GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

MEMOIR 343

GEOLOGY OF HOPEWELL MAP-AREA, NOVA SCOTIA

D. G. Benson

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PLATE I. Windsor conglomerate unconformably overlying Goldenville greywacke on Cox Brook.

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PREFACE

Many geologists have made field studies in northeastern Nova Scotia since the discovery of coal and iron in Pictou county early in the 19th century. One of the most renowned of these was Hugh Fletcher of the Geological Survey of Canada, who began a geological survey of the province during the last quarter of the century. His investigations took him into what is now the Hopewell map-area, and his geological findings were published in reports and maps about 1890. Since that time geological concepts have changed considerably and mapping methods have improved and the Geological Survey has been systematically re-examining many areas in Nova Scotia.

Dr. Benson undertook the geological re-examination of Hopewell map-area in 1960 and 1961 for publication on a scale of 1 inch to 1 mile. He has subdivided the Carboniferous strata into formational units currently recognized in northeastern Nova Scotia, and has contributed new geological information on the complex Antigonish Highlands.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, January 20, 1965

MEMOIR 343 — Kartenblatt des Hopewell-Gebiets (Neuschottland).

Von D. G. Benson

Dieser Bericht beschreibt die Geologie der Sedimente aus der Periode des Untersilurs bis zur Steinkohlenzeit und der devonischen Granitgesteine in einem Gebiet im Nordosten Neuschottlands.

ТРУД 343 — Хопуэллский лист геологической карты, Новая Шотландия.

Д. Г. Бэнсон

Этот отчет дает описание геологии осадочных пород от ордовикского до каменноугольного возраста включительно и девонских гранитных пород этого района северо-восточной Новой Шотландии.

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GEOLOGY OF HOPEWELL MAP-AREA, NOVA SCOTIA

Abstract

Hopewell map-area lies in the northeastern part of the Appalachian mountain system and is underlain by Ordovician to Upper Carboniferous rocks. Much of the area is covered by thick Pleistocene deposits and the bedrock exposures are found mainly in the stream valleys.

Quartzite, quartz wacke, greywacke, slate, and schist of the highly folded Ordovician Meguma Group outcrop near the southern boundary of the map-area. In the northeastern corner, Browns Mountain Group volcanic and pyroclastic rocks of Ordovician age are overlain unconformably by fine-grained clastic rocks of the Silurian Arisaig Group. These older Palaeozoic rocks are overlain with a marked unconformity by slightly deformed Carboniferous rocks belonging to the Horton, Windsor, Canso, Riversdale, Pictou, and Cumberland Groups. The Windsor Group consists of fine-grained calcareous sediments—limestone, gypsum, and anhydrite. All other Carboniferous strata are predominantly fine- to medium-grained clastic rocks. The Canso and Windsor Groups are intruded by rocks of diabasic composition.

Flora and fauna of both the Silurian and Carboniferous rocks are related to European forms and hence the European subdivision into epochs is used in this report.

The rocks were folded during both the Taconic orogeny in Late Ordovician time and the Late Devonian Acadian orogeny. The Acadian orogeny was accompanied by the intrusion of granite. The region was slightly affected by folding during the late Palaeozoic.

Lead minerals occur near Glenbervie along the Horton–Windsor contact and copper minerals were seen near old workings in the Canso rocks north of Lansdowne. A narrow bed of hematite-rich arenite belonging to the Arisaig Group is exposed in three places near MacPhersons Lake. Gypsum has been mined for local use at several sites.

Résumé

La région de Hopewell se trouve dans la partie nord-est du système montagneux des Appalaches et repose sur des roches datant de l'Ordovicien au Carbonifère supérieur. Une grande partie de la région est recouverte d'épais dépôts du Pléistocène et un nombre restreint d'affleurements rocheux se rencontrent surtout dans les vallés fluviales.

Du quartzite, de la wacke quartzeuse, du grauwacke, de l'ardoise et du schiste du groupe de Meguma de l'Ordovicien très plissé affleurent près de la limite sud de la région. Dans l'angle nord-est, les roches volcaniques et pyroclastiques du groupe de Browns Mountain datant de l'Ordovicien sont recouvertes en discordance de roches clastiques à grain fin du groupe d'Arisaig du Silurien. Ces roches paléozoïques plus anciennes sont recouvertes en discordance marquée de roches du Carbonifère légèrement déformées, appartenant aux groupes d'Horton, de Windsor, Canso, Riversdale, Pictou et Cumberland. Le groupe de Windsor se compose de sédiments calcaireux à grain fin: calcaire, gypse et anhydrite. Toutes les autres couches du Carbonifère consistent surtout

de roches clastiques à grain allant du fin au moyen. Les groupes de Canso et de Windsor renferment des roches d'intrusion de composition diabasique.

La flore et la faune des roches du Silurien et du Carbonifère se rattachent aux formes européennes et c'est pourquoi l'auteur utilise la division européenne des époques dans le présent rapport.

Les roches se sont plissées durant l'orogenèse taconique de l'Ordovicien supérieur et l'orogenèse acadienne du Dévonien supérieur. L'intrusion du granite a accompagné l'orogenèse acadienne. La région a été légèrement affectée par des plissements au cours du Paléozoïque supérieur.

On a noté la présence de minéraux plombifères près de Glenbervie, le long du contact de Horton-Windsor et de minéraux cuprifères près des vieux chantiers dans les roches du groupe de Canso, au nord de Lansdowne. Un lit étroit d'arénite à forte teneur en hématite, et faisant partie du groupe d'Arisaig affleure à trois endroits près du lac MacPhersons. On a extrait du gypse pour usage local à plusieurs endroits.

Chapter I

INTRODUCTION

Hopewell map-area, which covers about 435 square miles, is situated in northeastern Nova Scotia between latitudes 45°15′ and 45°30′N and longitudes 62°30′ and 63°00′W. It is accessible by road from New Glasgow and Stellarton to the north, and its northwest part is crossed by a line of the Canadian National Railways.

Most of the map-area is covered with mixed coniferous forest. This forest formerly supported a more extensive lumbering industry than at present, but now much of the wood cut is supplied to pulp mills. The forests, generally Crown-owned, are leased to private individuals and companies.

Mixed farming is carried out in narrow strips along the roads and river valleys in the northern third and southwest corner of the map-area. Numerous farms have recently been abandoned. In a few places there has been scientific reforestation on these farms, but generally this has not been attempted.

The geological mapping of Hopewell map-area was carried out during the summers of 1960 and 1961. Preliminary geological maps were published on a scale of 1 inch to 1 mile (Benson, 1961 and 1962).[1]

Acknowledgments

Able assistance in the field was provided by P. H. Smith, E. D. Warren, and D. F. Reid in 1960, and by R. Biggs, R. S. Hiltz, and W. W. Brideaux in 1961. Mrs. Gladys Fraser was the cook during both summers.

Fossil identifications were made by members of the Geological Survey of Canada. C. Harper, of the California Institute of Technology, identified most of the Silurian brachiopods.

Previous Geological Work

In 1828 Jackson and Alger showed two divisions in the Hopewell map-area: 1) "red and grey sandstone alternating with black and red shale containing impressions of vegetables; beds of coal. . . .", and 2) "transition clay slate". The following year (1829) they proposed the continuation of a 16-foot-wide fossiliferous iron bed

[1]Names and/or dates in parentheses are those of references listed in *Bibliography*.

from New Glasgow to Annapolis county. T. C. Haliburton (1829, p. 453) relying on second-hand information, vastly exaggerated the size of "great veins of iron ore" on the East River of Pictou. In 1836, Abraham Gesner (pp. 5,6) divided Nova Scotia into four districts, each underlain by distinctive rock types: 1) primary; 2) clay slate; 3) red sandstone; and 4) trap. The present Hopewell map-area is divided into these districts. He searched along the East River of Pictou for the iron-ore bed of Jackson and Alger but found none. Later, Gesner (1845, pp. 186-190) divided the rocks into: 1) granitic rocks; 2) stratified non-fossiliferous rocks; slate, greywacke, and schists; 3) Silurian Group; 4) old red sandstone or Devonian Group; 5) coal measures; sandstone, conglomerate shale, limestone, and coal; 6) new red sandstone; and 7) intrusive igneous rocks. These divisions all occur in Hopewell map-area. Sir W. E. Logan (1842, p. 711) concluded that the gypsum and limestone in Pictou county overlaid the coal measures. Lyell (1843) subdivided the Carboniferous of Nova Scotia into: 1) Lower Carboniferous: red sandstone and marl with gypsum and limestone; 2) Middle Carboniferous: coal measures; and 3) Upper Carboniferous: sandstone and shale with fossil plants. He also studied the coal measures of Pictou county and the gypsum along East River of Pictou.

Sir J. W. Dawson in 1845 (p. 329) in describing the Carboniferous rocks of Pictou county divided them into: 1) mountain limestone (or gypsiferous) formation; 2) older coal formation; and 3) newer coal formation. Dawson thought that the trap rocks along East River of Pictou were interstratified with the Silurian sedimentary rocks. He later (1850, pp. 347-364) described the metamorphic rocks of eastern Nova Scotia and also noted the presence of iron mineralization in the Lower Carboniferous rocks near the Silurian contact along East River of Pictou. In 1860 (pp. 132-143) he mentioned a "great bed of fossiliferous peroxide of iron" about 40 feet thick along East River of Pictou, and in *Acadian Geology*, he regarded a narrow strip along the East River of Pictou as the only Carboniferous section in Hopewell map-area. Most rocks now recognized as Carboniferous were called Devonian by him. At first Dawson (1878, p. 613) regarded the Meguma Group as Lower Silurian, but he later (1891, supplement, p. 81) called it Cambrian. In 1875 (pp. 129-138) he again referred to the "great iron bed" along East River of Pictou, which he traced along opposite sides of an anticlinal axis and which he thought would have great economic importance. He assigned a Ludlow age (Upper Silurian) to rocks along East River of Pictou (1881a, p. 2). In another paper (1881b, p. 333) Dawson referred to a great vein of specular iron on the west side of the East Branch of East River of Pictou. In 1888 (p. 805) he regarded most of the gold series (now the Meguma Group) as Cambrian with the exception of some of the slate associated with igneous rocks, to which he assigned an Ordovician age. He gave a Carboniferous section as follows: 1) lower series; 2) Carboniferous limestone; 3) millstone grit series; 4) main coal measures; and 5) Permocarboniferous series.

Honeyman (1864, pp. 333-345) reported the finding, in place, on East River of Pictou, of fossils found only in boulders at Arisaig, and described (1870, pp. 67-73) the iron deposits on East River of Pictou in more detail than Dawson had. In 1874 (pp. 31-40) he published a summary of his conclusions about Nova Scotia geology, many of which are erroneous, including his suggestion that the crystalline rocks near Arisaig (now regarded as Browns Mountain Group) were of Laurentian (Precambrian) age.

Hartley (1870b, pp. 365-442) made first mention of the source of the limonite boulders found along East River of Pictou. Harrington (1874, p. 215) mentioned the iron deposits near Bridgeville and also referred to a specularite bed of importance west of the East Branch of East River of Pictou. The limonite beds of the Bridgeville area were said to lie at the contact of the Silurian and Carboniferous rocks. Edwin Gilpin, Jr. (1882, pp. 31-38) stated that the limonite at Bridgeville replaced the limestone at the Silurian-Carboniferous contact. He later (1891, p. 108) described the "iron ore" at Websters and Blanchard as thin beds of hematite-rich sediments separated by slate.

The bedrock geology of Hopewell map-area was mapped in detail by Hugh Fletcher (1887, 1892), who was assisted in some of this work by E. R. Faribault. Their maps are still useful today, particularly in the location of outcrops and old mineral prospects and in the details of the drainage system. They regarded the nonmarine Mississippian as Devonian, even though they recorded the presence of numerous plant fossils within this division.

H. M. Ami collected fossils in Hopewell map-area in 1895 and 1896 and proposed a fourfold subdivision of the rocks at Arisaig (1900b, pp. 179A-180A).

Twenhofel studied the Silurian section at Arisaig (1909) and in 1913 (p. 295) published a subdivision of the Silurian section.

Faribault published on the Goldbearing series (now the Meguma Group) in 1913, and the following year Malcolm (1914) summarized the work done by Faribault and presented an excellent geological map of Nova Scotia. Malcolm and Faribault on revising this work in 1929 divided the Goldbearing series into the Goldenville Formation and the overlying Halifax Formation.

M. Y. Williams (1914) wrote an extensive report on the Cape George area which includes the Silurian section at Arisaig. His subdivision was used by Twenhofel (1913), who aided him in his work. Williams proposed that the term Browns Mountain Group be applied to the metamorphic rocks of the Pictou-Antigonish Highlands, and included the James River and Baxters Brook Formations described by Fletcher (1887) in this group.

Hayes (1919, pp. 112-122) attributed the Silurian iron deposits at Blanchard Brook to "precipitation of iron-bearing minerals in shallow marine water". He found the fauna of the iron bed to be the same as that in the McAdam Formation at Arisaig.

In 1924, McLearn wrote an extensive report on the palaeontology of the Silurian rocks at Arisaig.

Messervey (1944) gave a brief history of the development of the iron-ore occurrences in the Bridgeville area and a short description of the geological setting. Weeks (1948) subsequently investigated these deposits and concluded that the ore had formed probably as a result of weathering on the pre-Carboniferous land surface.

MacNeil (1947, 1948) examined the basal Carboniferous conglomerates along the contact with the Meguma Group while looking for residual gold deposits, and a few years later Hogg (1953) discussed the Pleistocene geology of Pictou county.

In Truro map-area to the west Stevenson (1958) found Carboniferous rocks like those found in Hopewell map-area. His work was used by the author as a basis for studying the comparable stratigraphy. Stevenson (1959a) also mapped two other areas (Shubenacadie and Kennetcook), which are underlain mainly by Carboniferous and Ordovician rocks that are correlative with those of Hopewell map-area.

Maehl (1960, 1961) investigated the Ordovician, Silurian, and Devonian rocks of Pictou county, giving particular attention to the stratigraphy and fossil fauna of the Silurian formations.

In 1962 P. H. Smith discussed the stratigraphy of the Horton Group in Hopewell map-area on the basis of work done in 1960 while he was an assistant to the writer.

