lockeport was also analyzed during the same study. Biotite was analyzed by both Ar/K and Sr/Rb methods and both techniques were used for some samples. The results of this investigation are reproduced in Tables II and III. Fairbairn, *et al.* also computed the radiation damage ratios for zircons from the Atwood Brook and Port Mouton samples.

Samples were collected from the Wedgeport and Negro Harbour areas and analyzed in the laboratories of the Geological Survey by the Ar/K method. Results of these analyses are also shown in Table III.

With regard to the Wedgeport sample, Fairbairn, *et al.* (1960, p. 405) commented as follows:

> "The anomalously low A/K age of 243 m.y. at Wedgeport cannot be evaluated at present. The sample contained considerable chlorite and hornblende which made it unsuitable for Sr/Rb analysis."

The sample from Wedgeport analyzed by the Geological Survey also contained considerable chlorite. However, an age of 290 m.y. is in much better agreement with other ages in the map-area.

Table II

Strontium-Rubidium Ages of Granitic Rocks

Sample No. and Locality	Lat. and Long.	Normal Sr (p.p.m. by wt.)	Radiogenic Sr 87 (p.p.m. by wt.)	Rb (p.p.m. by wt.)	Rb/Sr	*Sr 87/Sr	*Sr 87/Rb	Age (m.y.)
B.2092 Port Mouton	43°46′N 65°24′W	4.5	1.10	853	190	0.244	0.00455	326
B.2100 Shelburne	43°47′N 65°20′W	4.9	2.17	1666	340	0.443	0.00460	330
B.2094 Atwoods Brook	43°31′N 65°24′W	17.5	0.55	425	24	0.031	0.00457	325

Table III

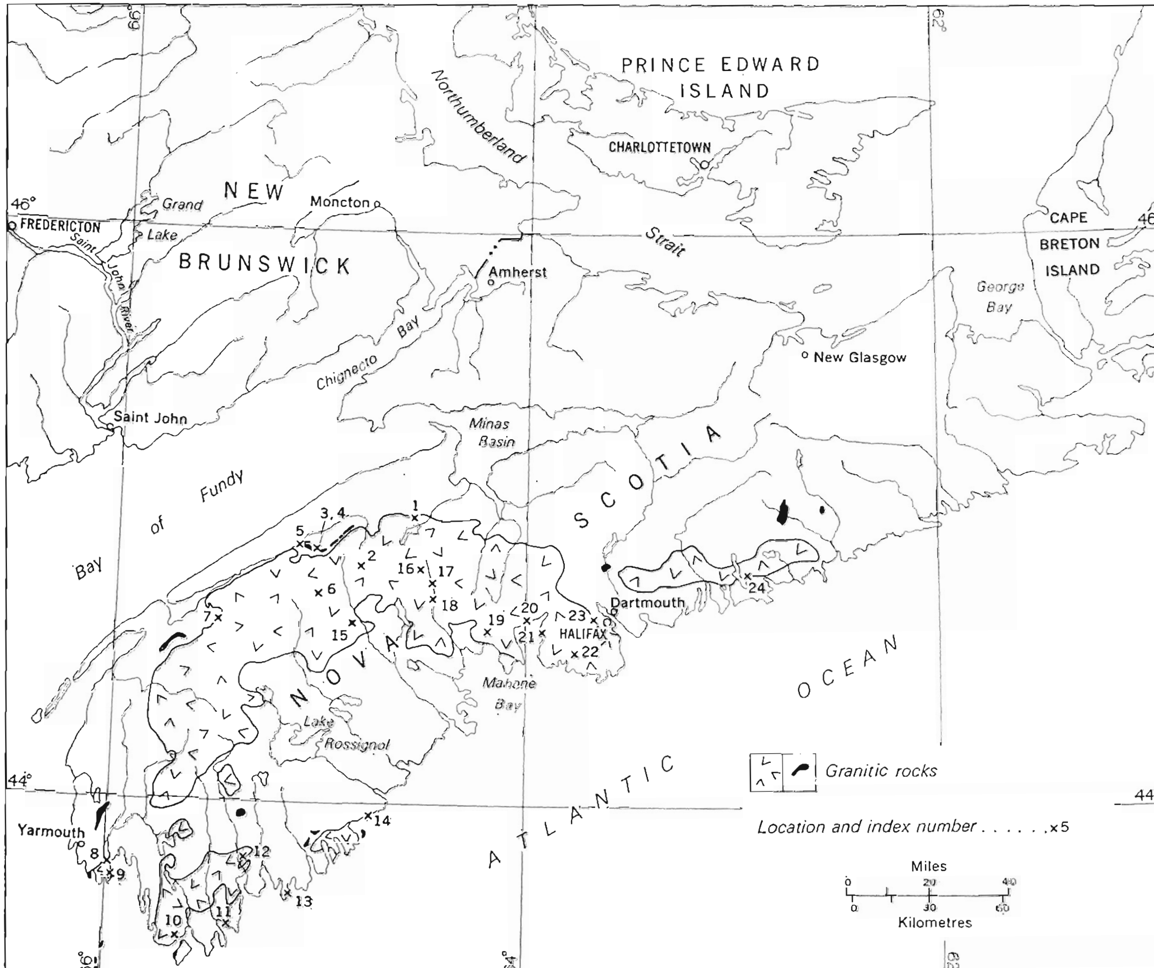
Potassium-Argon Ages of Granitic Rocks

Sample No. and Locality	Lat. and Long.	K per cent	Ar^{40}/K^{40}	Argon Age (m.y.)
B.2100 Shelburne	43°47′N 65°20′W	7.34	0.0190	300
B.2094 Atwoods Brook	43°31′N 65°42′W	7.62	0.0219	341
B.3249 Wedgeport	43°45′N 66°00′W	6.29	0.0152	243
GSC 61-194[1] Wedgeport	43°45′30″N 65°59′10″W	6.80	0.0184	290
B.3252[2] Lockeport	43°43′N 65°09′W	6.56	0.0216	338
TA59-T118[1, 2] Negro Harbour	44°33′40″N 65°24′50″W	6.04	—	383

[1]Analyzed in the laboratories of the Geological Survey of Canada.
[2]Samples are from biotite schists of the Goldenville Formation.

With the exception of the Wedgeport sample, all granitic samples from the map-area fall in the range 315–335 m.y., which indicated a time of intrusion in the Mississippian Period, according to Kulp (1961).

The ages of the granitic rocks within the map-area are consistently lower than those in larger granite areas farther north in Nova Scotia. In the map-area, they range from 245 (or 290) to 335 m.y., whereas farther north ages (Fig. 5) range from 345 to 405 m.y., an interval which embraces the Devonian Period of Kulp's (1961) time scale.



Index no.	Age in millions of years: Ar / K	Sr / rb	Final estimate
1(F)	B/368	B/376	370
2(G)	B/363		363
3(F)	B/333	B/391	360
4(F)	B/318	B/410	365
5(F)	B/370	B/358	365
6(F)	B/374	B/355	365
7(F)	B/370	B/370	370
8(F)	B/243		245
9(G)	B/290		290
10(F)	B/341	B/325	335
11*(G)	B/383		383
12(F)	B/300	B/330	315
13*(F)	B/338		340
14(F)		B/326	325
15(F)		B/355	355
16(F)		B/350	350
17(G)	B/400 M/410		405
18(F)	B/384		384
19(F)		B/357	355
20(G)	M/396		396
21(F)	B/340	B/368 M/332	345
22(F)		B/385 M/373	380
23(F)		B/372	370
24(F)	B/370	B/376 M/400	380

*Goldenville Formation
B, biotite M, muscovite
(F) Fairbairn et al (1960)
(G) Geol. Surv. Canada

GSC

FIGURE 5. Age determinations in southwestern Nova Scotia.

The younger ages along the south coast cannot wholly be attributed to analytical error and the difference in these ages from those of the northern granitic rocks may be real or may be the result of isotopic alteration subsequent to mica formation.

If one assumes that the ages 315–335 m.y. are valid, they imply a period of granitic intrusion during Carboniferous time or an extension of the Devonian time. Although Carboniferous granitic rocks are not common in the Atlantic provinces, they possibly occur in the Cobequid Mountains of Nova Scotia and in Newfoundland. In the latter province, some granites at Fortune Bay probably associated with the Acadian orogeny intrude beds of late Upper Devonian age and may be Mississippian (Weeks, 1957, p. 164). On this basis, it is possible that the ages 315–335 m.y. for the granitic rocks of Shelburne map-area are valid. On the other hand, if the ages of the granitic rocks in this map-area are indeed Mississippian, the mica in them must have formed at the same time that rocks of the Mississippian Windsor Group were being laid down unconformably on similar looking granitic rocks, whose ages were determined to be 355 m.y., at Mahone Bay only 50 miles to the northeast. The likelihood of these unrelated events occurring at the same time is remote.

The 315–335 m.y. ages could have resulted from the loss of argon brought about by slow cooling of the granitic rocks in Shelburne map-area. The extensive areas of metamorphic rocks in the almandine-amphibolite facies shows that the rocks in southwestern Nova Scotia have been subjected to higher temperatures than those to the north, where rocks belong to the greenschist facies. The higher temperatures accompanying the higher grade of metamorphism may have resulted in a protracted cooling period for the granitic rocks, permitting an escape of argon and thus producing lower isotopic ages than in the rocks where temperature was lower.