Physiography

Most of Hopewell map-area lies within the Hants-Colchester Lowland (Goldthwait, 1924). The southwest edge of the Pictou-Antigonish Highland projects into the northeast corner of the area, and the Southern Upland lies along the southeast border. These terms proposed by Goldthwait are useful descriptive physiographic divisions. Weeks (1957, pp. 125-126) used the terms Minas Lowland, Antigonish Highlands, and Atlantic Uplands to refer to these three divisions; and, although Goldthwait's report remains as the reference work on the physiography, Weeks' terms are used in this report.

The Minas Lowland in Hopewell map-area is underlain by Carboniferous sediments having varying degrees of resistance to weathering. Thus the area underlain by the calcareous Windsor rocks shows less relief than the areas underlain by the more resistant Canso rocks. The lowland is an area of low rolling hills whose maximum elevation is 400 feet. Minor amounts of karst topography are found where gypsum and anhydrite outcrop. The stream valleys are narrow except in the areas underlain by the Windsor Group.

The greatest relief occurs at the edge of the Antigonish Highlands, where the Ordovician-Silurian metamorphic complex that underlies the highlands is unconformably overlain by Windsor sediments. The hilltops are about 500 feet from the valley floors and are dissected by incised stream valleys. The interior of the highlands is hilly but contains a few swampy areas.

The Atlantic Uplands are underlain by granite and by metamorphic rocks of the Meguma Group. It is a remarkably uniform surface of rolling country with rounded ridges separated by lakes or swampy areas. Locally the streams have a series of falls near the northern edge of the upland, but within the upland they wander lazily.

Thick deposits of till and gravel, which are evidence of former glaciation, obscure the bedrock except in the stream valleys. Glacial striae were not seen, but Goldthwait's map (1924) shows some in the barrens at Maple Lake that indicate a south-southeast movement of the ice-sheet. The till, which is clayey, has rock fragments that may be of the same composition as the local bedrock. That the fragments are commonly of granite or basic igneous rock while the bedrock is sedimentary shows that some transport has been involved.

The most prominent surficial deposits are glacio-fluvial accumulations of gravel with sand lenses. Most of the gravel deposits appear to be kames of various thicknesses, the maximum thickness being about 80 feet. Large deposits are found between Gordon Summit and West River Station, and northeast of Eastville. Near Eastville, Stewiacke River flows through a glacial outwash plain that seems to be in part a modern flood plain (Pl. II). Flood-plain deposits are found along East River

PLATE II. Outwash plain of Stewiacke Valley. *D.G.B., 5-2-61*

of Pictou and West Branch of East River of Pictou between Hopewell and Elgin.

The stream floors are generally a mixture of gravel and boulders. Near their headwaters, many streams flow through thick mud banks overlain by swampy land. Boulder beaches are commonly found at the junction of two streams (e.g., at the mouth of Big Stewiacke) and on the inside of many stream curves. Sand banks occur at similar locations on the lower part of Stewiacke River and on some stretches of West Branch of East River of Pictou and East River of Pictou.

The streams are imperfectly graded, with stretches of calm water separated by falls or rapids. The falls are formed by resistant beds and by structural features such as folds. The stream courses do not appear to be controlled by geological features but are probably consequent to the initial slope of the land. However, the southwest-trending part of Stewiacke River flows along the crest of a fold. The height of land in the map-area separates three stream systems. The Stewiacke system flows southward and empties into Shubenacadie River and Cobequid Bay. West, Middle, and East Rivers of Pictou flow north to Pictou Harbour. West River St. Mary's flows east to St. Mary's River and thence to the Atlantic Ocean. The divides between these

PLATE III. Flood plain of Cox Brook and Stewiacke River cut into glacial outwash. *D.G.B., 1-7-61*

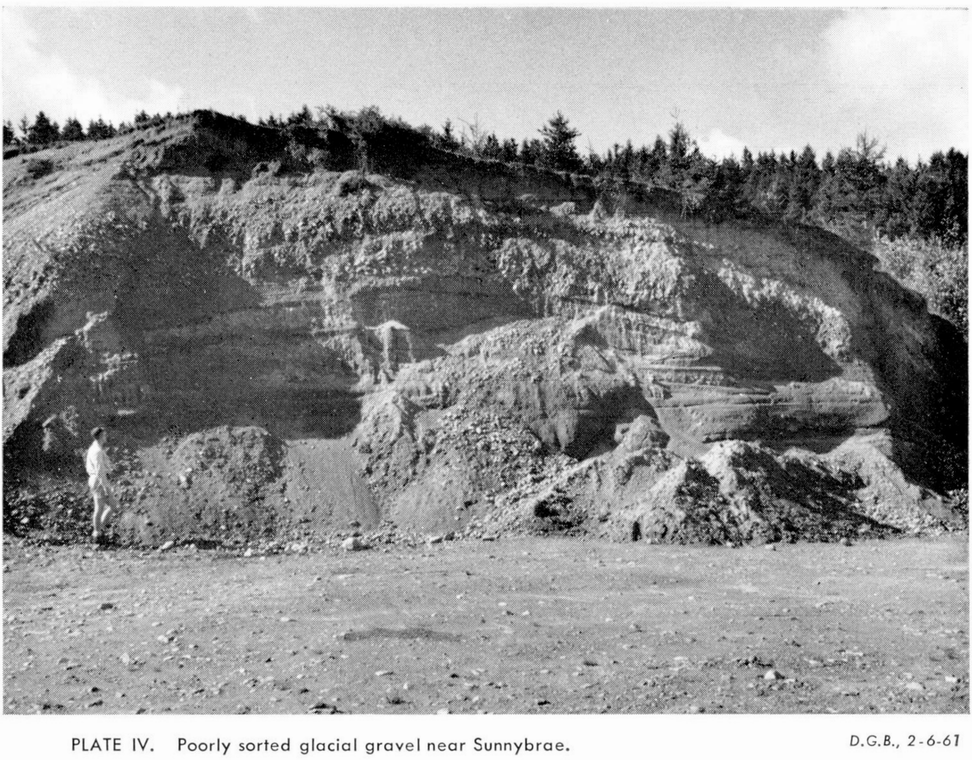

PLATE IV. Poorly sorted glacial gravel near Sunnybrae. *D.G.B., 2-6-61* systems are vaguely defined and are generally occupied by swampy areas, which apparently drain in two directions. Some lakes are found near the headwaters; although they lie in depressions, their present configurations are due in part to the work of beaver or old logging dams.

With the exception of the small areas of bedrock exposure, the entire map-area is covered with a thick mantle of till and associated deposits (Pl. IV). Immediately to the southwest, in Shubenacadie map-area, this till is regarded as Wisconsin (Hughes, 1957). A more detailed description of glacial features, much of which can also be applied to Hopewell map-area, is included in the report by Hughes (1957).

Chapter II

GENERAL GEOLOGY

Hopewell map-area is underlain by Palaeozoic sedimentary, metamorphic and igneous rocks. The unfossiliferous Browns Mountain Group may be Ordovician. It is composed of interbedded basic volcanic and pyroclastic rocks, argillite, and siltstone. These rocks are unconformably overlain by the fossiliferous Silurian Arisaig Group, which consists mainly of quartz wacke,[1] slate, and quartzite.

Grey quartz-mica schist, slate, and quartz wacke of the Meguma Group, of probable Ordovician age, are intruded by Devonian granite.

The rarely fossiliferous Lower Carboniferous Horton Group is divided into three units consisting predominantly of siltstone, arenite,[1] or mudstone. It unconformably overlies the Meguma Group and Devonian granite. Limestone, shale, gypsum, and anhydrite of the fossiliferous marine Windsor Group locally overlie the Horton Group disconformably and the Meguma and Arisaig Groups unconformably. The Windsor-Canso contact was not observed but is probably gradational. The Canso Group, composed of shale, mudstone, siltstone, and minor calcareous beds, has yielded only non-marine Upper Carboniferous fossils.

The rocks of the Riversdale Group, which contain Upper Carboniferous plant fragments, are shale, siltstone, and minor quartz wacke. As they occur within a fault block, neither their upper nor their lower contact was observed. The observed lithologies of an interbedded sequence of sandstone, mudstone, conglomerate, and shale are similar to those found in both the Cumberland and the Pictou Groups in the type areas, and fossil evidence suggests that rocks present in the map-area are correlative with both groups.

The tectonic history is similar to that for other parts of the Appalachian geosyncline in that Carboniferous and younger rocks are relatively undisturbed and the older rocks are intensely deformed.

Rocks of diabasic composition intrude the Carboniferous sediments.

[1] The terms 'wacke' and 'arenite', as defined by Williams, Turner, and Gilbert (1958, p. 290), refer to sandstone in which the argillaceous matrix makes up respectively more than 10 per cent and less than 10 per cent.

Table of Formations

Era	Period or Epoch	Stage	Group[1]	Formation	Lithology
Cenozoic	Recent				Stream sand and gravel
	Pleistocene				Gravel, sand, and clay
			Unconformity and(?) minor basic intrusive rocks		

Table of Formations (cont'd)

Era	System	Series	Stage	Formation	Member	Lithology
Palaeozoic	Pennsylvanian	Upper Carboniferous	Westphalian	Pictou and Cumberland(?)		Brown and grey sandstone and mudstone, red conglomerate, and black carbonaceous shale
				Disconformity(?)		
				Riversdale		Medium grey to black siltstone and shale, and minor grey quartz wacke
				Unconformity(?) and(?) minor basic intrusive rocks		
	Mississippian		Namurian	Canso		Red, green, and grey mudstone, shale, siltstone, and argillite. Minor narrow calcareous layers
				Conformable(?)		
		Lower Carboniferous	Visean	Windsor		Red and grey shale and calcareous shale and grey limestone
						Grey to black limestone, argillaceous limestone, gypsum, anhydrite, and conglomerate
				Minor disconformity		
			Tournaisian	Horton	Unit "c" 1,700′	Red and green mudstone and siltstone, and thin grey pebble-conglomerate
					Unit "b" 3,000′±	Grey siltstone, shale, and quartz wacke
					Unit "a" 2,000′	Grey quartz feldspar sandstone, siltstone, and wacke
				Unconformity		
	Devonian and Earlier(?) ? ?					Grey biotite and muscovite granite and minor syenite. Pink and green granite
	Silurian		Downtonian	Arisaig	Stonehouse	Bluish grey, reddish brown and grey siltstone, wacke, and calcareous siltstone
			Ludlovian		Moydart	Greenish grey, fine-grained quartz wacke
					McAdam	Grey silty shale and shale, bluish grey siltstone, and thin layer of hematite-rich quartz arenite
			Wenlockian		Ross Brook 500′+	Grey quartz wacke, purplish grey siltstone, silty shale, grey quartzite, dark grey laminated shale, and basalt grey quartz granule conglomerate
			Llandoverian		Beechhill Cove 80′	Greenish grey quartz wacke and thin basal conglomerate with minor mudstone and quartzite

Table of Formations (cont'd)

Palaeozoic (cont'd)	Minor unconformity (disconformity?)			
	Ordovician	Browns Mountain 2,500′+		Interbedded green to black argillite, green to purple andesite, tuff and agglomerate, and dark greenish grey greywacke
		Meguma	Halifax 2,000′±	Black slate
			Goldenville 2,400′±	Greenish grey quartzite and minor slate, grey quartz wacke, greywacke, phyllite, andalusite schist and biotite schist

[1] Present usage restricts the term 'Series' to a time-stratigraphic unit, but these divisions are rock-stratigraphic units and thus the term 'Group' is applied (*Bull. Am. Assoc. Petrol. Geol.*, 1961, p. 658).

Ordovician

Meguma Group

The exposures of the Meguma Group in Hopewell map-area are the continuation of larger exposures lying to the southwest in Shubenacadie map-area (Stevenson, 1959a, pp. 8-13). In the latter area, Wittenburg Mountain is made up of a series of northeast-trending folds in the Halifax Formation, which is underlain to the southeast by narrow isolated patches of the Goldenville Formation. This structure extends into Hopewell map-area, where it consists of an apparently simple syncline of the Halifax Formation underlain by the Goldenville Formation.

The best exposures of the Meguma Group are found along Cox Brook. Other good exposures are on West River St. Mary's and Fulton Brook. In Cox Brook the outcrops are generally found on the sides of the valley and in the stream bottom where the resistant rocks form small falls or rapids. The rocks commonly display good cleavage, but bedding planes are readily seen only where two different rocks are interbedded. The attitude of the cleavage varies less than that of the bedding. The rocks are tightly folded and differences in attitude of 120 degrees in 2 to 5 feet are locally common. In one 3-foot-high outcrop five tight folds occur within a length of 20 feet. Several small drag-folds were measured, but it was not possible to relate their varied attitudes consistently to the nearby major structures. Thus it was concluded that many of the drag-folds could be incongruous and of no use in determining major structures.

Rocks of the Meguma Group have interested geologists since Gesner (1836, p. 5) first regarded them as Primary (i.e., unstratified, "coeval with the earth"). Since then various early Palaeozoic and Precambrian ages have been assigned to this group (Malcolm, 1929, pp. 30-34). These ages were based on lithology and degree of deformation, which were compared with their counterparts in sections of known age found elsewhere. Crosby (1962, p. 20) found graptolite fossils near Wolfville, in Windsor map-area, in rocks interpreted as part of the Halifax Formation. These fossils have now been identified as *Dictyonema flabelliforme* (Eichwald) *sensu lato* and assigned an Early Ordovician age (Bulman, unpub. rept., June 1960). Thus, similar rocks, found elsewhere in Nova Scotia, where they are included in the Halifax Formation, are assigned an Early Ordovician age. By further inference the Meguma Group of Hopewell map-area, which is correlated on lithological grounds with the Meguma Group to the south and west, is also considered to be of Early Ordovician age. It must be stressed that, although the area of Meguma rocks in Hopewell map-area can be traced to other areas of undoubted Meguma, the so-called Halifax Formation of Windsor map-area is isolated from the extensive areas of Halifax rocks found elsewhere in Nova Scotia.

Dictyonema lived in a marine environment but, owing to its probable planktonic habitat, may have drifted into the area of deposition of black shales where it is now found (Twenhofel and Shrock, 1935, pp. 87-94) and thus need not be indicative of deep-water deposition.

Goldenville Formation

The best exposures of the Goldenville Formation are on Cox Brook; a few scattered outcrops occur elsewhere. The base of the formation is not known, and the rocks are highly folded. A suggested thickness of the Goldenville Formation exposed in Hopewell map-area is about 2,400 feet; the suggestion is based on interpretation of the steeply dipping strata on Cox Brook. Woodman (1904, p. 16) gave a thickness of 17,670 feet for a section that had an unknown base and was situated in the Fifteen Mile Stream district, about 12 miles south of Trafalgar. In southwestern Nova Scotia, Taylor (1967) estimated a thickness of 15,500 feet for Meguma strata below the Halifax Formation, at which point they are cut off by a granitic intrusion. As the thickness of Goldenville rocks in Hopewell map-area is appreciably less than that farther south, either a smaller part of the formation is preserved or the section originally deposited was much thinner than to the southwest.

Outcrops of the Goldenville Formation are mainly medium greenish grey quartz wacke, light to medium grey meta-siltstone, and phyllite with quartz eyes and minor quartzite. These rocks vary only slightly in grain size and mineralogy. They consist more than 50 per cent of quartz in interlocking subangular grains showing some evidence of recrystallization. The remainder is potash feldspar and minor albite of similar habit, and argillaceous matrix. Some of the finer grained rocks may more correctly be called phyllite.

The rock is locally highly fractured and in some places has two well-developed joint sets. In one outcrop the writer saw three planar features, two of which may be metamorphic features, and the third, relic bedding. The rock is in general well indurated and massive, so that it breaks either along the joints or with an irregular conchoidal fracture. The outcrops are not continuous, and the covered interval is probably underlain by less resistant rock, probably slate, like that found nearby as boulders.

The Goldenville quartz wacke, as determined from thin sections, is composed of quartz 50 to 60 per cent, feldspar 5 to 10 per cent, and argillaceous matrix 20 to 40 per cent. The quartz grains are generally subangular, with only a small proportion subrounded to rounded. Feldspar was determined with difficulty owing to the clouded condition of the grains; most of it was identified by staining as potassium feldspar. The matrix is mainly fine-grained clay minerals with some identifiable mica and chlorite. The name 'quartzite', given to the diagnostic Goldenville rock by early writers (Dawson, 1850, p. 348; Woodman, 1904, p. 16; Faribault, 1913, p. 158; Malcolm, 1914, p. 46) does not apply. Stevenson (1959a, p. 12), though he used the term 'quartzite', called attention to the argillaceous content of the rock.

On a fresh surface the phyllite is medium to dark grey, but a weathered or fracture surface is generally olive-green to greenish brown. Minor amounts of mica and chlorite, in some places in parallel orientation, are visible in thin sections of the rock.

A narrow aeromagnetic anomaly shown on GSC Map 762G appears to be caused by a belt of andalusite-bearing schist, which outcrops on Cox Brook. The schist consists of quartz, chlorite, mica, chloritoid, andalusite, cordierite, colourless garnet, and magnetite. This belt borders a granitic intrusion, and the andalusite metacrysts may be due to thermal metamorphism. These metacrysts, some of which have nearly cubic outlines, range from a fraction of a millimetre to 4 mm across.

A black biotite schist outcrops a mile south of the mouth of South Brook. Pyrrhotite and magnetite, occurring as blebs in this rock, may be the cause of the small aeromagnetic anomaly in the immediate area. Development of this schist was probably influenced by its proximity to the granite body. To the northeast, on West River St. Mary's, quartz-feldspar-muscovite gneiss, biotite-garnet gneiss, and quartz-biotite schist may be the continuation of the same horizon. These rocks have narrow veins of pegmatitic material.

The slate boulders, which may represent the covered interval, vary from greenish grey to dark grey and generally have a slightly micaceous sheen.

The upper limit of the Goldenville Formation was taken as the top of the highest quartz wacke ('quartzite') bed.

Halifax Formation

Rocks, regarded as part of the Halifax Formation, are best exposed along Cox Brook and Fulton Brook. On meagre evidence, the thickness of the formation in the area is estimated to be 2,000 feet. The probable maximum on Wittenburg Mountain is 5,000 feet (Stevenson, 1959a, p. 13). Woodman (1904, p. 24) suggested a thickness for the Halifax Formation of about 11,600 feet near Halifax and 4,800 feet near St. Mary's Bay. Taylor (1967) gives a possible maximum of 5,800 feet in southwestern Nova Scotia.

The Halifax Formation of Hopewell map-area is composed of grey to black slate, in part graphitic, with lesser amounts of interbedded siltstone.

The slate ranges from dark grey to black, the lighter coloured rock generally being silty. In most outcrops the cleavage forms an angle with the bedding, as is shown by interbeds. Colour laminations within the slate beds are obscure; they are visible only where they are nearly parallel to the cleavage and thus intersect a fresh surface. Slate sections from 1 foot to 6 feet thick occur, as well as sections of unknown maximum thickness. Blebs and fracture fillings of pyrite give some outcrops a rusty weathered appearance. One outcrop has minute irregular crenulations in the plane of the cleavage. Cleavage plates are generally about a millimetre thick, but in some outcrops there are paper-thin plates.

Browns Mountain Group

The greater part of the Antigonish Highlands in the northeastern part of the map-area is underlain by Lower Palaeozoic rocks. The more resistant and older rocks, which are a metamorphic complex of mixed volcanic and sedimentary origin, make up the Browns Mountain Group. Near Arisaig, rocks assigned to this group by Williams (1914, p. 55) contain Lower Ordovician fossils. No fossils have been found in these rocks in Hopewell map-area, but as they underlie Lower Silurian rocks on Glencoe Brook with apparent disconformity, they are assigned an Ordovician age. The rock types and areal distribution of the Browns Mountain and Meguma Groups suggest that the Browns Mountain Group was deposited in a eugeosyncline that lay offshore from the shelf and the developing miogeosyncline in which the Meguma Group was deposited.

Fletcher (1887, p. 18) divided the rocks of his "Cambro-Silurian" system found in the Antigonish Highlands into: "1) The lower flinty slates, quartzites and 'whin'-like rocks of James River and Eigg Mountain; 2) the soft reddish and olivaceous slates of Baxter's Brook and Brian Dalys Brook; and 3) the reddish and grey sandstone, grit and conglomerate of Bear's Brook." He stated that a large proportion of the material of the Cambro-Silurian is of volcanic origin, and he included the associated igneous rocks such as traps, diorite, and felsite with each of the divisions. The rocks along James River are generally poorly sorted and impure sediments with interbedded dark coloured volcanic rocks. On Baxter Brook the sedimentary beds are partly derived from the volcanic rocks that make up most of the section. Red and green sandstone, grit, and shale are found with dark green diorite and grey felsite. Fletcher included felsite with the conglomerate, quartzite, banded slate, and argillite in his Bear Brook division. He included outcrops from Hopewell map-area in his discussions of both Baxter Brook and Bear Brook divisions.

Williams (1914, p. 53) proposed that the metamorphic rocks of the Antigonish Highland be divided into the Browns Mountain Group, which he subdivided into the James River and Baxter Brook Formations, and the overlying Malignant Cove Formation. The first two formations were equivalent to Fletcher's divisions and the name 'Malignant Cove' was applied to coarse conglomerates and grits northeast of Arisaig.

Bell (1940, p. 7) proposed the name Stewart Brook Formation for a few scattered outcrops of conglomerate, grit, and argillite at McLellan Mountain. He commented on the close lithological resemblance to the Malignant Cove Formation, with which he correlated it.

In place of the names 'Malignant Cove Formation' and 'Stewart Brook Formation' the author proposes retention of 'Bear Brook Formation'. This name should be applied to the flows and tuffs and the coarse sediments derived therefrom that underlie the Silurian Arisaig Group and overlie the laminated sediments and volcanic rocks of the lower part of the Browns Mountain Group.

Maehl (1960, pp. 83, 85) proposed the names 'Charcoal Formation' and 'Sunnybrae Formation' for flows and tuffs overlain by banded shales and slates exposed on Glencoe Brook. These names, however, seem unnecessary, for the section described is incomplete, the formational boundaries are vague, and the formations cannot be traced laterally.

It is probable that the interbedded sedimentary and volcanic rocks of the Antigonish Highlands that are exposed in Hopewell map-area belong to the James River Formation and, in part, to the overlying Bear Brook Formation. Continued examination of similar rocks exposed to the east (Benson, 1963) may suggest an alternative correlation, within the Browns Mountain Group.

In Hopewell map-area the Browns Mountain Group consists of intermediate to basic volcanic flows and tuffs and the sediments derived from these volcanic rocks. As the more prominent ridges and cliffs are underlain by fairly massive dark green andesite, this rock type appears to predominate. In the valleys of Glencoe Brook and Sam Cameron Brook, where discontinuous sections occur, there appear to be nearly equal amounts of andesite, agglomerate, and tuff, and fine- and coarse-grained sedimentary rocks derived from the volcanic rocks. It was not possible to determine the probable succession of these rock types. A minimum thickness of 2,500 feet is suggested for the rocks on Sam Cameron Brook. In Glencoe Brook the oldest rocks appear to be flows with a few pyroclastic beds, which are overlain by a tuffaceous sequence and in turn by interbedded fine-grained tuffs and laminated argillites. On Sam Cameron Brook more flow rocks occur near the top than near the bottom of the section and poorly sorted sediments are interbedded with the coarser grained pyroclastic rocks in the lower part. Most outcrops are slightly fractured, but cleavage is well developed only near the fault zones.

The more massive flow rocks are generally dark green with a few red patches and are in part coarse grained. They are generally andesitic, but owing to alteration the original composition is difficult to determine. The main constituent is plagioclase feldspar (andesine or oligoclase) occurring in lath-shaped crystals that are now altered to saussurite or sericite. Chlorite is fairly common, having completely replaced the mafic mineral or minerals, which were probably hornblende. Single flakes of biotite were seen in some thin sections. Minor carbonate occurs as vein material and as amygdules. Varying amounts of hematite occur as shapeless blebs and as crystals of specularite. Quartz grains are rare and do not constitute more than a fraction of one per cent of the rock. No pillows were observed, and evidences of flowage were seen only in thin section.

Andesite is associated with dark green tuffaceous rocks, and gradations between both types occur in the field area. The mineral composition of the tuff is similar to that of the andesite except for the presence of an unidentifiable fine-grained matrix.

The tuff beds grade into greenish grey, medium- to coarse-grained greywacke, and most of them are less than 10 feet thick. The greywacke consists of angular fragments of plagioclase, diabase, andesite, argillite, and tuff set in an argillaceous matrix. Near the headwaters of Sam Cameron Brook the greywacke is interbedded with fine pebble-conglomerate and agglomerate with the same type of rock fragments as the greywacke. In most outcrops these fragments are angular to subangular, but in one outcrop there are rounded fragments. These poorly sorted rocks are generally massive, and attitudes are difficult to determine.

Fine-grained sedimentary rocks are interbedded with the other rock types, but generally have sharp contacts. The most common rock type is laminated argillite. The argillite may be composed entirely of clay-sized material, in which case the laminae are due to colour differences, or the laminae may be caused by layers of silt-sized subangular quartz grains. Most samples contain angular to subangular quartz, altered plagioclase, chlorite, and specularite grains in a finer grained argillaceous matrix. Though most outcrops are greenish grey or grey, there are brownish grey, olive-grey, moderate brown, and black laminations.

Silurian

Arisaig Group

Most of the Arisaig Group outcrops along the shore near Arisaig Point, 30 miles northeast of the map-area. The first intensive study of these rocks was undertaken in 1900 by Ami, who stated (1900b, p. 179A):

> Having received instruction to describe and illustrate the fauna of the Silurian formation at Arisaig, Nova Scotia, the writer has begun his task by arranging the collections of Arisaig fossils already in the possession of the Geological Survey Department into natural formational divisions, ascribing certain faunas and strata to certain formations.

He divided the strata into "four series", "the Arisaig, McAdam, Moydart, and Stonehouse formations", based on "palaeontological as well as lithological characteristics" (Ami, 1900b, p. 180A). Ami did not, however, fix precise limits to these divisions. Twenhofel (1909, pp. 143-164) divided the Arisaig series into forty zones based on the character of the sediments, and these zones are grouped into four subdivisions equivalent to Ami's four series plus an underlying unnamed subdivision. Twenhofel (p. 146) found it difficult to fix palaeontological boundaries to these zones, for there is no sharp faunal break in the section except at the top of zone 12 (highest Clinton, beneath the McAdam Formation). Williams (1912, p. 245) named the two lower subdivisions and gave the following section:

	Feet
Stonehouse formation: red shale and limestone, argillaceous limestone and grey shale. Thickness (Twenhofel)	1,075
Moydart formation: the red stratum or red shale, argillaceous limestone and shale. Thickness (Twenhofel)	379
McAdam formation: black shale and argillaceous limestone. Thickness (Twenhofel) plus iron-zone	1,120
Ross Brook formation: green shale with thin sandstone, dark papery slate, etc. Obscure basaltic?, intrusive. Thickness (Twenhofel)	833
Beechhill Cove formation: sandstone, limestone and shale resting on aporhyolite flow and volcanic breccia. Thickness (estimated from width of outcrop)	200

This subdivision is still followed, with the exception of the addition by Maehl (1960) of the French River Formation above the Ross Brook. Maehl (1960, p. 36) believed that the French River Formation is present at Arisaig Point but is faulted out of the beach section. W. S. McKerrow (pers. com., June 1962), has confirmed the presence of these strata at Arisaig in outcrop away from the beach. The French River Formation was not recognized in Hopewell map-area.

Correlation of the Arisaig Group is of particular interest, as the fossils it contains bear greater resemblance to those of Europe than to those of North America. Hence the ages of the Arisaig beds are said to be Llandoverian, Wenlockian, Ludlovian, or Downtonian. There is controversy as to whether the Downtonian is Silurian or Devonian and thus, by implication, as to whether the Stonehouse Formation is Silurian or Devonian. This report accepts a Silurian age for the Downtonian. Maehl (1960, pp. 78, 96) found a lower Gedinnian (lowest Devonian) brachiopod fauna in the Stonehouse Formation near Forbes Lake and lower Llandoverian fossils in the strata of the Beechhill Cove Formation. The Arisaig Group thus spans the entire Silurian period and extends into the Lower Devonian, and is composed of five formations whose boundaries in the type section may be fixed on lithological differences.