The two ages determined for schists of the Goldenville Formation must also be borne in mind. The one at 340 m.y., Lockeport, corresponds well with those from the granitic rocks and tends to confirm either a younger, Mississippian, intrusive period or slower cooling. The other at 383 m.y., Negro Harbour, however agrees with the ages from the main batholithic area to the north and suggests that the lower 315–335 m.y. ages have undergone isotopic alteration.

Isotopic alteration is most frequently referred to a thermal event subsequent to the crystallization of the mineral involved. In southwestern Nova Scotia, no geological evidence exists upon which to base such thermal activity. In fact, the geological history, with the possible exception of deeper erosion, is the same in southwestern Nova Scotia as in the central part of the province. If a thermal event did occur to produce the 315–335 m.y. ages it is problematical as to why the 383 m.y. Negro Harbour sample escaped unscathed. Other causes of isotopic alteration, such as weathering and groundwater action, are probably the same for all the samples. Whether alteration took place during, immediately after, or continuously throughout the history of the micas cannot be determined at present.

In the light of present evidence it is impossible to resolve the age problem. Until further evidence is available, the age of the granitic rocks is best considered to be Devonian with the possible extension of the intrusive period into the Mississippian.

Post-granitic Basic Intrusive Rocks

Some basic rocks are known to intrude the Devonian granite and are therefore younger than it. A few others are assigned to this rock unit because of lithological similarity to known post-Devonian rocks.

Quartz Diabase (Map-unit 12a)

Rare exposures and boulder occurrences mark the position of the quartz diabase dyke (map-unit 12a) that extends from LaHave Islands, northeast of the map-area, west-southwest to Pubnico peninsula. Only six outcrops are present in the map-area: one north of Jordan Falls, two north of Shelburne, one south of Harper Lake, and two on Pubnico peninsula. Boulders of this distinctive rock occur intermittently throughout the area along the projected strike. Air magnetic maps show an anomaly along the length of the dyke.

The dyke is 250 feet wide north of Jordan Falls and, although the contact is not exposed, a decrease in grain size is evident on both the north and south extremities of the outcrop, suggesting that contacts are nearby.

Faribault (1918, p. 18) reported that the dyke cuts both the granodiorite and schists along Roseway River, but the contact was not found during the present survey, although the dyke undoubtedly cuts the granodiorite in this area.

This diabase is a medium- to coarse-grained rock with light grey plagioclase laths enclosing greenish black pyroxene. On the weathered surface the pyroxenes are characteristically reddish brown and the plagioclase yellowish grey. As no other rock types in the eastern part of the map-area weather in this fashion, boulders of this rock are readily identifiable.

Microscopically, this rock shows good ophitic texture, with plagioclase (chiefly labradorite) with rare andesine in the outer zones of a few zoned crystals. All the feldspar is fresh except for minor sericite. Augite is cloudy and locally altered to uralite, which in turn is altered to chlorite. Minor biotite is present locally as an alteration product of augite. Quartz occurs in small amounts interstitially and more abundantly in a micrographic intergrowth with sodic plagioclase. Magnetite is common chiefly as skeletal crystals. A few crystals of apatite are present.

In the past this dyke has been tentatively assigned to the Triassic (Faribault, *et al.*, 1938a). However, as the only basis for this correlation is its vague lithological similarity with Triassic volcanic rocks along the northwest coast of Nova Scotia, it has been dispensed with.[1]

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[1] Recent paleomagnetic data and a potassium–argon whole-rock age determination have shown this dyke to be of Triassic age (Larochelle, A. and Wanless, R. K., The paleomagnetism of a Triassic diabase dike in Nova Scotia; *J. Geophys. Research*, vol. 71, No. 20, pp. 4949–4953, 1966).

Biotite Diorite (Map-unit 12b)

A mile north of Cranberry Point, a medium-grained biotite diorite dyke about 350 feet thick, trending east-northeast and dipping almost vertically, intrudes the Goldenville Formation. The south contact is hidden but the north contact is exposed, and there diorite is fine grained and slightly schistose for about 6 feet in from the wall. The contact itself is sharp.

This is the only basic dyke in the map-area in which biotite is the only common mafic mineral, and in this dyke the biotite forms 15 per cent of the rock. Andesine forms 75 per cent of the rock and is extensively altered to sericite and epidote. In many grains the cores are altered whereas the rims are fresh. Augite, chlorite, hornblende, calcite, and quartz occur in small amounts. A few grains of apatite and magnetite are also present as accessory minerals.

Faribault (1920, p. 151) first reported the presence of this dyke but he did not speculate on its age. As it intrudes folded Goldenville Formation, it probably postdates the Devonian orogeny. Its relationship to the granite is unknown, but as its trend approximately parallels that of the quartz diabase (map-unit 12a), it has been assigned the same map number as that rock unit.

Olivine Diabase (Map-unit 12c)

A 5-foot-thick olivine diabase sill, first reported by Honeyman (1881), occurs near the top of the Goldenville Formation at Chebogue Point. This medium-grained, olive-black rock shows good ophitic texture in thin section, with about 25 per cent mafic constituents in well-developed laths of labradorite. Olivine and augite occur in equal amounts, although the former is extensively altered to serpentine and iddingsite(?) whereas the latter is fresh. Chlorite is common interstitially and well-formed magnetite is abundant.

No other rock within the map-area is lithologically similar to this sill. However, it closely resembles rocks of the Triassic-age North Mountain Basalt Formation, which occurs along the southeast side of the Bay of Fundy, and may possibly have originated at about the same time.

Hornblende-quartz Diorite (Map-unit 12d)

On the north side of Cockerwit Passage, a west-northwest-trending hornblende-quartz diorite is present in a few outcrops. Contacts are covered but outcrop distribution suggests that this diorite cuts highly contorted biotite greywacke containing granitic veins and irregular patches.

This quartz diorite is light to dark grey, medium to coarse grained, with the mafic minerals contrasting sharply with quartz and plagioclase on the weathered surface. Plagioclase forms rare anhedral phenocrysts up to one-quarter inch long in the medium-grained more mafic parts of the rock. The coarse-grained parts are more felsic and occur in elongate patches trending N30°E to S10°E.

This quartz diorite consists of unaltered, partly zoned andesine, green hornblende, brown biotite (the last two minerals each forming about 10 per cent), and quartz in a hypidiomorphic fabric. Magnetite and apatite are present as accessory minerals.

Relationship with the Barrington Passage quartz diorite body (map-unit 11c) is not known. However, the lack of metamorphism, the absence of granitic intrusions into it, and its probable intrusion into metasediments impregnated with granitic rock suggest that this quartz diorite is younger than the Barrington Passage quartz diorite pluton. It also differs from that quartz diorite in that it contains significant amounts of hornblende and much less quartz.

This rock (map-unit 12d) is also different from the gabbro (map-unit 10a) at Murray Cove in that it contains more sodic plagioclase, more quartz (about 7 per cent), and abundant biotite (10 per cent), compared with only a trace of quartz and biotite at Murray Cove. Therefore it is probably not related to the Murray Cove gabbro body. The possibility exists that it is a late phase of the quartz diorite at Barrington Passage (map-unit 11c).

Diorite and Basalt (Map-unit 12e)

On Mud Island, a porphyritic, fine-grained, medium dark grey dyke, 4½ feet thick, trending north-northeast, cuts porphyritic biotite granite (map-unit 11af). Jointing is prominent normal to the dyke walls and the centre of the dyke is weakly vesicular. In thin section, this rock consists predominantly of sericitized plagioclase, possibly andesine, with reddish brown biotite, some of which is altered to chlorite. Biotite is in part euhedral and porphyritic, and its distribution is heterogeneous so that the rock has a mottled appearance. A few plagioclase grains occur in clusters, up to one-eighth inch in diameter, which impart a glomeroporphyritic texture to the rock. Calcite and magnetite occur in small amounts.

On the east side of Seal Island, lying 25 feet apart half a mile north of the lighthouse, are two dark greenish grey basalt dykes, 4 and 6 feet thick, which strike north-northeast and dip southeast about 65 degrees. They cut coarse-grained, weakly porphyritic biotite granite. The western dyke occupies a fault and its east contact is composed of 1 foot of mylonitized granite. As seen microscopically, this basalt consists of about 60 per cent labradorite, in part porphyritic, with 35 per cent hornblende, half of which is altered to chlorite. Biotite forms about 5 per cent, and minor amounts of epidote and magnetite are also present.

On the east side of Barrington Bay, 1 mile south of Beach Point, two diorite dykes, 3 and 4 feet thick, intrude biotite-muscovite-quartz paragneiss (map-unit 5). Both dykes strike north-northeast and dip vertically. These olive-grey, fine-grained, massive diorite dykes consist of anhedral, cloudy and sericitized andesine with subordinate amounts of epidote, augite, and chlorite after biotite. Magnetite and calcite are also present in small quantities. Although these dykes do not intrude the Devonian granitic rocks, they are younger than the metamorphism that produced the paragneiss and may therefore be post-Devonian.