Sedimentary rocks with lithology and fossils similar to those at Arisaig occur in Hopewell map-area, but the outcrop frequency and distribution is quite different, with the result that absolute comparison of exposed sections is not possible. At Arisaig Point, for instance, the entire Ross Brook Formation is observed, whereas on Glencoe Brook many of the less resistant beds are not well exposed.

The Arisaig Group in the map-area consists of fine-grained sediments whose lithology, structure, and fossil content suggest shallow-water marine deposition. The only good section is exposed on Glencoe Brook, and scattered outcrops occur elsewhere. It was not always possible to map the individual formations in Hopewell map-area even though all but the French River were recognized in some outcrop sections. Because of lithological similarities of some rocks found in all Arisaig formations it is not always possible to identify the particular formation present in isolated outcrops.

Maehl (1960) proposed that the Arisaig Group in southeastern Pictou county be divided into the Glencoe Formation, the overlying Kerrowgare Formation, and the upper Stonehouse Formation. The author, however, does not at present feel that the introduction of the 'Glencoe' and 'Kerrowgare' names is fully justified. On Glencoe Brook Maehl's Glencoe Brook Formation consists of both the Beechhill Cove Formation and the Ross Brook Formation. Maehl's Kerrowgare Formation is a poorly defined unit that includes all Silurian rocks not in the Glencoe Brook or Stonehouse Formations. The present report discusses such rocks under the heading 'Undivided Arisaig Group'.

Beechhill Cove Formation

The Beechhill Cove Formation on Glencoe Brook consists of about 80 feet of medium grey, fine-grained quartz wacke with an 8-foot bed of basal quartz-pebble conglomerate. This conglomerate unconformably overlies Browns Mountain greenish grey, laminated argillite. The strike on either side of the contact differs by only 5 degrees, and the dip differs by 20 degrees. On Sam Cameron Brook this contact is exposed in a small fault block, where there is a difference in strike and dip of about 40 degrees. In these limited exposures there is no channelling of the underlying surface or presence of other features to suggest a major unconformity.

The quartz wacke, which occurs in beds generally about a foot thick, is composed of silt to fine sand sized, subrounded quartz grains with minor altered plagioclase grains in an argillaceous matrix. Parts of the exposed section that are less well cemented may more correctly be termed mudstone. There are minor thin beds of quartzite.

Ross Brook Formation

The Ross Brook Formation has a minimum thickness of 550 feet as calculated from exposures on Glencoe Brook, where it conformably overlies the Beechhill Cove Formation. The basal 30 feet is light grey quartz granule conglomerate in beds from 1 foot to 4 feet thick interbedded with 6-inch beds of grey poorly cemented, coarse-grained quartz wacke. The base of the Ross Brook at Arisaig is characterized by laminated black shale, which is not found on Glencoe Brook. This conglomerate is overlain by 70 feet of medium to dark grey, medium- to fine-grained quartz wacke, siltstone, and silty shale. This lithology is continuous to the top of the section except for a few purplish grey beds, occasional beds of light grey, fine-grained quartzite, and a few tuffaceous lenses. Although the gross lithology is similar throughout the exposure on Glencoe Brook, most individual beds are less than 4 feet thick. On Sam Cameron Brook there are fewer quartzite beds and near the base of the section is found a dark grey to black, paper-thin, laminated shale. This shale may be the only true basal member of the Ross Brook Formation in the map-area, and if this is so the conglomerate on Glencoe Brook would represent minor local erosion, as it contains only quartz pebbles but no volcanic debris.

The only recognizable mineral constituents are quartz and minor altered plagioclase and muscovite. The rocks are highly fractured, and are veined with quartz and rarely with siderite. A few outcrops contain traces of specularite. Near the fault zone on Sam Cameron Brook two—occasionally three—fracture directions are visible.

The following fossils (identified by C. Harper, who assigned a Ross Brook correlation) are from a siltstone bed near the mouth of Sam Cameron Brook:

GSC loc. 45436: *Camarotoechia nucula* var. *planorugosa* McLearn
Tentaculites canadensis Ami
Eocoelia sp. cf. *E. hemispherica* (Sowerby)

GSC loc. 50912: *Leptostrophia* sp.
Protochonetes sp.
dalmanellid brachiopod
Fardenia sp.

On Cross Brook, 1,500 feet north of the map-area, grey siltstone and silty shale, similar to the siltstone and shale found in the map-area on the same brook, contain the following fossils (identified by C. Harper and assigned a Ross Brook correlation):

GSC loc. 45433: *Eocoelia* sp. cf. *E. hemispherica* (Sowerby)
dalmanellid brachiopod

McAdam Formation

Grey silty shale and shale, dark grey thinly bedded shale, and medium bluish to greenish grey siltstone of the McAdam Formation are exposed on the west branch of Blanchard Brook. Greyish red-purple, medium-grained, hematite-rich, quartz arenite is exposed in a field to the west of the brook, 2 miles to the northwest, and again at Websters 4½ miles farther north. This arenite was previously described as a "great iron bed" (Dawson, 1875, p. 130). It consists of rounded quartz grains about 50 per cent and hematite matrix 40 per cent, the remainder being carbonate and minor hornblende.

Individual beds in the shale and siltstone are generally less than one quarter inch thick. Quartz and minor feldspar are the identifiable detrital minerals.

The outcrop distribution of the quartz arenite outlines a large fold. No top determinations could be made in outcrops of the McAdam Formation, nor is this formation in observed contact with any other formation. The rocks that outcrop on McLellan Brook, however, are similar to rocks in the lower part of the Arisaig Group, and the fold is therefore interpreted as a plunging syncline.

The following fossils from the arenite bed northwest of the west branch of Blanchard Brook were identified by C. Harper as from zone "a" of the McAdam Formation:

GSC loc. 46443: *Meristina billingsi* (Dawson)
Cornulites serpularia Schlotheim
Leptaena sp. cf. *L. depressa* Hall

Moydart Formation

Several isolated outcrops of possible Moydart correlation are exposed between Springville and Bridgeville near the top of the hill. They are described as part of the undivided Arisaig Group.

Stonehouse Formation

Isolated exposures of the Stonehouse Formation are found north of MacLean Lake and north from there along a ridge. Nearly all Stonehouse outcrops examined are fossiliferous, though lithologies are varied. The most common rock type is a bluish grey to grey siltstone or very fine grained wacke. Reddish brown siltstone, grey calcareous siltstone, and minor light grey, fine-grained quartzite also occur. As in the other formations of the Arisaig Group, the recognizable constituents of these rocks are rounded grains of detrital quartz, minor plagioclase, and some calcite.

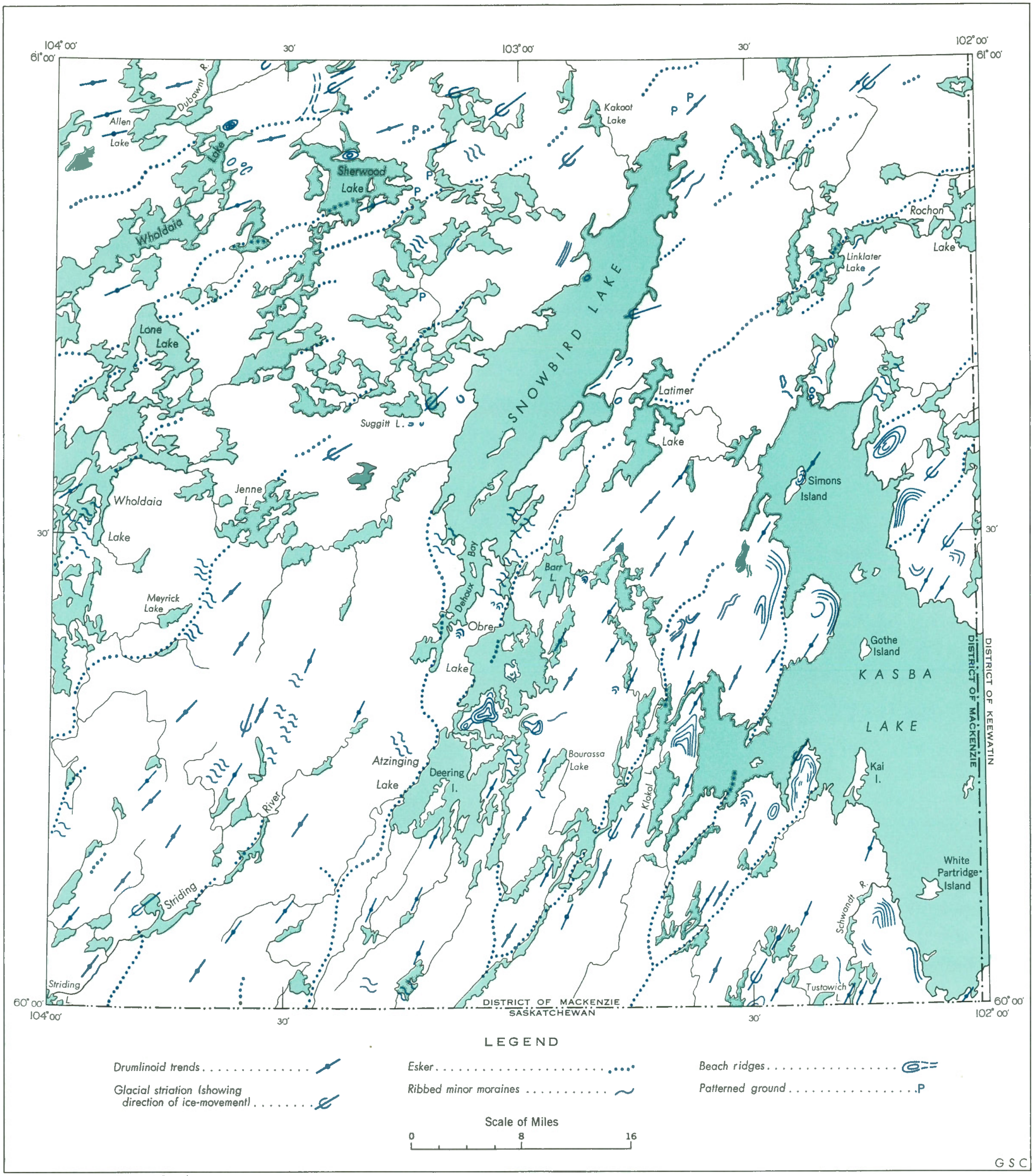

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Figure 1. Glacial and post-glacial features in Snowbird Lake map-area

The following fossils, which were collected from two separate areas, were all assigned a Stonehouse correlation. Except where noted, all these fossils were identified by C. Harper, of the California Institute of Technology.

MacLean Lake

GSC loc. 46444: *Calymene intermedia* var. *antigonishensis* McLearn
Pterinea honeymani (Hall)
Delthyris rugaecosta (Hall)
Protochonetes novascoticus (Hall)
Rhynchospirina sinuata (Hall)

GSC loc. 45434: *Macrypsilon salterianum* (Jones)
Hemsiella maccoyiana (Jones) (ident. by M. J. Copeland)
Protochonetes novascoticus (Hall)

GSC loc. 45435: *Neobeyrichia* (*Nodibeyrichia*) *tuberculata* (Kloeden) var. *strictispiralis*? (Jones)—ident. by M. J. Copeland
Pterinea honeymani (Hall)—ident. by L. M. Cumming

GSC loc. 45438a: *Pterinea gesneri* McLearn

Southeast of Forbes Lake

GSC loc. 46441: *Camarotoechia marklandensis* McLearn
Camarotoechia squamifera McLearn
Protochonetes novascoticus (Hall)

GSC loc. 46450: *Goniostropha aciculata* (Hall)—ident. by L. M. Cumming
Neobeyrichia (*Nodibeyrichia*) *pustulosa* (Hall)—ident. by M. J. Copeland

GSC loc. 45432: *Proschizophoria* sp.
Lingula sp.
fish plates—probably from a Pteraspid—ident. by L. M. Cumming

Undivided Arisaig Group

Most of the Arisaig Group may be present along the hillside between Charcoal and Springville. North of Charcoal there are outcroppings of light grey, fine-grained quartz wacke and siltstone similar to interbeds of the Beechhill Cove and Ross Brook Formations. Fossils were found in frost-heaved rubble immediately adjacent to outcrop with the same lithology. A single pelecypod (*Pterinea*) was also found in outcrop. The following fossils were identified by C. Harper, who assigned a Glencoe or Beechhill Cove Formation correlation.

GSC loc. 46445: *Eostropheodonta beechhillensis* (McLearn)
Atrypinid, n. gen. et sp.
Pterinea sp. cf. *P. honeymani* (Hall)
Bucanella sp. cf. *B. trilobata* (Conrad)
Liospira sp.

Dark grey to black laminated shale similar to that found in the Ross Brook Formation outcrops on the small brook east of Corrimony road. Minor dark reddish brown, ferruginous shale that outcrops in a small brook west of Corrimony road may be within the McAdam Formation. Light greenish grey, fine-grained wacke with a few narrow (¼-inch) brownish grey fossiliferous beds is exposed near the top of the ridge between Bridgeville and Springville. Harper assigned the following brachiopods to the Moydart Formation.

GSC loc. 46440: *Sphaerirhynchia staffordi* (Hall)

A few feet farther north, bluish grey siltstone resembling Stonehouse strata outcrops. The following fauna from the siltstone was identified by C. Harper, who assigned a Stonehouse or uppermost Moydart correlation:

GSC loc. 46439: *Howellella moydartensis* (McLearn)
Delthyris rugaecosta (Hall)
Homalonotus dawsoni (Hall)
Atrypa sp.

A small outcrop of grey siltstone on Holmes Brook contains fossils, with possible McAdam correlation, which were identified by C. Harper.

GSC loc. 45438: *Sphaerirhynchia obtusiplicata* (McLearn) *non* Hall

No reliable attitude determinations were made in this area, but a general northwestward strike with a southwest dip is suggested. Thus strata from the entire group may be present, but because of limited exposure they are mapped as undivided Arisaig Group.

Medium to dark grey shale, siltstone and laminated shale, suggestive of the Ross Brook Formation, outcrop on McLellan Brook west of Websters. At Brookville a single fossil, identified by C. Harper as correlative with the Beechhill Cove Formation, was found in quartz wacke within a fault zone.

GSC loc. 45437: Atrypinid, n. gen. et sp.