Pleistocene and Recent

During the Pleistocene Epoch an ice-sheet covered the map-area. Glacial striae are common along the coast, but are rare inland where bedrock exposures are poor (Fig. 6). Most striae range from S40°E to S10°W and show a south-southeastward direction of ice-movement. Locally, a second set of striae are also present, ranging between S70°E and S45°E, and on one outcrop near Jones Island three sets occur. The relative ages of these striae were not established except near Jones Island, where striae resulting from ice-movement in the direction S5°E post-date striae trending N55°E. The direction of ice-movement producing the latter striae is not known.

Ice-movement in central Nova Scotia was established by Hickox (1958) as occurring in two phases. The first consisted of an advance of ice in a southeasterly direction across the Bay of Fundy and the province. The striae between S70°E and S45°E are probably a product of this ice advance. The second phase of ice-movement was outward from the interior of the province, and the majority of the striae in the map-area are no doubt a product of this movement. The presence of a third striae direction near Jones Island is probably the result of a local movement of the older ice advance.

Glacial grooves occur in a few places along the coast, especially where direction of ice-movement coincides with the strike of the bedrock. Ice polish is present on a few slate outcrops near Arcadia.

With the retreat of the ice an extensive cover of glacial drift was left. By far the largest part of the glacial debris is till. Material in the till ranges from clay-sized particles to huge boulders, the size of the latter depending, in part, upon the dominant rock type in the immediate or upstream area. In general, till in the granite areas contains the largest boulders, many up to 20 feet long. Locally, schist boulders are almost as large as the granite boulders. On the other hand, till in the slate areas, such as near Chebogue, contains few large boulders and these are chiefly of volcanic rocks. The maximum thickness of till is unknown, but road cuts near Arcadia and Quinan expose 20 and 30 feet, respectively.

Drumlins form many of the islands in the Tusket area and at the mouth of Chebogue River. Some at Chebogue River have been eroded by wave action exposing a clayey till with greywacke boulders up to 2 feet in diameter. Drumlins in the Tusket estuary are composed of much coarser and gravelly till.

Eskers occur sporadically throughout the map-area. Most of them are short and low in profile so that in heavily wooded areas they are not readily recognized. With minor exceptions they trend parallel with the direction of ice-movement. Many of those close to roads have been used for gravel. Inland the tops of several eskers have been cleared and with small effort bush roads have been constructed.

Outwash forms much of the Clyde River valley extending from its mouth north for more than 10 miles. Smaller areas of outwash are common throughout most of the map-area and are particularly common in Shelburne county.

Kames, many of which have been used for gravel, are present in many places.

At several localities (Fig. 6) along the coast the sea has encroached on and

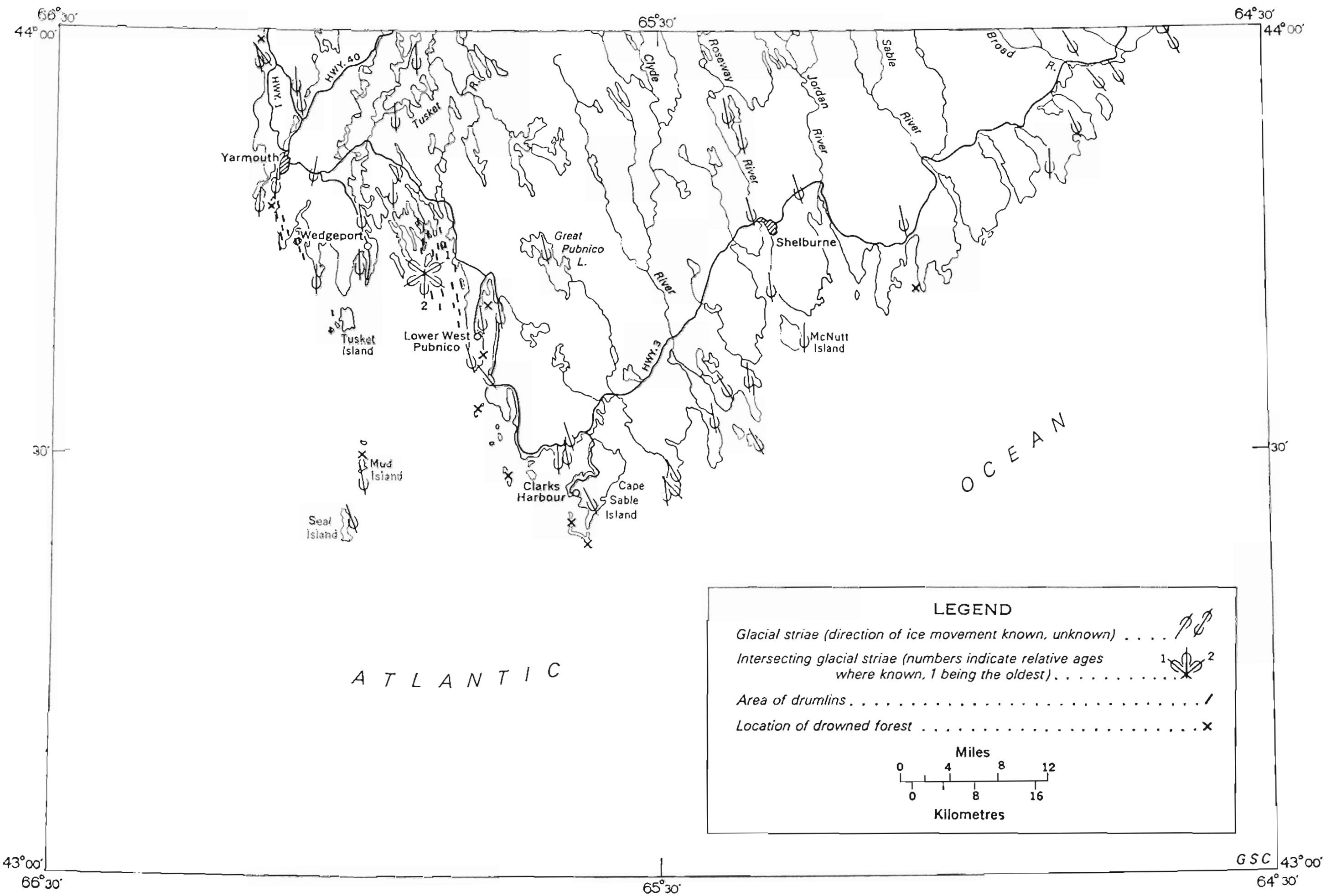

FIGURE 6. Glacial striae, drumlins, and drowned forest localities in Shelburne map-area.

drowned well-established forest growth. The maximum extent of the encroachment is not known, but at Sunday Point tree stumps are present throughout the intertidal zone and are visible in the water below low-tide line. In the Yarmouth area, the tidal range is about 15 feet. The largest stump at this locality is 12 inches in diameter and 40 growth rings are visible over 5 inches of the stump.

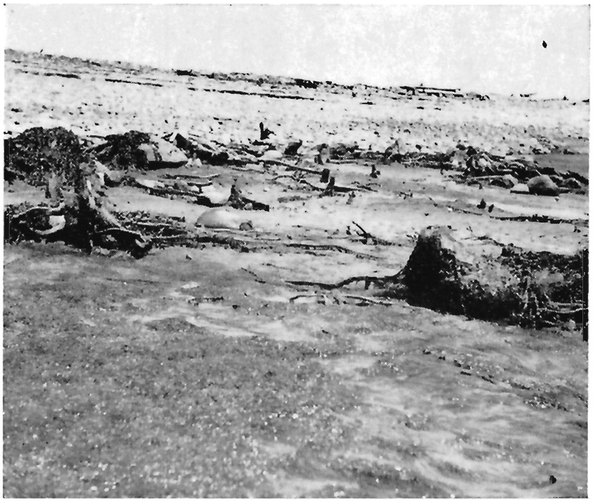

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PLATE XI
Drowned forest at Sunday Point. High tide line shows on the cobble beach in the background.

The stumps in the intertidal zone at Sunday Point stand in a layer of semi-rotted leaves, twigs, and cones. The surface is chiefly covered by sand up to 4 inches thick; the peaty material extends at least 45 inches below the surface, below which depth water intake and a network of limbs and logs up to 12 inches in diameter prevented further excavation. The other occurrences are similar in character, all being exposed at low tide and commonly partly buried by sand.

Whether these forests were drowned because of eustatic oscillations of sea-level, or crustal warping, or both must be considered. Harrison and Lyon (1963) investigated drowned forests in New Hampshire, U.S.A. and west-central Nova Scotia, and concluded that crustal downwarping of west-central Nova Scotia occurred during the period 3,800–3,400 B.P. Upwarping of the same area took place between 3,400 and 3,250 B.P., and renewed downwarping, from 3,250 to 3,000 B.P. They suggest a hinge line lying to the north of Fort Lawrence, Nova Scotia. The same authors submit a continuous transgression of the sea, at about 0.31 foot per century, during the period 4,500 to 3,200 B.P.

In view of the closeness of the area studied by Harrison and Lyon (1963), it is reasonable to assume that the events they propose probably also affected Shelburne map-area. On the other hand, the drowned forests of Shelburne map-area may be related to more recent drownings such as those reported from Maine, U.S.A., ranging from 1,280 to 3,250 B.P. (Hussey, 1959), or from Prince Edward Island at 915

B.P. (Frankel and Crowl, 1961). However, it is ill advised to speculate further as to the sea-level behaviour pattern until a detailed examination of drowned forest localities of southwestern Nova Scotia is undertaken and analysis by radiocarbon methods of specimens of wood is carried out.