To the south and east of the McAdam Formation there are very few outcrops, but the lithology suggests Moydart and Stonehouse rocks. The two areas, separated by the McAdam Formation, are shown as undivided Arisaig Group. A small area of medium to dark grey silty shale and shaly siltstone on Blanchard Brook at Sunnybrae is also assigned to the undivided Arisaig Group. The only fossil that was identified by C. Harper is found from the Ross Brook to Stonehouse Formations.

GSC loc. 45439: *Atrypa* sp. cf. *A. reticularis* (Linnaeus)

Devonian and Earlier (?)

Light grey, medium- to coarse-grained granite has intruded the Meguma rocks near the southern margin of the map-area. The scarcity of outcrop in areas underlain by this granite has concealed most of its contacts with the surrounding rocks. Because of this, the areal extent of the granite shown on the accompanying geological map is outlined mainly on the basis of the distribution of large frost-heaved boulders and the configuration of the aeromagnetic map (GSC Map 762G, 1960).

The effects of contact metamorphism of the intruded Meguma rocks are shown mainly by the development of andalusite and biotite schist in the Goldenville Formation. Near the mouth of Gorman Brook narrow pegmatite dykes intrude Goldenville quartz-muscovite schist and phyllite. The pegmatite varies in composition from a quartz-rich facies to a schistose biotite- or muscovite-rich facies. Small (1 mm) garnet crystals are developed in the phyllite near a gneissic dyke. The Lower Carboniferous Horton sedimentary rocks that outcrop north of the granite have not been affected by the granite, but granite boulders are common in the conglomerate of the Horton Group; thus the granite is dated as post-Ordovician (Goldenville Formation) and pre-Lower Carboniferous.

Fairbairn (1960, p. 408) measured an age of 380 million years (Devonian) by the K-Ar method on biotite and muscovite from granite that outcrops on the road through the Liscombe Game Sanctuary just south of the map-area. The granite he sampled is part of a large pluton, a small part of which outcrops in Hopewell map-area.

The granite is generally medium grained and hypidiomorphic granular with about 90 per cent quartz and feldspar. The quartz is colourless and rarely has inclusions. The feldspar, which may be slightly altered to sericite, is white to light grey orthoclase and albite. Variations in the composition of the granite are not common. In a sample from the small body on West River St. Mary's, however, the albite and orthoclase are in about equal amounts, which may be the result of assimilation of the intruded Meguma rocks. Muscovite is more common than biotite and both rarely constitute more than 10 per cent of the rock. The mica cleavage flakes are slightly bent in the coarser grained granite, and some of the mica has been altered to chlorite.

West of Lorne, two outcrops of granitic rock that are probably part of a single body appear to be outliers within the younger Carboniferous sediments. The apparent shape of the pluton is indicated by a small 'high' on the aeromagnetic map (GSC Map 762G, 1960).

A concentration of large angular boulders of dark green amphibolitic hornfels about 800 feet east of the Lorne railway crossing suggests the presence of this rock in outcrop beneath the overburden. The rock consists of hornblende and labradorite with accessory pyrite, sphene, calcite and magnetite cut by scapolite veins. This mineralogy could result from the metamorphism of a basic volcanic rock such as the andesite that occurs in the Browns Mountain Group. Thus it is thought that the Lorne granite has intruded the Ordovician volcanic rocks and is therefore post-Ordovician. As it is lithologically dissimilar to the Devonian granite to the south and is gneissic, the Lorne granite is thought to be older than the Devonian granite. On Big Brook, poorly consolidated Carboniferous granule conglomerate contains weathered grains of possible granitic origin. Light brown unaltered Windsor limestone outcrops nearby and is probably underlain by the granitic rocks. The granitic rocks are therefore regarded as pre-Carboniferous and are possibly related to the granite and granodiorite of the Antigonish Highlands (Benson, 1963).

The pink and green gneissic granite that outcrops near the Lorne cemetery is composed of milky quartz, pink kaolinized feldspar, dark green mafic minerals (almost entirely altered to chlorite) and minor apatite, specular hematite, and calcite. However, the granite that outcrops three quarters of a mile to the north, though mineralogically similar, is an equigranular rock that shows no effect of deformation.

Lower Carboniferous

Horton Group

The Horton Group, as first described by Bell (1929, pp. 30-45) consists of the Horton Bluff and the Cheverie Formations. Neither of these has proven to be mappable on a regional scale (Weeks, 1948, p. 15; Stevenson, 1958, p. 21). At the type section, near Windsor, Nova Scotia, the Horton Bluff is unconformable upon granite and Meguma rocks and is disconformably overlain by the Cheverie. The Horton Group is sparsely fossiliferous and the floras were correlated (Bell, 1960, pp. 14-17) with the Tournaisian part of the Lower Carboniferous of Europe and the Pocono flora of the Mississippian of North America. The Carboniferous fossils from Nova Scotia are generally more easily correlated with European than with North American forms.

On Cape Breton Island there is a good Horton section along Southwest Mabou River, which Murray (1955, p. 16) divided, from top to bottom, into the following three conformable formations: "Ainslie Formation—red and non-red fine to coarse clastics, Strathlorne Formation—entirely non-red fine clastics with thin limestones, Craignish Formation—red and non-red medium and coarse clastics". Kelley (1957) divided the Horton Group in Baddeck map-area into lower, middle, and upper parts, and later (1958, p. 177) used the names proposed by Murray for these divisions.

To the west of Hopewell map-area, Stevenson (1958, p. 21) was not able to subdivide the Horton Group stratigraphically, though he described the lithology in four separate parts. These are:

1) light grey to reddish brown feldspathic grit, sandy shale, and siltstone;
2) light grey, fine-grained arenaceous shale and minor calcareous sandstone;
3) light to dark grey shale and siltstone; and
4) chocolate-brown and green shale, arkosic grit and grey to maroon sandstone.

Similar rocks are found in Hopewell map-area, where they fit into three distinct lithological units characterized by:

a) light grey arenite and siltstone;
b) light to medium grey shale and siltstone; and
c) red and greenish grey mudstone and siltstone.

These units can be traced to the east, into Lochaber map-area (Benson, 1963). Their contact relations were not observed. If the sequence, which is suggested by outcrops on Pembroke and Stewiacke Rivers, is true, then these units in the above order may be correlative with the Craignish, Strathlorne, and Ainslie Formations.

The contact relations of the units in Hopewell map-area are in doubt but further study to the east may suggest adoption of these formational names.

The Horton sediments, which may have been derived from the Meguma massif to the south, were deposited in an east-west basin. The basal unit was deposited mainly near the source area and was then overlain by unit "c" and farther north by unit "b". Later folding resulted in the present outcrop distribution.

Bell (1960, p. 2) measured Horton sections along the coast near Windsor, and gave thicknesses of 3,500± feet for the Horton Bluff and 625+ feet for the Cheverie. In Truro map-area, Stevenson (1958, p. 21) gave a minimum thickness of 4,000 feet, which was determined from several incomplete sections. At the type section in Cape Breton Island the following thicknesses were measured (Murray, 1960, p. 11): Craignish Formation, 5,130 feet; Strathlorne Formation, 1,050 feet; and Ainslie Formation, 1,820 feet. No complete sections occur in Hopewell map-area, and most observed sections are cut by many small faults. The following thicknesses are based on many small sections whose relations to each other are commonly in doubt: unit "a", 2,000 feet; unit "b", 3,000 feet; and unit "c", 1,700 feet.

In his thesis on the Horton Group of the western half of the map-area, Smith (1962) used the same data as were available to the writer. He used units for his Horton subdivisions, regarding Unit "A" (unit "b" of this report) as the oldest (Smith, 1962, p. 20), Unit "B" (unit "a" of this report) as partly equivalent to Unit "A" and partly overlying it (p. 46), and Unit "C" (unit "c" of this report) as overlying both Unit "A" and Unit "B". This interpretation was formerly held by the writer (Benson, 1962).

Unit "a"

The best exposures of unit "a" in Hopewell map-area are on Pembroke and Stewiacke Rivers, and in the barrens near McKinnon Lake (Pl. V), where the unit consists of well-indurated grey siltstone and sandstone.

The contact between unit "a" and the overlying unit "b", which is probably conformable, is taken as the top of the highest coarse-grained sandstone bed. On Pembroke and Stewiacke Rivers, where these two units are in closest proximity, the beds are overturned. The beds on both sides of the contact dip steeply, and on first examination unit "b" was thought to underlie unit "a". The contact of unit "a" with unit "c" was not observed but was arbitrarily drawn at the base of the first red bed above which red beds comprise more than 50 per cent of the unit. In most places this contact is the base of the first red bed, as true red beds are rare in unit "a".

The most common rock type in the exposed sections is light to medium grey, medium- to coarse-grained sandstone. In one location, however, in the barrens, an interbedded section 600 feet thick consisted of 100 feet of sandstone and 500 feet of fine-grained grey siltstone and shaly siltstone. A few minor lenses of red siltstone and sandstone are interbedded with the grey sandstone in some sections. The sandstone layers are about 20 feet thick and are separated by thinly bedded, finer grained sediments with aggregate thicknesses of up to 100 feet. Individual sandstone beds are generally about 1.5 feet thick, though beds from a few inches to 5 feet thick are

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PLATE V. Outcrops of Horton unit "a" arenite on barrens near McKinnon Lake and intervening covered areas underlain by siltstone.

common. A few sandstone beds seem to fill old channels in the underlying rocks and are of limited areal extent, but in outcrops in the barrens there are no visible lateral changes in the thickness and composition. Crossbedding is common, and minor graded bedding is visible in a few outcrops.

The sandstone varies from wacke on Pembroke River to arenite on Stewiacke River and farther to the east. It is composed of subrounded to subangular mineral grains with an interstitial matrix of mica and clay minerals. More than 60 per cent of the rock is generally quartz, and some arenite contains about 90 per cent quartz. The quartz shows minor undulatory extinction, and a few trains of inclusions. No recrystallized or rounded grains were observed.

The remaining detrital grains are feldspar and a few rock fragments. Staining did not show the presence of any potash feldspar. Almost all feldspar is twinned sodic plagioclase, which is altered to kaolin. Owing to complete removal of the feldspar most weathered surfaces are pitted, and owing to its alteration many fresh surfaces show only white clay-like minerals. The rock fragments are phyllite and slate, which are similar to the Meguma rocks. The wacke matrix is composed of very fine grained clay minerals with a few cleavage flakes of muscovite. A few narrow veinlets and small grains of carbonate in the wacke are thought to be due to post-deposition processes. A few veins of siderite cut the wacke on Sucker Brook.

The medium to dark grey siltstone and shaly siltstone occur in beds from a fraction of an inch to 5 feet thick, though the average thickness is about 4 inches. Crossbedding on a small scale was found in a few siltstone beds, but graded bedding is rare. Though the intervening arenite beds rarely show evidence of deformation, cleavage and fractures are common in the shaly siltstone. The mineralogical composition is similar to that of the sandstone except for a greater amount of clay matrix. Plant fragments were found in a few of the darker beds. Mica, mainly muscovite, may amount to as much as 2 per cent and is generally aligned parallel to the bedding, with the result that most bedding surfaces have a micaceous sheen.

On Pembroke and Stewiacke Rivers there are limited occurrences of pebble conglomerate and conglomeratic sandstone. These rock types are wackes with varying amounts of medium-grained or smaller pebbles. The pebbles are of grey greywacke, phyllite, and quartz wacke, and lesser quartz and black slate. The quartz pebbles are equidimensional, whereas the other pebbles are flat and elongate.

The narrow band of unit "a" sediments near the headwaters of Stewiacke River is interpreted as forming a small fold, which is exposed through erosion of the overlying unit "b" sediments. The outcrops are light grey coarse-grained quartz arenite and wacke and could be interpreted as a beach or bar deposit within unit "b".

Correlation with the Craignish Formation of Cape Breton (Kelley, 1958, p. 177) is on the basis of lithology and the relation to adjacent shale containing known Horton fossils. Unit "a" has been recognized 25 miles east of Hopewell map-area (Benson, 1963) and probably extends even farther to the east. In Truro map-area (Stevenson, 1958) to the west and in the Horton type section near Windsor, coarse-grained sandstones of similar type occur in the lower part of the Horton section.

Unit "b"

Good outcrop sections of unit "b" are on Sutherland Brook, Big Stewiacke River, West Branch of East River of Pictou, and McDonald Brook. As outcrops are generally widely separated and show varying evidences of folding and faulting, no thick section could be measured. A thickness of about 3,000 feet is tentatively given on the basis of sections on Pembroke and Stewiacke Rivers.

The basal contact with unit "a" has been discussed in the section on unit "a". The northern extent of unit "b" is limited by two main faults. The evidence for the fault separating Riversdale and Horton strata is the presence of a shear zone in the Riversdale strata on the lower part of Calvary Stream and the slightly different attitudes and lithologies near the fault zone. The fault separating the Horton and Windsor or Canso strata is more easily located owing to the greater contrast of the rock types and evidence of intense shearing. The Canso-Horton contact is marked by a narrow valley for about 6 miles.

An interesting section is exposed about 500 feet upstream from the mouth of Little Stewiacke River (*see* Fig. 1). This outcrop, though only 80 feet long, displays seven fold axes and seven faults and shows the intense folding that affected the sediments. The writer was thus cautioned against attempting structural interpretations based on widely separated small outcrops. Most outcrops of unit "b" in the map-area display cleavage and are moderately to highly folded.

The main rock types of unit "b" are dark grey to black shale and siltstone and minor medium grey, fine-grained wacke, but gradations between these types are common. The coarser grained rocks are generally of a lighter grey than the shale.