Tidal alluvium has built up salt marshes along Chebogue and Little Rivers, part of Tusket River, and a small amount at the head of Pubnico Harbour. The material composing these marsh lands is a grey to olive, uniform mixture of silt and sand. The marshes are covered by salt-tolerant vegetation, chiefly marsh grass, sea-blite, glasswort, and spurrey (Hilchey, *et al.*, 1960).

Stream alluvium occurs chiefly in old beaver meadows and on the upstream sides of abandoned dams. It consists of light olive-grey silt and sand with some organic material.

Peat covers large areas particularly in Shelburne county and the eastern part of Yarmouth county. The largest deposits are west of Great Pubnico Lake, east of Clyde River village, and southeast of Clements Pond. They are devoid of forest cover except for rare, small tamarack, fir, and black spruce. Peat thickness rarely exceeds 15 feet; most deposits are 5 to 6 feet deep.

Recent beach sands are present at Green Cove on the west coast, near Villagedale on Barrington Bay, on the coast east of Round Bay, at Lockeport, and at Summerville Beach. Smaller sand beaches are present in many coves and inlets throughout the area, especially where granite is either close to or forms the bedrock along the shore. This sand is chiefly fine grained, light coloured, and contains much mica as well as quartz and feldspar. Garnet and iron ore occur in small amounts.

At Green Cove, Villagedale, Lockeport, and Summerville, wind action has created small dunes above the storm line, which have been stabilized, for the most part, by coarse grasses.

Soil surveys of the map-area have been made by Cann and Hilchey (1959), Hilchey, *et al.* (1960), and MacDougall, *et al.* (1961).

Chapter III

METAMORPHISM

All the layered rocks and some of the basic intrusive rocks in the map-area have been metamorphosed. The metamorphism involves recrystallization accompanied in a few places by orientation of newly formed minerals and is the result of high temperatures and pressure and, in part, shearing stress. Although bulk chemical composition has not been changed to any great extent for most of the rocks, some, close to granitic intrusive plutons, probably had additions of material. The metamorphism is predominantly regional, and contact metamorphism is only locally developed. Some rocks however cannot be classified under either of these headings with certainty.

Regional Metamorphism

Regional metamorphism in Shelburne map-area is represented by the greenschist and almandine-amphibolite facies (Turner and Verhoogen, 1960). Distribution of these facies is shown on Figure 7.

The greenschist facies is expressed by the following mineral assemblages for the pelitic and psammitic rocks present in Shelburne map-area:

1. Quartz-albite-muscovite-chlorite subfacies
   a) Quartz-muscovite-chlorite-albite
   b) Quartz-chlorite-albite
2. Quartz-albite-epidote-biotite subfacies
   a) Biotite-muscovite-quartz-albite-epidote
   b) Biotite-muscovite-chlorite-quartz-albite
   c) Biotite-quartz-albite
   d) Biotite-chlorite-quartz-albite
   e) Muscovite-chloritoid-chlorite-quartz
3. Quartz-albite-epidote-almandine subfacies
   a) Biotite-muscovite-almandine-quartz-albite
   b) Muscovite-chloritoid-almandine-quartz

Rocks characteristic of the quartz-albite-muscovite-chlorite subfacies are limited to three areas in Yarmouth county underlain by the Meguma Group. The biotite

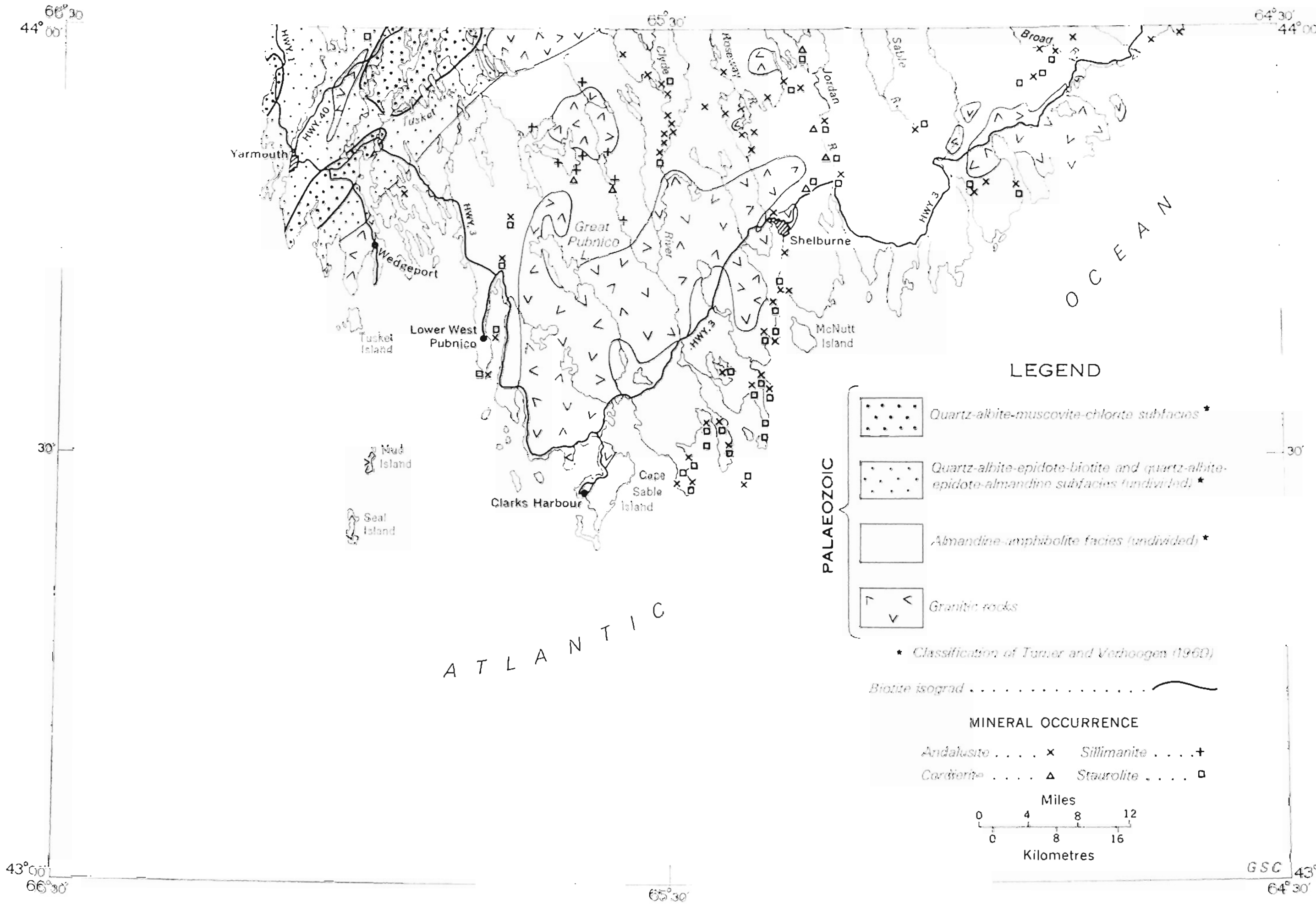

FIGURE 7. Distribution of metamorphic facies in Shelburne map-area.

isograd marking the areal limits of this subfacies is shown on Figure 7. All rocks in these three areas are characteristically greenish.

The areal distribution of the quartz-albite-epidote-biotite and the quartz-albite-epidote-almandine subfacies is not known with certainty, as locally they are mixed. Rocks of both subfacies are present in some places such as near Chegoggin Point where the assemblage muscovite-chloritoid-almandine-quartz is associated with rocks of the quartz-albite-biotite subfacies. In general, however, rocks characteristic of the quartz-albite-epidote-almandine subfacies are restricted to an area extending from Brooklyn to just south of the railway line near Yarmouth airport. Chloritoid-bearing members occur only in rocks of the White Rock Formation.

The basic (mafic) schist assemblages present are:

1. Albite-epidote-actinolite-quartz
2. Albite-epidote-actinolite-quartz-biotite
3. Albite-epidote-actinolite-chlorite-quartz

These are typical of the quartz-albite-epidote-biotite subfacies. The amphiboles characteristically show blue-green pleochroism, with extinction angles, C to Z, of between 10 and 15 degrees. Three amphiboles were determined by X-ray as actinolite. Sphene is present in many places and ilmenite is common also. None of the basic schists examined microscopically consists of hornblende, and the anomalous association of these actinolitic rocks with pelitic and psammitic rocks of the quartz-albite-epidote-almandine subfacies requires more detailed mapping to resolve.

Within the area shown as being underlain by rocks of the greenschist facies are a few outcrops showing mineral assemblages characteristic of higher grades of metamorphism. A quarter mile south-southwest of Brooklyn and also just north of the first crossroad north of South Ohio, cummingtonite occurs in metasedimentary rocks. At the latter locality the metasediment is intimately associated with basic schists. The assemblages containing cummingtonite at these two localities are:

1. Cummingtonite-biotite-quartz-plagioclase
2. Cummingtonite-garnet-chlorite-quartz

The presence of cummingtonite shows that these White Rock Formation rocks are rich in magnesia, and also suggests a higher metamorphic grade.

Collins (1942) reported a cummingtonite assemblage, similar to the first one listed above, from Sutherland where it is probably in the almandine-amphibolite facies. The second assemblage listed above is similar to the cummingtonite schists assemblage of North Dakota. There, Gustafson (1933) considered that the cummingtonite schists did not reach equilibrium and could not be classified with either the greenschist or amphibolite facies. The present rocks, which are, in part at least, closely associated with actinolitic basic schists show no evidence for retrogression and appear to have attained equilibrium. Their precise classification cannot at present be determined.

Staurolite-andalusite schists occur along the Brazil Lake–Pleasant Valley road and a few boulders of the same rock lie along the eastern edge of the Brenton pluton west of Hooper Lake. The status of these rocks, which are bounded by typical greenschists, is not clear. Their spatial relationship with the Brenton pluton suggests a possible genetic relationship with the pluton and they may be a contact rather than a regional phenomena.

The eastern limit of the greenschist facies is not accurately known, in part due to the scarcity of outcrop. Rocks immediately east of the limit shown on Figure 7, however, show oligoclase-andesine rather than albite, and in one locality near Amirault Hill andalusite is present. East of the line shown, chlorite, unless obviously retrogressive, is scarce. Except for a few outcrops of the Halifax Formation along the west side of Pubnico peninsula and northeast of Broad River, rocks in this area are undoubtedly members of the almandine-amphibolite facies. The slates on the west side of Pubnico peninsula are characterized by the assemblage garnet-muscovite-chlorite-quartz. The garnet shows retrogression to chlorite and is full of quartz inclusions. The composition of the plagioclase in these fine-grained rocks is uncertain, but it is probably more calcic than albite.

Northeast of Broad River, chlorite is common and these rocks may belong to the greenschist facies.

The following assemblages in the almandine-amphibolite facies are present in Shelburne map-area:

1. Quartz-plagioclase-biotite-(almandine-muscovite)
2. Quartz-staurolite-plagioclase-almandine-biotite-muscovite
3. Quartz-staurolite-andalusite-plagioclase-almandine-biotite-muscovite
4. Quartz-staurolite-cordierite-plagioclase-almandine-biotite-muscovite
5. Quartz-staurolite-andalusite-cordierite-plagioclase-almandine-biotite-muscovite
6. Quartz-andalusite-plagioclase-almandine-biotite
7. Quartz-sillimanite-almandine-plagioclase-muscovite-biotite
8. Quartz-sillimanite-cordierite-almandine-plagioclase-muscovite-biotite

The inclusion of andalusite in these assemblages, although it is commonly considered to be a mineral characteristic of contact metamorphism, is based upon widespread occurrence throughout the eastern two-thirds of the map-area (*see* Fig. 7). Its development cannot be fully related to the surface distribution of granitic rock plutons as it is equally well developed in many places remote from known plutons. Read (1923) recorded a similar occurrence of andalusite schists in the Banff district of Scotland and proposed a regional metamorphic history for them. Schiller (personal communication, 1963) reported the development of andalusite on a regional scale from the northeastern mainland of Nova Scotia. There, the andalusite occurs in schists of the Meguma Group in rocks characteristic of the greenschist facies.

Cordierite occurs in two areally limited associations. The assemblage quartz-sillimanite-cordierite-almandine-muscovite-biotite-plagioclase is present in a few of the paragneiss (map-unit 5) outcrops in the area centred about Quinan Lake. Cordierite in these rocks is commonly extensively altered to pinite, in some specimens is completely altered and shows anhedral outlines, is equigranular, and shows twinning. These rocks are similar in many respects to those described by Read (1952) from the Ythan Valley of Scotland and by Pitcher (1953) from Ireland. The occurrence of the present assemblage is similar to the above references in the association with migmatitic development. Fyfe, *et al.* (1958) refer this assemblage to deep-seated metamorphism.

The assemblages containing cordierite-staurolite and cordierite-andalusite are present only in the Jordan River valley and along Highway 3 between Jordan Falls and Shelburne. Cordierite there is entirely different from that in the Quinan Lake area, being porphyroblastic, in part up to 2 inches long, and displaying pseudohexagonal outlines. In thin section, this cordierite contains many inclusions, although these are fewer and smaller than those in associated andalusite. Twinning does not occur. Rarely pinite or a yellowish isotopic substance forms a narrow rim about the crystal.

The question arises as to whether the cordierite is a product of regional or contact metamorphism. The geographical distribution as shown on Figure 7 does not suggest a close relationship to granite plutons, and a contact metamorphic origin requires speculation as to a granite body at a shallow depth. Cordierite does not occur in any granite contact zones elsewhere in the map-area. Therefore, it is possible that a regional metamorphic origin produced the cordierite. Read (1923) found both cordierite and andalusite in the Fyvie schists of Scotland, which he considered to be of regional metamorphic origin. Hietanen (1956) also reported cordierite and andalusite from regional metamorphic zones.

Tourmaline, which occurs as an accessory mineral throughout the Meguma Group, is probably a product of metamorphism. It ranges from short stubby grains to long, slender, subhedral to euhedral crystals. The euhedral crystals commonly show a 10 to 1 ratio of length to width and locally as much as 18 to 1. They are up to 0.35 mm long and many show cross fractures. The stubby grains are widely distributed throughout the matrix of the Meguma rocks. On the other hand, the long euhedral grains are more limited in distribution and occur chiefly in the schists (map-units 2 and 4) and at Pinkney Point in a contact zone. Tourmaline is pleochroic from dusky blue-green (Z) to colourless or pale yellow (X) and is probably in the schorlite-dravite series. The slender euhedral habit of some crystals indicates a metamorphic origin, and as all observed grains of tourmaline are similar optically they are probably all of metamorphic origin.

The distribution of the greenschist and almandine-amphibolite facies (Fig. 7) shows that the eastern two-thirds of the map-area has undergone more intense temperature and pressure conditions than the western third. Whereas granitic bodies are more common in the eastern part of the area these are probably not the major influence with respect to higher metamorphic grade, as the Brenton and Wedgeport plutons abut greenschist rocks for much of their perimeter. The higher metamorphic grade in the eastern part is possibly a reflection of deeper erosion. The absence of any representatives of the White Rock Formation in the eastern part of the map-area also suggests that erosion is deeper there.

Contact Metamorphism

Contact metamorphism is apparently not extensive, for, although visible contacts are scarce, observed contacts with granitic rocks reveal little or no indication of contact metamorphism.

At Pinkney Point, within 1,000 feet of the granite, greywacke of the Goldenville Formation is characterized in some horizons by the development of light grey spots up to one-quarter inch in length. In thin section, these are seen to be composed chiefly of sericite, with smaller amounts of quartz, albite, biotite, tourmaline, sphene, and epidote. The sericite is probably a retrogressive alteration product of andalusite. The matrix consists predominantly of biotite with quartz, albite, epidote, tourmaline, and rare opaque minerals and garnet, the latter full of inclusions and poorly developed. It is probable that andalusite developed in the argillaceous beds during the emplacement of the granite. A slow cooling resulted in the breakdown of the andalusite into sericite.

Tourmaline is much more abundant at Pinkney Point than elsewhere. As its development occurs only in the contact zone it is probable that boron was in part, at least, derived from the granite.

Except for the Pinkney Point occurrence, clearly defined contact metamorphic phenomena are not known. It may be that the sillimanite-cordierite gneisses in the Quinan Lake area are contact products. The question arises as to where to draw the line between the two metamorphic types.

The lack of recognizable contact effects can probably be attributed to the fact that the regional metamorphic grade for most of the area is at least as high as temperatures and pressures accompanying the emplacement of the granitic plutons, hence masking any local contact metamorphic effects.

Retrogressive Metamorphism

Retrogressive metamorphism has not played a significant role in the map-area. Locally, however, the following retrograde effects have been recognized:

garnet	→	chlorite
biotite	→	chlorite
andalusite	→	sericite
cordierite	→	pinite or opaque rim
staurolite	→	sericite and minor chlorite
plagioclase	→	epidote and albite

Chapter IV

STRUCTURAL GEOLOGY

Shelburne map-area forms part of the Appalachian Mountain system. The layered rocks were folded during the Acadian orogeny into north- to northeast-trending folds and these form the dominant structural element of the map-area. Faults are scarce and, with rare exceptions, of local significance only.

Folds

Top determinations in the layered rocks, although not abundant, are sufficient to establish the major folds, particularly in the coastal areas. Graded bedding, cross-bedding, and ripple-marks in the sedimentary rocks and pseudograded bedding in the metamorphic rocks were used for top determinations. In the volcanic rocks, fragmental flow tops, bomb sags, and graded bedding provided top information.

The most important fold, in that it has preserved the Silurian strata from erosion, is the Yarmouth syncline, which extends from Yarmouth Harbour to north of Lake George. Cleavage and/or schistosity to bedding relationships show that the axis of this fold is mainly horizontal but that it plunges locally as much as 50° both to the north and south. Rare drag-folds, probably related to this syncline, show plunges ranging from 10° to 25° also both to the north and south. Considered as a whole, this syncline probably plunges southward less than 15°. Cleavage and schistosity range in dip from 70°E to 70°W and are vertical in many places. The axial surface is probably vertical or close to it.