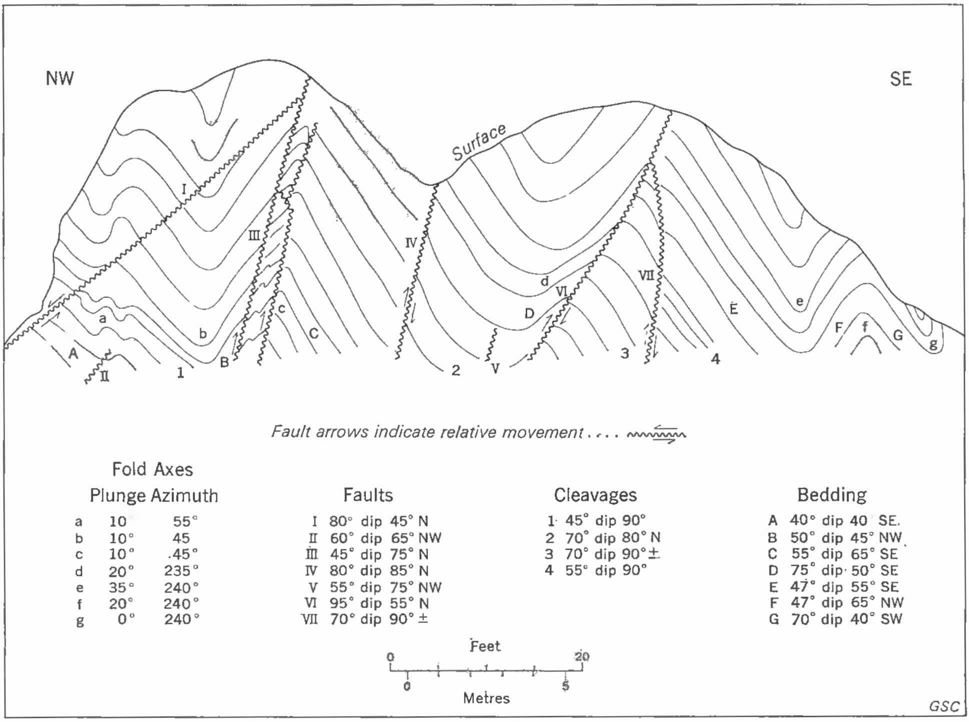

FIGURE 1. Folded and faulted Horton Group cross-section at mouth of Little Stewiacke River.

Most of the rocks contain considerable argillaceous matrix. Mica is commonly concentrated along the bedding planes but is readily visible only on a fresh surface. The shale and siltstone are generally finely laminated because of alternating laminae, about $1/16$ inch thick, of siltstone, silty shale, and shale. Beds in the wacke are more massive and are generally from 1 inch to 2 feet thick. It was not possible to trace any bed more than a few feet along strike. Crossbedding is common in many outcrops, and ripple-marks and small scale channelling are found in a few places.

About 75 per cent of the siltstone and sandstone is composed of angular to subangular quartz grains. Most grains show undulatory extinction and some have tiny inclusions. Other important detrital grains are feldspar and rock fragments. The feldspar, which is mainly twinned sodic plagioclase, occurs as subangular laths that are often altered to clay minerals. Shale, phyllite, and greywacke make up most of the rock fragments. The shale fragments are probably locally derived. The muscovite grains are generally bent laths of detrital origin. Detrital chert and chlorite are rare constituents. The matrix content ranges from 10 to 30 per cent, the higher values being from the siltstone. The matrix is mainly clay minerals, but in the coarser wacke a few quartz grains are found in it. Ferruginous and carbonaceous material are locally found in the wacke matrix.

Minor irregular crystal aggregates of carbonate are regarded as due to replacement. Some of the carbonate is associated with iron oxide and may be siderite or ankerite.

Several boulders of dark green amygdaloidal basalt associated with outcrops of unit "b" sediments were seen on Big Stewiacke River about 1.5 miles from its mouth. No basalt was found in outcrop. Although they may have come from volcanic members of the Horton Group, the boulders are more likely glacial erratics derived from Ordovician rocks. Schiller (1961) suggested that in the Guysborough map-area volcanic rocks might be interbedded with Carboniferous sediments.

The unit "b" lithology in Hopewell map-area compares favourably with that of the Strathlorne Formation, in central Cape Breton Island (Kelley, 1958, p. 177). Fragmentary plant remains were found in many outcrops, but only a few contained identifiable fossils. The following fossils were identified by W. A. Bell and M. S. Barss, of the Geological Survey of Canada and assigned a Horton Group correlation:

GSC loc. 5637: *Vallatisporites* sp.
GSC locs. 5630, 5665, 5664: *Lepidodendropsis corrugata* (Dawson) Bell
GSC loc. 5630: *Lepidodendropsis* sp. A Bell
GSC loc. 5632: *Lepidodendropsis* sp. B Bell
GSC loc. 42031: *Eoleaia leaiaformis* (Raymond)
Leaia sp.
Euestheria lirella Bell

M. J. Copeland indicated the following possible identification of a Horton species:

GSC loc. 57580: *Euestheria lirella* Bell 1960

Unit "c"

The best exposures of this unit are on Pembroke River and the lower part of West River St. Mary's. These sections, as are most exposures of unit "c", are characterized by red sediments.

Basal conglomerate is exposed along West River St. Mary's near the contact with the underlying Meguma rocks. This conglomerate and nearby outcrops of finer grained Horton sediments are only slightly deformed. The Horton-Meguma contact is an angular unconformity with a discordance of about 50 degrees. The Meguma rocks at the contact probably mark the edge of a fault scarp with pre-Carboniferous movements. The distribution of the Horton conglomerate suggests that the movement was greatest to the east. The contact between unit "b" and unit "c" is not visible, but the outcrop attitudes suggest a conformity. Unit "c" is overlain by calcareous Windsor sediments in the southwest corner of the map-area.

Unit "c" consists of interbedded quartz wacke, siltstone, mudstone, conglomerate, and greywacke that varies in colour from light grey to greenish grey to greyish red. These beds generally contain more mica than the older Horton sediments; the mica is locally in large (¼-inch) plates. On Pembroke River about one third of the beds are grey and the other two thirds are red. To the east, in the vicinity of West River St. Mary's, about half the beds are fine grained and grey, a quarter are fine grained and greyish red, and the remaining quarter are red and grey conglomerate.

The contact between the red and grey beds is generally sharp in the coarser sandstone, and gradational in the siltstone and mudstone. The greywacke displays the more massive beds, which are from 1 foot to 4 feet thick with well to poorly defined bedding planes. The fine-grained, grey siltstone may be laminated or thinly bedded with individual beds from $1/16$ to 1 inch thick. The bedding surfaces are often marked by mica. The greyish red siltstone, though it also has considerable mica, is in blocky beds from 1 foot to 2 feet thick. The greyish red mudstone is commonly highly fractured and bedding surfaces are only rarely seen. The conglomerate sections are from 10 to 15 feet thick, though there are a few poorly defined beds about 2 feet thick.

Unit "c" is less well indurated than the other Horton rocks. The grey quartz wacke and siltstone have compositions similar to those of unit "a" and unit "b" except for a higher matrix content. The coarse-grained greywacke has Meguma-type black slate fragments plus a few wacke fragments of probable Horton origin. The red sediments derive their colour from iron-stained clay minerals and minor grains of hematite in the matrix. The conglomerate exposed along West River St. Mary's is poorly sorted and contains fragments from granule to boulder size. In some places the boulders consist entirely of granite, and in others of granite, quartzite, and quartz wacke. The cobbles and pebbles are black slate, phyllite, and medium greenish grey quartz wacke. The granules and matrix are arkosic or argillaceous and the matrix commonly contains mica books.

The red and grey sediments comprising unit "c" in Hopewell map-area are lithologically like those in Cape Breton, described by Kelley (1958, p. 178). Fossils were found only in the grey beds in the map-area. These plant fossils, which were fragmentary remains, were tentatively identified by W. A. Bell, who said that the assemblage is found throughout the entire Horton Group.

GSC loc. 5635: *Lepidophyllum fimbriatum*? Jongmans, Gothan and Darrah
estherioid (?) shell

Poorly preserved spores, which were recovered from dark grey sandy shale exposed on West River St. Mary's about a mile west of the mouth of Upper Bryden Brook, were identified by M. S. Barss, who indicated an age equivalent to that of the Cheverie Formation in the type section.

GSC loc. 5757: *Spinozonotriletes* sp.
Convolutispora spp.
Punctatisporites spp.
Calamospora sp.
Pustulatisporites pretiosus Playford
Endosporites micromanifestus Hacquebard
Verrucosisporites congestus Playford
Cyclogranisporites commodus Playford
Reticulatisporites cheveriensis Playford
Dictyotriletes submarginatus Playford
cf. *Perotriletes perinatus* Hughes and Playford
Punctatisporites limbatus Hacquebard

Windsor Group

Bell (1929, p. 45) used the name "Windsor series" to refer to Carboniferous marine sediments in the Windsor region of Nova Scotia. He divided these beds into two main faunal zones, which are further divided into five subzones:

(1) Upper Windsor—zone of *Martinia galataea*
  Subzone E—characterized by *Caninia dawsoni* and *Chonetes politus*
  Subzone D—characterized by *Productus semicubiculus*
  Subzone C—characterized by *Dibunophyllum lambii* and *Nodosinella priscilla*

(2) Lower Windsor—zone of *Composita dawsoni*
  Subzone B—characterized by *Diodoceras avonensis*
  Subzone A—basal limestone

The Windsor strata in the Antigonish region (Sage, 1954) and in Cape Breton (Stacy, 1953) have also been subdivided into these faunal zones.

In Londonderry and Bass River map-area, northeast of Windsor, Weeks (1948, pp. 19-27) differentiated the upper and lower Windsor and subdivided the lower Windsor into five "formational units". Stevenson, in Truro (1958, pp. 25-41) and Shubenacadie and Kennetcook (1959a, pp. 18-30) map-areas, described the Windsor Group under the following divisions: Macumber Formation, Pembroke Formation, lower Windsor, upper Windsor, and undifferentiated Windsor. Although Weeks and Stevenson were able to correlate with the Windsor as outlined by Bell, and although certain of the formations used by them are partly equivalent to Bell's faunal zones, they were not able to use the faunal zones as an aid to mapping.

In Hopewell map-area the Windsor Group was divided lithologically into lower Windsor unit, which is mainly limestone, gypsum, and anhydrite; and upper Windsor unit, which is mainly calcareous shale. Because of limited exposure in the southwest corner of the map-area, the strata are shown as undivided Windsor. Fossils from the map-area were identified by W. A. Bell and are generally those of subzones E, B, and C.

The fauna from the Windsor Group in the type area is correlative with the Viséan (upper Lower Carboniferous) of Europe and the Chester (Upper Mississippian) of North America (Bell, 1929, p. 56). The Windsor fauna very clearly shows an European affinity, but a great contrast with that of the interior of North America (Bell, 1929, pp. 62-74). It would therefore be more logical to say that the Horton and Windsor Groups are Lower Carboniferous than to continue referring to them as Mississippian. For this reason the Table of Formations in this report shows the limits of both Mississippian and Lower Carboniferous.

Lower Windsor

The lower Windsor strata unconformably overlie the Ordovician-Silurian complex. The contact was observed on Holmes Brook and the presence of residual limonite deposits at the Silurian-Windsor contact near Bridgeville confirms an erosional period. Dips are generally less than 30 degrees in the Windsor rocks, whereas the

Silurian rocks commonly dip at an angle of more than 45 degrees. A thickness of 800 feet for the lower Windsor strata is estimated from meagre evidence.

Near the Ordovician-Silurian complex the overlying Windsor rocks are mainly limestone. This limestone varies from a light grey to brownish grey argillaceous variety to black massive limestone. The limestone commonly includes calcite veins, and iron-bearing dolomite, barite, and malachite are found in an old quarry near Springville. Small outliers of limestone occur in Holmes Brook. The map of the area by Fletcher (1902) shows numerous occurrences of limestone north of Springville, some of which were seen by the author. At Black Rock, greenish grey pebble limestone conglomerate, greyish red calcareous mudstone, and edgewise limestone conglomerate outcrop in East River of Pictou. White to light grey gypsum and anhydrite appear to overlie these rock types. In the extensive outcrops south of Bridgeville one cliff of anhydrite is capped by greyish red calcareous wacke. Gypsum is exposed in many of the sink holes south of Forbes Lake. Several small depressions on the southwest side of West River of Pictou upstream from Springville may be sink holes. The gypsum and anhydrite appear to be interbedded with light grey calcareous siltstone.

Fossils found in the limestone quarries at Springville and Black Rock were identified by W. A. Bell as being probably from Windsor subzone B. They consist of the following two species:

GSC locs. 45447 and 45452: *Dielasma latum* Bell
Serpula annulata (Dawson)

In the southwest corner of the map-area, the lower Windsor strata are in contact with both Horton and Meguma rocks. On Cox Brook at the Windsor-Meguma contact and in isolated outcrops upstream, red pebble-conglomerate unconformably overlies greenish grey Meguma greywacke (Pl. I). Most of the pebbles are small, flat fragments of slate or greywacke. Similar conglomerate is found on Scrub Grass Brook, Fulton Brook, and Spring Brook, and also on Bentley Brook where it appears to overlie red Horton mudstone. Structural evidence suggests that the conglomerate is overlain in most places by gypsum and anhydrite, which outcrop nearby. There is no discordance between adjacent Windsor and Horton sediments, and this contact is postulated to be a minor disconformity. No estimate could be made of the thickness of lower Windsor sediments in this area.

On Bentley Brook and south of Eastville the gypsum-anhydrite outcrops in cliffs up to 120 feet high. Near Eastville a small brook flowing in front of the cliff begins at the head of a steep valley with walls about 100 feet high. The valley wall forms part of the side of a large sink hole about 500 feet across, the centre of which appears to be slightly below the valley floor. Samples from four outcrops were examined by X-ray diffractometer. In one outcrop on Stewiacke River, white, pure gypsum overlies light grey to white anhydrite containing about 15 per cent gypsum. Another outcrop, about 1,000 feet downstream, is composed of light grey anhydrite with no detectable gypsum. Samples of the white to light grey gypsum exposed on Bentley Brook contain less than 10 per cent anhydrite. Generally the anhydrite can be recognized in the field by its greyish colour and the fact that it is more resistant to weathering than the gypsum. The areal extent of the gypsum and anhydrite is shown by the presence of sink holes.

The basal Windsor conglomerate on Bentley Brook is overlain by grey dolomitic limestone. To the west the lowest observed Windsor unit is medium to dark grey argillaceous limestone with alternating highly fossiliferous and massive beds. Black fossiliferous argillaceous limestone is exposed east of Stewiacke River. Fossil assemblages from these areas have been assigned to subzone B by W. A. Bell.