East of the Yarmouth syncline, a dearth of outcrops places structural interpretation on tenuous grounds, but a few bedding attitudes and the presence of a syncline near Pubnico suggest that an anticlinal axis exists near a line from Clearwater Lake to Indian Sluice. Rare top determinations on the west limb of this postulated anticline show that tops of beds face west but the beds dip to the east. Therefore this fold is probably slightly overturned to the west with a steeply dipping axial surface. Cleavage planes in the Wedgeport area dip 60° to 70° east, but many of those on the east limb, in the region of Morris Island, dip to the west between 65° and 85°. Cleavage-bedding relationships show plunges predominantly horizontal or southward at 10° or less. A single drag-fold near Surette Island plunges 20°N.

In the Pubnico area, the Halifax Formation is present in an overturned syncline. Possibly only the east limb of the Halifax Formation is exposed, and on this basis the trace of the axial plane is drawn from near Turtle Pond to Argyle Sound. However, the axial plane may be as much as a mile farther east. Cleavage planes dip chiefly to the east between 60° and 85° and probably parallel roughly the axial plane. This syncline probably plunges southward at a low angle as cleavage and bedding attitudes are parallel in many places, and in others the line of intersection plunges chiefly southward between 30° and 55°. Rare drag-folds show plunges of 30° both north and south.

Schists along the Clyde River lie in a syncline plunging south between 15° and 25°. The axial plane there dips 75° to 80° west-northwest.

East of the Barrington Passage and Shelburne plutons, a syncline extends from near Shelburne to Port La Tour. This syncline is also horizontal to southward-plunging. Top determinations on the east side of McNutt Island and on the mainland to the north show beds overturned, and therefore the east limb is overturned in this area. Farther south on Blanche Island and The Salvages, bedding attitudes show no overturning and there the syncline is inclined but not overturned. Cleavage planes chiefly range from 50° to 80° east, which suggests that the axial plane dips steeply eastward.

A syncline north of Jordan Falls plunges northeast at about 10°. The axial plane dips northwest at about 65° and the northwest limb is overturned near Four Mile Brook.

Several folds are distinguishable northeast from Jordan Bay to the northeast limit of the map-area. Synclines through Lockeport Harbour and crossing Broad River are better defined than any others in the map-area. Bedding-schistosity relationships show the Lockeport syncline to plunge north to northeast. The amount of plunge ranges from zero to 70°. The axial plane (if one assumes it to be parallel with the schistosity) ranges from 70°E to 55°W and is possibly vertical. Rare drag-folds on Western Head plunge 10°N. The axial plane of the Broad River syncline dips 80°NW and the plunge is zero or to the northeast at a low angle.

Numerous small folds are present, especially within the Meguma Group associated with and in harmony with the major structures. These are particularly evident where outcrop is abundant, such as along the west side of Green Harbour. It is probable that many small folds occur in areas of few outcrops in the interior and the structure there is undoubtedly more complex than shown on the map.

Faults

Only a few faults have been mapped in Shelburne map-area. This is no doubt in part due to the lack of horizon markers, particularly in the Goldenville Formation, and also to the scarcity of outcrop in many places, as most of the faults mapped are along the coast in areas of good and abundant outcrops. However, it is probable that faulting was of minor significance in comparison to folding in the map-area's structural history and that faults are indeed rare.

Faults in the area are of two types: longitudinal and transverse. The longitudinal faults are present principally along the west coast north of Chegoggin Point in slates of the Halifax and White Rock Formations. They commonly intersect bedding planes at low angles, chiefly less than 20°. Several longitudinal faults are present in the Halifax Formation near Pembroke Cove. There, drag on beds shows that the west side moved north with respect to the east on some faults whereas on others the opposite movement is indicated. Drag-folds related to one fault plunge 55° to the N35°E. In the White Rock Formation slates west of the silica quarry near Chegoggin Point, drag-folds associated with a longitudinal fault plunge 50° to 70°S 30°W. North of Chebogue Point, a vertical longitudinal fault in the Halifax Formation shows 1 foot of gouge and highly fractured slates in a cliff face. On the Carleton River, a normal fault in the Goldenville Formation strikes northeast and dips 70°NW. Associated drag-folds plunge 25°NE. Longitudinal faults also are present on Cape Fourchu (East Cape) east of Yarmouth lighthouse, and also near Villagedale in paragneiss.

Transverse faults, with strikes ranging primarily between N50°E and N70°E and dips 70° or more both to the north and south, occur erratically in the western half of the map-area. Most of them are in the Goldenville Formation. Near Little Lake a fault shows a left-hand strike separation of 2 feet. At Red Head a left-hand strike separation of about 120 feet is evident.

South of Pinkney Point village, two faults in the Goldenville Formation show right-hand separation of as much as 2 feet. Their attitudes are N50°E and N70°E with dips to the north on both of 80°. The latter fault fracture is filled by a granite dyke and therefore pre-dates the granite dyke.

On the small island south of Paul Island in Pubnico Harbour, several faults striking S50°E and dipping 80°SW cut andalusite schists and greywacke. All show left-hand movement with strike separation up to 12 feet. A 1-inch pegmatite is present in the schist and the faults are post-pegmatite.

The only lengthy fault in the map-area is a transverse fault inferred from aeromagnetic maps. A northeast-trending anomaly north of Gull Lake shows an offset on its southwest end along a line trending south-southeast. The extension of this line offsets the anomaly coinciding with the quartz diabase dykes (map-unit 12a) near Wabi Lake. The same line extends southward to within 2 miles of Clements Pond and may reach the coast at Barrington Bay. Bloody Creek valley, which follows the fault line for much of its course, may be the topographic expression of this fault. Offset on the anomaly north of Gull Lake suggests a strike separation of about a mile.

A second fault is inferred parallel with the one mentioned above and 4 miles to the west-southwest. It possibly extends from Peter Lake to Quinan Lake along which line two anomalies are terminated abruptly near Quinan Lake, and isomagnetic lines near Peter Lake show orientation roughly normal to the regional trend.

The age of faulting in Shelburne map-area is not known with certainty. Most faults are probably related to the Acadian orogeny. The two faults inferred in the central part of the map-area may be more recent. A similarly oriented fault along the northeast coast of Mahone Bay, 50 miles north of the map-area, cuts Carboniferous (Windsor Group) rocks (Sage, 1954), and those in Shelburne map-area are possibly of the same age.

Cameron (1949) considered the quartz diabase dyke (map-unit 12a) to occupy a pre-existing fault fissure. Although the contact of this dyke was not seen during the present study, Faribault (1918, p. 18) made no mention of any fault characteristics at the contact with granite and schist (where he observed it) on Roseway River. Aeromagnetic data show no offset of anomalies that parallel the regional trend along the course of the dyke even though the dyke itself shows as an anomaly. Therefore this dyke is not regarded as being associated with a fault zone.

Powers (1915) was of the opinion that the area from Port La Tour to Round Bay was block-faulted, but present mapping revealed no basis for this interpretation.

Chapter V

ECONOMIC GEOLOGY

The area does not offer much encouragement to the prospector, in part because of the dearth of outcrop. Recent geochemical and aeromagnetic surveys have not shown the area to be prime prospecting ground. A survey of waters and stream sediments for heavy metal (Zn, Cu, Pb) by Boyle, *et al.* (1958) did not show any significant concentrations of metals. Aeromagnetic data (Geological Survey of Canada, 1957a to i) in general can be correlated with known geology. The major exception is an anomaly lying between Great Pubnico and French Lakes, which is probably caused by a magnetic body that lies well below the surface. Future exploration will require the use of refined prospecting tools, such as electromagnetic surveys, as all surface showings have probably already been discovered. In the past, the Meguma Group has received most of the prospector's attention, but the White Rock Formation could prove to be more fruitful as it is much better exposed.

Although the Meguma Group rocks have been host for most of the gold mined in Nova Scotia, Shelburne map-area has not contributed any appreciable amount of metal. A few prospects have been located in the past and these are listed below with brief descriptions of the occurrences. Small amounts of molybdenite, beryl, and spodumene are known but none have been developed.

Quarrying of building stone and silica provide the only economic mineral production at the present time. Sufficient sand and gravel from glacio-fluvial deposits and eskers is available for road and building construction in most parts of the area.

Gold

Cream Pot Gold Mine

References:

Bailey, L. W.

1898: Report on the geology of Southwest Nova Scotia; *Geol. Surv. Can.*, Ann. Rept., vol. 9, pt. M, p. 140.

Faribault, E. R.

1920: Investigations in Southwestern Nova Scotia; *Geol. Surv. Can.*, Sum. Rept., pt. F, pp. 18-20.

Malcolm, W.

1929: Gold fields of Nova Scotia; *Geol. Surv. Can.*, Mem. 156, pp. 77-78.

The Cream Pot Gold Mine site is situated at Cranberry Head, about 6 miles north of Yarmouth, in light greenish grey slate of the Halifax Formation. According to Faribault (1920, p. 18), gold was discovered in 1868 in a vein 4 to 8 inches thick that pinches and swells with an inch or less of quartz in the pinched parts. Four shafts, the deepest to 220 feet, were sunk on the property and gold worth $30,000.00 was mined. Galena and arsenopyrite occurred in the vein along with the gold. Work ceased in 1903 and has never been resumed. In 1960 the only evidence of former activity was a small dump of waste rock and rock-filled shafts.

Dominique Gold Prospect

Reference:

Report by E. R. Faribault, on file, *Geol. Surv. Can.*

Located a mile east of Arcadia, the Dominique gold prospect was discovered around the turn of the century. A shaft, 35 feet deep, was sunk and trenches dug near two pieces of galena-bearing drift. Six veins were encountered in what was described as blue-black slate and greenish blue quartzite. When water filled the shaft the project was abandoned. In 1960 only a depression in the drift remained of the shaft site. No outcrop occurs in the area, which is probably underlain by the Goldenville Formation.

Pubnico

Reference:

Malcolm, W.
1929: Gold fields of Nova Scotia; *Geol. Surv. Can.*, Mem. 156, p. 219.

Gold was reported at Pubnico in 1868, and some surface work was undertaken in 1885. A trench, in dark grey Halifax slate, is present east of the school and about halfway to the shore. No mineralization was evident when the prospect was examined in 1959.

Beryllium

References:

Mulligan, R.
1960: Beryllium occurrences in Canada; *Geol. Surv. Can.*, Paper 60-21.
N.S. Dept. Mines (1961): Ann. Rept., 1960, p. 74.
N.S. Dept. Mines (1962): Ann. Rept., 1961, pp. 73, 74–75.
Oldale, H. R.
1960: Beryllium explorations in Southwestern Nova Scotia; *N. S. Dept. Mines*, Mimeo. Rept., pp. 17-26.
Vokes, F. M.
1958: Beryllium in Canada, Metallogenic Map; *Geol. Surv. Can.*, Map 1045A-M2.

Beryllium, in the form of beryl, occurs in several places in the eastern half of the map-area and near Brazil Lake associated with a spodumene pegmatite. Two types of occurrences, as distinguished by Mulligan (1960), are present: (1) pegmatite and pegmatitic quartz veins; and (2) high temperature quartz veins, which are notable by the apparent absence of feldspar. All but one (Jordan Falls) beryllium occurrence in the map-area are of the first type.

With the exception of the Jordan Falls and Brazil Lake occurrences, the beryl is closely associated with the Port Joli and Shelburne granodiorites and either lies within the plutons or near their margins. All the occurrences are small and only a few show any continuity. The occurrences in the eastern half of the map-area were investigated by Oldale (1960) in 1959 using a berylometer.

Jordan Falls

This occurrence is located about half a mile east of a point 3 miles by road north of Jordan Falls. A trail leads from the road to the showing. Beryl occurs in a quartz vein that was previously prospected for molybdenite.

The vein cuts relatively flat-lying biotite greywacke of the Goldenville Formation, which may be near the crest of an anticline. No other outcrop occurs in the immediate area; in fact the one exposure was the result of trenching on quartz drift located in the immediate vicinity.

The beryl occurs in a high temperature quartz vein up to 4 feet thick, which was exposed by stripping for about 100 feet in 1959. The vein, which strikes N55°E and dips 80°NW, divides toward the northeast end around a horse of country rock. There the vein narrows to 18 inches on either side of the horse. Two small veins trending more easterly than the stripped area show no beryl.

The quartz is glassy, locally pink, and commonly laminated. Muscovite occurs along about 60 per cent of the southeast wall in a band up to 6 inches thick. It is present erratically on the northwest wall. Beryl, pale greenish yellow to white, is in small crystals and shapeless stringers. It is most abundant in the northeast part of the vein and within 3 inches of the vein wall. Molybdenite clots, up to 1 inch in diameter, on the other hand, are more common near the centre of the vein. Tourmaline is present locally. A survey of the vein exposed in 1959 with the berylometer (Oldale, 1960) at 1-foot intervals gave an average assay of 0.46 per cent BeO.

In 1960, Cadamet Mines Limited lengthened the exposure by stripping and trenching to 262 feet, with an average width of 2.9 feet. In 1961, Talisman Mines Limited carried out a spontaneous polarization survey and ground magnetic survey of the area to trace possible extensions of the vein and outline additional veins. The latter company drilled four holes on the showing (Northern Miner, 27 April, 1961). Three of the holes were drilled down the dip of the vein, whereas the fourth, drilled normal to the strike, intersected the vein at a vertical depth of 65 feet. This drilling revealed the existence of 2 more veins, the width of which was not disclosed, and a widening of the main vein at depth. In September, 1962, the property appeared to be abandoned.

Port Mouton Area

Beryl occurs in several places along the coast between Port Hebert and Western Head. All the beryl occurs in pegmatite dykes or veins either in biotite granite or in the

Goldenville Formation close to the granite contact. The pegmatite dykes are in general poorly defined, narrow, and commonly occur as irregular stringers. The beryl is pale greenish yellow to white, commonly occurring as crystals or aggregates up to 3 inches long. Reddish brown garnet, locally in clusters up to 1 inch in diameter, black tourmaline, and muscovite are common associates. Some of the muscovite occurs with quartz in a plumose texture.

The best showing occurs on the southwestern side of Mouton Island where pegmatites are common in an area about 300 feet long by 60 to 100 feet wide. This and other occurrences at Newhouse Cove and Sandy Cove have been mapped in detail by Oldale (1960). Rare crystals of beryl are also located at Port Hebert, Hunts Point, Cadden Bay, and Western Head. It is doubtful that any of these localities are of economic significance as the pegmatites are poorly defined and discontinuous, and beryl occurs erratically within them.

Roseway River Area

A few beryl crystals are present in pegmatites in the Roseway River valley, upstream from Highway 3. Their occurrence is similar to those in the Port Mouton area. No significant amount of beryl was located.

Pegmatite similar to that in the Port Mouton and Roseway River areas is common in the Barrington Bay area, particularly on Cape Sable Island. Plumose quartz-muscovite textures similar to those at Sandy Cove are present in this area also. Although beryl was not located in this area further investigation is probably warranted.

Lithium

Reference:
N.S. Dept. Mines (1962): Ann. Rept., 1961, pp. 69, 78.

A boulder of spodumene-bearing pegmatite was discovered in 1960 along the side of the Brazil Lake–Pleasant Valley road. Mr. L. E. Rodney of Yarmouth staked four claims covering the immediate area. A group of boys resident in the district drew the writer's attention to an outcrop of pegmatite 2,500 feet southeast of the Brazil Lake crossroads. Subsequent work, chiefly stripping, by Mr. Rodney disclosed two outcrops of pegmatite north of the road. The outcrop pattern suggests the presence of two parallel sills (or dykes) of pegmatite.

The sills occur within the White Rock Formation and probably intrude metavolcanic rocks of that formation. Several outcrops of distinctive White Rock Formation quartzite are present between the two sills. A sketch-map of the geology of the area is shown on Figure 8.

Neither the length nor the thickness of the sills is known accurately. The eastern one is exposed for 70 feet parallel with the regional trend and 20 feet normal to it. An outcrop of hornblende-feldspar gneiss is present 20 feet to the northwest but to the southeast there are no nearby outcrops. The western sill is at least 35 feet thick at the northernmost outcrop and probably exceeds 320 feet in length.