GSC loc. 42029—½ mile north of Pembroke:

Composita dawsoni (Hall and Clarke)
Composita windsorensis Bell
Dielasma latum Bell
Pugnax dawsonianus (Davidson)
Leptodesma acadica (Beede)
Murchisonia abrupta Bell

GSC loc. 46454:

Fenestella lyelli Dawson
Batostomella exilis (Dawson)
Batostomella abrupta Ulrich
Linoproductus lyelli (Verneuil)
Diaphragmus tenuicostiformis (Beede)
Composita dawsoni (Hall and Clarke)
Composita windsorensis Bell
Spiriferina verneuili Bell
Dielasma latum Bell
Parallelidon dawsoni Beede
Leptodesma dawsoni (Beede)
Naticopsis howi Dawson
Straparollus minutus de Koninck
Orthoceras vindobonense Dawson
Diodoceras avonensis (Dawson)

Upper Windsor

Upper Windsor strata outcrop in generally low-dipping, moderately deformed beds. The best exposures in the northern part of the map-area are on East River of Pictou and its West Branch. The basal contact is placed below the lowest section, which is more than one quarter shale. An approximate minimum thickness of 1,100 feet was calculated between fold axes on East River of Pictou.

Exposed sections are mainly red, fine-grained clastic sediments except in a few places on East River of Pictou where argillaceous limestone is more common. Examples of these two lithological suites are as follows:

1) Overburden	*Feet*
Brownish grey, slightly calcareous siltstone	10
Medium grey, fine-grained wacke	15
Brownish grey, fractured calcareous mudstone	2
Grey fractured mudstone	5

	Feet
Brownish grey and greenish grey siltstone	15
Brownish grey, fractured calcareous mudstone	25
Overburden	
2) Overburden	
Medium grey, argillaceous limestone	12
Medium grey, calcareous siltstone	6
Light grey, argillaceous limestone	2
Medium grey, calcareous siltstone	6
Medium grey, argillaceous limestone with two beds (2′) light grey oölitic limestone	15
Medium grey, fine-grained calcareous wacke	8
Overburden	

The most common rock type is brownish grey, slightly calcareous mudstone with patches that are mottled purplish and greenish grey. The beds are generally massive, but minor finely divided mica is sometimes found on the bedding planes. Many of the mudstone beds are highly fractured. The mudstone is generally associated with brownish grey siltstone and silty shale that varies from slightly calcareous to very calcareous.

Medium grey to black argillaceous limestone, commonly veined with calcite, occurs in sections up to about 20 feet thick. Individual beds are 2 to 3 feet thick, though more massive beds are found. Most of the fossils were found in medium grey argillaceous limestone or adjacent beds of grey calcareous shale. One outcrop at Hopewell has a trace of pyrite occurring as cubes plus very rare malachite staining thought to be due to weathering of chalcopyrite. No chalcopyrite was seen at Hopewell, but tiny blebs of possible chalcopyrite were seen in grey limestone interbedded with black calcareous shale on East River of Pictou near Eureka. Three 2-foot beds of grey pebble-conglomerate were distinguished near Hopewell on West Branch East River of Pictou. Rounded limestone and calcareous shale fragments comprise most of the pebbles. Light brown crystalline limestone is exposed north of Lorne in some old pits. Limestone was formerly quarried near Marshdale, but the extent of the work is not visible at present.

Minor amounts of grey and greenish grey clastic sediments, which are generally coarser grained than the red sediments, are interbedded with them. Calcareous siltstone and fine-grained wacke predominate. Rounded grains of quartz and feldspar and flakes of mica are easily recognized in some wacke beds.

Single outcrops of medium grey arenaceous dolomite and dolomitic mudstone, as well as dark reddish brown calcareous conglomerate, occur on East River of Pictou.

Several fossil collections from subzone E were identified by W. A. Bell as follows:

GSC loc. 45275—West Branch, ¼ mile above mouth of Big Brook:

Composita windsorensis Bell
Camarotoechia atlantica Bell
Ambocoelia acadica Bell
?*Buxtonia cogmagunensis* Bell
Conularia? sp.

GSC loc. 45276—Big Brook, 2 miles from mouth:
Productus spinocardinata? Bell
?*Buxtonia cogmagunensis* Bell
Linoproductus lyelli (Verneuil)
Productus avonensis Bell

GSC loc. 45277—Big Brook, ¾ mile from mouth:
Linoproductus lyelli (Verneuil)
Productus avonensis Bell
Camarotoechia atlantica Bell
Pugnoides? sp.
Pugnax? sp.
Schizodus sp.

GSC loc. 45441—East River of Pictou, 3,800 feet below Springville bridge:
Schuchertella pictoense Bell
Martinia galataea Bell
Ambocoelia acadica Bell

GSC loc. 45442—East River of Pictou, 3,200 feet below Springville bridge:
Schuchertella pictoense Bell
Camarotoechia atlantica Bell
Bucanopsis beedii Bell

GSC loc. 45443—East River of Pictou, 2,500 feet below Springville bridge:
Sanguinolites niobe Bell

GSC locs. 45445 and 46453—East River of Pictou, 1,000 feet north of Springville bridge:
Schuchertella pictoense Bell
Linoproductus sp.
Camarotoechia? sp.

GSC loc. 45451—East River of Pictou, 7,000 feet north of Springville bridge:
Linoproductus lyelli (Verneuil)
Diaphragmus tenuicostiformis (Beede)
Camarotoechia atlantica Bell
Bucanopsis beedii Bell
Schizodus sp.

Three other collections, which gave less definite results, were also examined by W. A. Bell:

GSC loc. 45446—1,000 feet southwest of Marshdale. Probably subzone C or D:
Linoproductus lyelli (Verneuil)
Edmondia hartti Dawson

GSC loc. 45448—East River of Pictou, 6,000 feet south of Eureka. Probably subzone C, D, or E:
Edmondia sp. cf. *E. rudis* McCoy
Bucanopsis beedii Bell

GSC loc. 45449—East River of Pictou, 7,500 feet south of Eureka. Windsor Group fauna:

Parallelidon? sp. cf. *P. dawsoni* Beede
Sanguinolites? sp. cf. *S. parvus* Bell

A few poor outcrops of upper Windsor rocks are found on Pembroke River. The most common rock type is brownish red, slightly calcareous mudstone containing some fine-grained rounded quartz. This red mudstone is often associated with interbedded reddish and greenish grey calcareous mudstone, very fine grained wacke and siltstone, which contain minute mica flakes and fine-grained quartz. Salt casts remain in one greenish grey bed, and another single outcrop displays ripple-marks. Parts of the fine-grained wacke contain very little argillaceous material and may be mistaken for arenite. Light grey to black argillaceous limestone not more than 10 feet thick occurs in isolated outcrops. Thin beds of oölitic limestone are found in two places, and light grey very fine grained fragmental limestone outcrops once. All observed limestone is argillaceous and there are gradations between it and calcareous shale or siltstone. A suggested approximate thickness of 1,500 feet is based on the assumption of non-repetition of beds in the covered interval. Fossils from the upper Windsor strata were identified by W. A. Bell, as follows:

GSC loc. 42028—Pembroke River, 4,500 feet north of Pembroke. Windsor Group ostracoda:

Leptodesma acadica (Beede)
Cyclonema? *subangulatum* Hall

GSC loc. 42030—Pembroke River at Pembroke. Subzone E:

Buxtonia cogmagunensis Bell

Upper Carboniferous

Canso Group

The use of the term 'Canso Group' is contentious at present. The main point in dispute is that the group was originally set up on palaeontological information and thus should not be used as a rock-stratigraphic term.

Bell briefly mentioned the Canso rocks of Hopewell map-area in his memoir on the Pictou coal field (1940, p. 14). He wrote (1940, p. 11) as follows:

> The Canso series comprises freshwater strata that immediately overlie the Windsor series in many localities of Nova Scotia, and that contain commonly *Anthracomya angulata* Dawson, and rarely a small species of *Carbonicola*, in addition to characteristic crustaceans (*Anthrapalaemon* sp. and *Belinurus* sp.).

The lithology is described as divisible into two facies, one characterized by alternating red and grey sandstone, red mudstone and siltstone, and the other characterized by the inclusion of dark grey argillaceous and silty beds. Later (1944, p. 3) Bell reported that

> . . . subdivision of the Upper Carboniferous strata into groups is based primarily on the vertical distribution of plant species.

In the same report (Bell, 1944, p. 5) the Canso Group was redefined as

> . . . non-marine red and grey shales and sandstones that overlie the marine Windsor Group or non-marine rocks of equivalent age.

The Canso was regarded as Namurian (basal Upper Carboniferous). The North American correlation hinges entirely on the relation of the European Namurian zones to the North American Chester zones, and thus the Canso appears to straddle the Mississippian-Pennsylvanian boundary. Bell (1944, p. 6) thought the Canso-Windsor contact was disconformable in the Mabou district of Cape Breton but conformable in parts of mainland Nova Scotia. The Canso-Riversdale contact may be either a disconformity or an unconformity. According to Copeland (1957, p. 8) the

> . . . interval of non-deposition or erosion shown by Bell to separate the Canso and Riversdale Groups cannot be certainly distinguished on the basis of faunal assemblages.

Copeland (p. 8) placed the Canso in the basal part of the Upper Carboniferous (Namurian).

By present usage the term 'group' is restricted to a rock-stratigraphic meaning, but, the Canso Group, as outlined, is primarily a time-stratigraphic unit that fortuitously appears to be lithologically mappable. The Canso Group has been mapped in the field and the problem could apparently be solved by redefinition.

An entirely different approach was taken by Belt (1962), who suggested dropping the term 'Canso' in favour of the newly defined 'Mabou Group'. Belt proposed that the type section be on Mabou River in Cape Breton and that the Canso type section near the Strait of Canso be a reference section. His Mabou Group divisions are based on the lithologies present at these sections. On mainland Nova Scotia Belt did not recognize a hiatus between the Canso and Riversdale Groups but suggested that they are different facies of the same formation, which he called the Parrsboro Formation. It is divided into 1) the grey facies composed of dark to medium grey shale and a very few red lutite beds and 2) the red facies, found only west of Parrsboro, composed of red and greenish grey lutite and sandstone. Belt mapped the rocks in Hopewell map-area containing Canso fossils as the Alma facies (part of the grey facies), and those containing Riversdale plants as the grey facies of the Parrsboro Formation. In so doing he apparently recognized the existence of two different lithologies, but his facies classification is doubtful.

The Canso Group, as described in this report, consists of interbedded red and grey mudstone, shale, siltstone, and minor fine-grained sandstone. Exposures are poor and any interpretation is further hampered by numerous small faults. The basal contact with the Windsor Group is not exposed. On Archibald Brook and West Branch of East River of Pictou, however, there appears to be a conformable sequence from Windsor to Canso. The Windsor beds are red calcareous siltstone and mudstone and the overlying Canso beds are red, greenish grey and dark grey mudstone and shale. The contact is placed below the first dark grey bed in the sequence. The contact of the Canso with the overlying rocks was not observed either, but is assumed to be a fault. The rocks along West River of Pictou and to the east of the West Branch of East River of Pictou are highly sheared.

The best exposures are on Archibald Brook and Middle River of Pictou. Cross-bedding, ripple-marks, and scour-and-fill were noted only on Middle River. About two thirds of the Canso rocks are red; the remainder are mainly grey. A larger fraction of non-red beds is found in the upper part of the group. The most common rock type is reddish brown massive mudstone with minor greenish grey interbeds, in part faintly laminated. The mudstone is interbedded with 2-inch to 2-foot beds of reddish brown to reddish grey siltstone and fine-grained wacke and commonly grades into these rock types. The red colour is caused by fine-grained interstitial hematite and minor hematite cement. A few beds are slightly calcareous. The mudstone is generally highly fractured. A few thin beds (4 inches to 2 feet) of medium grey argillaceous limestone, light grey very fine grained crystalline dolomite interbedded with grey calcareous siltstone, and black calcareous shale outcrop on Middle River of Pictou near Concord Mills. The more calcareous beds weather light brown. Similar calcareous rocks occur on Archibald Brook.

Along West River of Pictou, which follows a fault zone, the rocks are interbedded light to medium greenish grey and minor reddish brown laminated argillite and shale. The laminae are caused by variations in colour and not by variations in grain size. Veins up to a quarter of an inch thick of specularite and minor pyrite and a few veinlets of quartz and ankerite occur in the argillite and shale beds. These rocks and the similar laminated argillite exposed near Glengarry Station may represent inliers of the older Browns Mountain Group. Strata in the upper part of the Canso Group contain isolated beds of light grey, fine-grained quartz wacke and arenite, shaly siltstone and chloritic shale, and minor medium to dark grey laminated shale. Near Gordon Summit and the headwaters of Black Brook outcrops of medium grey pebble-conglomerate appear to overlie the other Canso rocks.

On Calvary Stream a small fault block is composed of rocks believed to belong to the Canso Group. They are continuous with rocks in Truro map-area shown as Canso (Stevenson, 1958) and the rock types are comparable to those found to the northeast. The stream valley in part follows a fault zone, with the result that the exposed rocks are highly sheared. The more common rock types are light grey and greenish grey argillite, greyish red to reddish brown mudstone and argillite, and light greenish grey fine-grained quartz wacke and argillite. Pyrite cubes and ankerite veinlets are common in all these rocks. Light grey pebble-conglomerate outcrops at a single location.

One mile northwest of Glengarry Station there are several outcrops of very dusky red-purple and dark green sheared argillite. The rock contains numerous calcite veins that comprise up to 75 per cent of the rock. At one time the rock was used as a source of agricultural lime. There are numerous boulders of diabase in the vicinity but no outcrops.

The small area on West Branch of East River of Pictou north of Elgin may belong to either the Windsor or the Canso Group. The outcrops are reddish brown and greenish grey mudstone and shale siltstone, rock types that are found in both the Windsor and the Canso Groups. A single fossil, which was found in rubble at the base of one outcrop, was identified by W. A. Bell, who indicated a Canso correlation:

GSC loc. 45440—*Leaia acutilirata* Copeland

No fossils were found in the outcrop, and the shaly siltstone fragment containing the fossil, although identical with the outcrop and still angular and not weathered, may have been transported from Canso strata to the south.