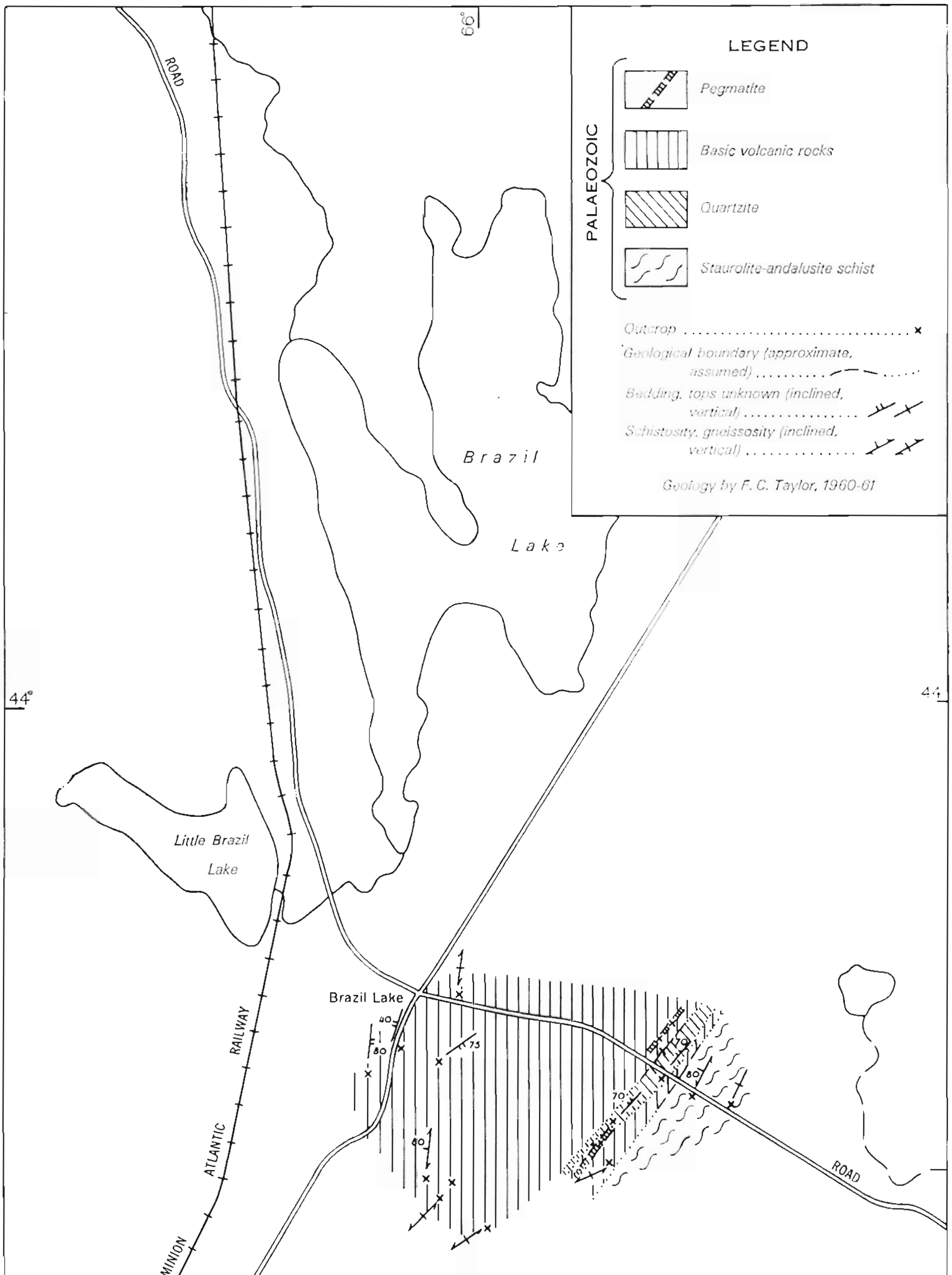

FIGURE 8. Geology of the Brazil Lake area.

The sills consist of feldspar, quartz, spodumene, muscovite, beryl, tourmaline, biotite, and apatite in decreasing abundance. Feldspar consists chiefly of white plagioclase with small amounts of pink potash feldspar. Quartz is glassy, clear to dark grey, and almost smoky. Spodumene, pinkish grey on weathered surfaces, occurs in crystals up to 4 feet long that are well scattered in the eastern sill but north of the road occur in concentrations only in parts of the pegmatite. In the most northern exposure, spodumene is concentrated on border parts of the sill so that the core is devoid of this mineral.

Pale greenish yellow beryl occurs only in the eastern sill, chiefly on a southeast-facing edge of the exposure. Crystals up to 1 inch in diameter occur sporadically with quartz crystals, both of which lie approximately normal to the length of the pegmatite.

Muscovite is the commonest mica and is well distributed throughout the pegmatite both as crystals up to one-half inch in diameter and as tiny grains, the latter commonly within spodumene. In the northern exposures, a mixture of medium-grained muscovite and plagioclase forms pale greenish yellow patches up to 3 feet long. Biotite is rare and occurs chiefly in what is probably an inclusion on the southeast side of the eastern sill. Dark green apatite crystals, up to one-half inch long, are present, with plagioclase in a 4-foot-wide zone in the core of the northernmost outcrop, but were not seen elsewhere. Black tourmaline in tiny crystals is present in a 4- by 1-inch patch on the southeast side of the southern outcrop.

A modal analysis of the southern outcrop with points on 1 foot centres shows the following mineral content:

feldspar	52.4%
quartz	34.0%
spodumene	10.7%
mica (chiefly muscovite)	2.6%
beryl	0.5%
Total	100.2%

Molybdenum

References:

Bailey, L. W.

1898: Report on the geology of Southwest Nova Scotia; *Geol. Surv. Can.*, Ann. Rept., vol. 9, pt. M, p. 146.

Faribault, E. R.

1918: Investigations in Western Nova Scotia; *Geol. Surv. Can.*, Sum. Rept., 1917, pt. F, p. 19.

Molybdenite was first observed by Bailey (1898) along a small tributary of the Jordan River. This occurrence, just west of the Lake John road, was reported by Faribault to consist of several quartz veins, the largest 26 inches wide, and containing muscovite, tourmaline, ilmenite, and rare molybdenite. Smaller veins a few feet south of the main vein also showed scattered molybdenite.

In 1959, the occurrence was extensively overgrown and only the main vein exposed. Rare molybdenite grains, a few tourmaline crystals, and muscovite were located in banded quartz of this vein. It strikes east-northeast, dips vertically, and cuts massive greywacke of the Goldenville Formation. The scarcity of the molybdenite offers little encouragement to the prospector.

Farther northeast, molybdenite occurs with beryl in what may be the extension of the same vein.

Feldspar

Reference:
N.S. Dept. Mines (1932): Ann. Rept., 1931, p. 134.

A pegmatite, 2.7 miles northeast of Brooklyn, was prospected for feldspar in the early 1930's. In 1960, an overgrown and partly rock-filled pit, 30 feet long and 7 feet wide, showed a pegmatite dyke about 7 feet wide trending N15°E parallel with the foliation of the granite country rock. The pegmatite consists of potash feldspar, quartz, rare muscovite up to 1 inch in diameter, and tourmaline up to 2 inches long. Although this pegmatite is of doubtful use as a source of feldspar its presence roughly on strike with the spodumene pegmatite suggests that possibly intensive search in this region may disclose other dykes containing minerals of economic importance.

Building Stone

References:
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1955: The granite industry in Canada; *Mines Branch*, Canada, No. 846, pp. 38-41.
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1948: The Shelburne granite area; *N. S. Dept. Mines*, Ann. Rept., 1947, pp. 148-154.
Parks, W. A.
1914: Building and ornamental stones of Canada, vol. II, Maritime Provinces; *Mines Branch*, Canada, No. 203, pp. 136-137.

Granite quarrying has been carried on in the Shelburne area since before the turn of the century. Most of the rock used was derived from huge boulders, but several small quarries have also been worked. At the present time two types of commercial granite are quarried by Scotia Granite Quarries Limited, a grey granite and a black granite. The grey granite is now obtained from a new quarry at Hart Point, but prior to 1960 most of the rock was obtained from Shepherds Island on the west side of Shelburne Harbour. The black granite is quarried near Birchtown. Both stones are trucked to a plant on the east side of Shelburne Harbour for cutting and polishing.

The grey granite is quarried from the Shelburne granodiorite pluton (map-unit 11b). The stone is fine to medium grained, grey, and polishes to a high gloss. Only rare pitting of the biotite grains mars the finish. The black granite is obtained from hornblende diorite (map-unit 11g). This rock polishes to a dark greenish black and is used chiefly for monuments.

Another black granite was quarried at one time from the quartz diabase dyke (map-unit 12a) from an abandoned railway cutting east of Jordan River and from the same rock east of Roseway River. Neither has been used recently. Faribault (1918) reported that this stone takes an excellent polish of a rich greenish black colour.

Recent granite production from the Shelburne area was:

1952	520 tons*
1953	545 "
1954	417 "
1955	286 "
1956	448 "
1957	200 "
1958	223 "
1959	245 "
1960	347 "
1961	436 "

* Total black and grey granite production.

Silica

Reference:

Collings, R. K.

1956: The Canadian silica industry; *Mines Branch*, Memo. Ser. No. 134.

N. S. Dept. Mines: Ann. Repts., 1945 to 1961.

Chegoggin Point

Silica is quarried at Chegoggin Point from a pit opened in 1945. The rock is crushed at the quarry site and trucked to Yarmouth for rail shipments to Sydney, Nova Scotia, where it is used in the manufacture of silica brick. Sufficient rock is shipped in a few months for about two years consumption so that quarrying is on an intermittent basis.

The rock quarried is from thick quartzite beds of the White Rock Formation. Although much of the quartzite is white, yellow and brown shades are common. A few thin beds of slate are present in parts of the quarry. Collings (1956) reported a typical analysis of the rock to be:

SiO_2	—	97.1 %
Al_2O_3	—	0.97%
Fe_2O_3	—	0.51%
CaO	—	0.28%
MgO	—	0.10%

As this rock is part of a sedimentary unit, extensive reserves are undoubtedly available, although thick overburden may be encountered. Production to 1961 is as follows:

1945	1,050 tons
1946	2,274 "
1947	6,709 "
1948	7,651 "
1949	9,253 "
1950	11,355 "
1951	13,981 "
1953	11,557 "
1955	7,528 "
1957	8,378 "
1960	8,333 "

Peat

References:

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1930: Peat bogs in Southeastern Canada; *Geol. Surv. Can.*, Mem. 162.
Leverin, H. A., and Cameron, J. R.
1948: Peat and peat mosses in Nova Scotia, pt. I; *N. S. Dept. Mines*, Ann. Rept., 1947, pp. 187-264.

Peat deposits although extensive have not been worked commercially. Several bogs have been examined in detail by Leverin and Cameron (1948) in Yarmouth and Shelburne counties. Numerous deposits are close to roads and rail and possibly could be developed commercially.

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1957h: Aeromagnetic Map, Shelburne, Map 608G.
1957i: Aeromagnetic Map, Port Mouton, Map 609G.

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