The following fossils from Canso greenish grey shale near the contact on Archibald and McDonald Brooks have been identified by M. J. Copeland:

GSC loc. 46438: '*Estheria*' sp.
Leaia tricarinata Meek and Worthen
Leaia sp. cf. *L. baentschiana* (Beyrich)

GSC loc. 45274: *Leaia* cf. *L. tricarinata* Meek and Worthen
Leaia acutilirata Copeland
Leaia sp. indet.
Euestheria sp. cf. *E. dawsoni* (Jones)
Euestheria sp. cf. *E. lirella* Bell
Lioestheria? *striata* (Goldfuss and Munster)

South of Lorne several conchostracans were found in outcrop of similar lithology. The grey shale beds on Middle River of Pictou at Concord Mills yielded the following fossil, which M. J. Copeland assigned a probable Canso correlation:

GSC loc. 42479: *Carbonicola*? *angulata* (Dawson)

Riversdale Group

The Riversdale Group was defined by Bell (1944, p. 12) from type sections near Riversdale, about 2 miles west of Hopewell map-area. These sections are highly faulted and are thus incomplete. Bell did not describe them in detail, but gave a generalized description (1944, p. 12):

> The group is entirely continental in origin, comprising alternating red and grey sandstones and shales, and including locally a basal formation of conglomerate.

These sections, included in Truro map-area, were examined by Stevenson (1958, pp. 45-48). Because of folding and extensive faulting of unknown displacement, however, he was unable to provide an accurate thickness or description of the group. The Riversdale Group was described as having a preponderance of grey to black, fissile, sandy shales with lenses of grey, grey-green, and grey-red sandstones. There are also abundant black coaly shales but no workable coal seams. As the contacts between both the underlying and overlying Carboniferous sediments are faults, Stevenson assigned an approximate thickness of 3,000 feet from sections along Salmon River.

In Hopewell map-area the Riversdale and Canso lithologies are distinctly different, and the difference is accentuated by the lack of red beds in the Riversdale.

Bell (1944, p. 26), on the basis of the flora, correlated the Riversdale Group with the interval from late Namurian through Westphalian A (Upper Carboniferous) of Europe and with the Pottsville (Lower Pennsylvanian) of the United States. Using arthropod fauna, Copeland (1957, p. 9) correlated the group with the lower and middle Westphalian A zone of western Europe. The Riversdale Group thus seems unquestionably to be of mid-Carboniferous age.

No continuous sections of the Riversdale Group are exposed in Hopewell map-area. The best exposures are on Calvary Stream, which is nearly parallel to the general strike of the rocks. The group consists about half of shale and silty shale, a quarter of siltstone, and a quarter of fine-grained wacke, all of which are grey to black. The most common rock type is medium grey to black silty shale and shaly siltstone in beds about 2 inches thick with a few narrow slightly calcareous interbeds. Dark grey to black laminated shale is interbedded with these rock types. These fine-grained sediments grade into grey siltstone, in beds from an eighth of an inch to 4 inches thick, and light to medium grey, fine-grained quartz wacke, which is in part feldspathic. The wacke is mainly massive, but in a few outcrops bedding is faintly visible. Beds of black Carboniferous shale, which may or may not be laminated are common. The arenaceous sediments consist of at least one quarter argillaceous matrix with varying amounts of subangular quartz grains. The Riversdale sediments are distinguished from the Strathlorne Formation by their almost total lack of mica. Pyrite is a common accessory mineral in the darker sediments.

Slight breaks in deposition occurred during the formation of the Riversdale Group, as shown by small-scale channelling and in one place on Calvary Stream by an extensive ripple-marked surface that climbs a foot in the section over a lateral distance of 50 feet. Near the fault contact with the Horton Group, the Riversdale beds have shallow dips of less than 40 degrees, whereas the Horton dips more steeply. On Big Brook the rocks that outcrop near the fault are highly sheared, graphitic beds and argillite are developed, and the numerous tension fractures are filled with pyrite. The northern contact of the Riversdale Group is also a fault; thus only part of the Riversdale may be exposed. The medium grey pebble-conglomerate that outcrops about a mile southeast of West River Station may be near the base of the section. The pebbles are all of sedimentary rocks and give no indication of their source.

Decorticated plant remains were found in several beds of the carbonaceous shale, but identifiable fossils were found in only one location on the headwaters of Calvary Stream, where plant fragments are associated with blebs of pyrite in dark grey silty shale. The following two species identified by W. A. Bell are indicative of the Riversdale Group.

GSC loc. 5631: *Neuropteris smithsii* Lesquereux
Whittleseya desiderata D. White

Cumberland Group and/or Pictou Group

The area shown as the Cumberland Group and/or the Pictou Group is adjacent to similarly designated rocks in Truro map-area (Stevenson, 1958, p. 48). The rocks of Hopewell map-area are mainly red, grey, and greenish grey sandstone, siltstone, and shale, with minor mudstone and conglomerate. The fossil megaplants may be correlative with either the Cumberland or the Pictou Group. In Truro map-area the rocks are predominantly grey, grey-green, or brown and range in grain size from coarse conglomerate to fine shale.

The term 'Cumberland series' was first used for rocks in Springhill map-area. It was described in part as follows (Kerr, Jones, and Bell, 1938):

> The Cumberland series, 7000 to 11000 feet thick, is so variable in lithological character along individual horizons that subdivisions may be made only on an arbitrary basis.

> The divisions mapped are based on the presence or absence of appreciable quantities of conglomerate. . . . The series is entirely freshwater in origin and represents river alluvium deposited in a progressively sinking trough of deposition. . . .

In Springhill map-area the series is divided into four units: a) shale, sandstone, calcareous bituminous shale, coal; b) conglomerate, some sandstone; c) conglomerate, sandstone, shale, coal; and d) sandstone, shale. The flora indicates an upper early Westphalian (Pottsville) age. Later (1940, pp. 19, 20) Bell included the New Glasgow conglomerate as the basal part of the Cumberland series. This conglomerate is typically a coarse boulder conglomerate and ranges in thickness from 1,900 feet near New Glasgow to about 300 feet at Merigomish, 15 miles to the east.

The Pictou series was defined by Bell (1926, p. 171c) and redefined by him as the Pictou Group (1944, p. 21) from the type section on West Branch River John, as follows:

> The strata there are brownish red to brick-red, soft, micaceous, impure quartz sandstone and arkosic grits, thinly bedded or shaly to massive, alternating with zones of red shales or mudstones, and with minor amounts of red and grey mottled sandstones, grey sandstone, grey, arkosic grits, and red or grey, intraformational limestone-conglomerate.

In the type section the base is a thin conglomerate bed that unconformably overlies the Riversdale Group. Near New Glasgow the Pictou Group disconformably overlies the New Glasgow conglomerate. The Pictou Group is of mainly Westphalian C and D age (Bell, 1944, p. 29).

Exposures are very poor in those parts of Hopewell map-area that are underlain by the Cumberland and/or the Pictou Group. The only extensive outcrop occurs in railroad cuts from 2 to 3½ miles west of West River Station. The frequency of outcrop and the boulder distribution suggest that about 40 per cent of the group is composed of sandstone and 20 per cent each of siltstone, shale, and conglomerate. It is not possible to give any estimate of the thickness of these groups in the map-area.

About half the sandstone is reddish brown, fine-grained quartz wacke. The bedding is faint and the outcrops break along partings a foot to 2 feet apart. The wacke is in part hematitic and is commonly interbedded with blocky mudstone that has a few green beds. Medium grey, fine- to coarse-grained quartz feldspar wacke with minor arenite makes up the other half of the sandstone. It outcrops in beds up to 2 feet thick, displays prominent crossbedding and channelling, and contains carbonaceous fragments. The quartz grains in both types of sandstone are generally subangular.

The siltstone is commonly brownish grey to grey, but greyish red, grey, and greenish grey varities also outcrop. It grades into fine-grained sandstone and shale, and the matrix content varies from about 10 to 50 per cent. The samples with low matrix are composed mainly of subangular quartz grains. Most beds are from 3 to 6 inches thick, but more massive and laminated varieties are found. The greyish red siltstone contains some white specks of kaolin, perhaps from decayed feldspar, and a few grains of hematite.

Several beds of intraformational grey pebble-conglomerate up to about 6 feet thick were seen. The pebbles are of shale and sandstone set in a quartz matrix. Near Botany Bay Lake there are large areas of greyish red conglomerate boulders that may represent an extensive conglomerate horizon perhaps equivalent to the New Glasgow conglomerate.

Reddish brown shale predominates over the grey finely bedded and black fissile carbonaceous varieties. Most of the fossils were collected from shale beds.

The following section is exposed about 3 miles west of West River Station on the north side of the railway tracks. The beds strike 60 degrees and dip 45°NW, with the tops to the northwest.

10′ — medium grey siltstone
6′ — reddish brown and greyish red laminated siltstone
6′ — medium grey siltstone with thin shaly beds
3′ — greenish grey laminated siltstone
8′ — medium grey siltstone with three 6-inch beds of greyish red shale
8′ — greyish red shaly siltstone
20′ — grey massive siltstone with 2-inch bed of shale in the middle
12′ — reddish brown and grey silty shale
4′ — grey massive siltstone
15′ — alternating beds of reddish brown and grey silty shale with one narrow carbonaceous bed with numerous plant fragments
12′ — dark grey massive siltstone
10′ — reddish brown shaly siltstone
4′ — grey siltstone
20′ — interbedded reddish brown shaly siltstone and minor grey siltstone

The following fossils collected along the railroad embankments were identified by W. A. Bell, who indicated a probable Cumberland or Pictou correlation:

GSC loc. 5636: *Pecopteris plumosa* (Artis) Brongniart
Alethopteris lonchitica (Schlotheim) Goeppert
Cordaites principalis (Germar) Geinitz
Samaropsis cornuta (Dawson) Bell

GSC loc. 5638: *Samaropsis cornuta* (Dawson) Bell
Alethopteris lonchitica (Schlotheim) Goeppert
Cordaites principalis (Germar) Geinitz

Spores found in one sample, however, indicate a Pictou Group correlation. M. S. Barss identified these spores as follows:

GSC loc. 5638: *Laevigatosporites* sp.
Lycospora sp.
Florinites sp.
Triquitrites sp.

Post-Carboniferous (?)

Intrusive rocks, mainly of basic composition, appear to cut Canso and Windsor strata in the area near Lorne. These rocks have not yet been seen to cut Upper Carboniferous rocks and may have been emplaced between deposition of Canso and Riversdale strata. In the same area, large frost-heaved boulders of igneous rock near metamorphosed Carboniferous rocks suggest the presence of other intrusive bodies. GSC map 762G (1960) shows small magnetic highs over these areas of possibly igneous rocks.

The maps drawn by Fletcher (1902) show numerous small bodies of felsite, syenite, and diorite intruding rocks that he regarded as Devonian (Canso and Windsor rocks of this report). However, Fletcher's report (1892, Part P, pp. 35, 149, and 150) described only one outcrop and in other instances it referred to blocks, debris, and occasionally rocks. These maps probably show the distribution of these intrusive rocks to be more widespread than it actually is.

At Centredale, dark green, fine-grained diabase outcrops near Windsor shale that has been metamorphosed and is now argillite. The contact between these rocks was not observed. The diabase is predominantly labradorite and augite with minor hornblende, chlorite, magnetite, and muscovite. The unoriented plagioclase laths lie in a matrix of augite and hornblende, and the result is an ophitic texture. Crystals of magnetite occur in the hornblende and chlorite. There is only slight alteration of the plagioclase to kaolin, and the mafic minerals are partly chlorite. Similar diabase outcrops near Canso rocks to the southeast on Black Brook.

A small body of dark green diorite with ophitic texture outcrops near Windsor sediments on the headwaters of Cameron Brook, 2½ miles southwest of Hopewell. The major constituents are plagioclase (andesine to labradorite) and hornblende, with minor orthoclase, chlorite, epidote, magnetite, and augite. The diorite shows similar alteration to the diabase, plus reaction rims of epidote around the hornblende.

On McDonald Brook 1,000 feet south of the Sunnybrae road dark green schist cuts reddish brown breccia and light grey quartz wacke. These two sedimentary rock types are more indurated than the nearby sediments, thus suggesting that the schist is a metamorphosed intrusive rock, possibly of andesitic composition. No other igneous rocks were observed on this brook.

The diabasic texture observed in some of the Browns Mountain flows may be intrusive dykes similar to those intruding the Carboniferous.

Chapter III

STRUCTURAL GEOLOGY

The rocks of Hopewell map-area probably underwent at least two periods of deformation. The distribution and small size of the outcrops restrict observations to minor structural features. Structural trends continuous over large areas are noted, but their locations must be assumed most of the time. The Ordovician and Silurian sedimentary and metamorphic rocks are more highly faulted and folded than the Carboniferous Horton strata. The younger Carboniferous rocks that overlie the Horton Group are the least deformed and are generally shallow dipping. The Triassic sedimentary rocks to the west in Truro map-area are relatively flat lying and undisturbed (Stevenson, 1958, p. 60).

Folds

The Meguma, Browns Mountain, and Arisaig Groups are steeply dipping. The slate, quartzite, and schist of the Meguma Group are the product of regional deformation plus contact metamorphism that occurred during the emplacement of the Devonian granite, which took place during the late stages of the deformation. The deformation must have occurred prior to the deposition of the Horton sediments, which unconformably overlie the Goldenville rocks on West River St. Mary's. There are several steeply plunging tight folds in the Goldenville and Halifax Formations on Cox and Fulton Brooks. The folded rocks are generally highly fractured, and drag-folds, where observed, are incongruous.

The Ordovician and Silurian rocks of the Antigonish Highlands are deformed similarly to the Meguma rocks. Minor folds and drag-folds occur in Arisaig rocks on Holmes and Sam Cameron Brooks. Near McLellan Brook the distribution of McAdam "iron formation" outcrops suggests the presence of a major fold. As the rocks that outcrop downstream on McLellan Brook probably belong to the Ross Brook and Beechhill Cove Formations the structure is shown as a southeast-plunging syncline.

The rocks of the Horton Group underlie an east-west sedimentary basin, but most folds strike more nearly east-northeast. There is evidence in unit "a" of late cross-folding. The only feature that can be traced from one outcrop to another is the possible anticline of unit "a" parallel to the headwaters of Stewiacke River. There are many folds that can be inferred from bedding-cleavage relations, but they are shown only where there is additional evidence from bedding attitudes.

The largest single exposure of the Horton Group is within siltstone and shale of unit "b" near the mouth of Little Stewiacke River. The main details of the structure of this outcrop are shown in Figure 1. At the top of the exposure fold, axis *g* plunges about 30 degrees to the southwest, but none of the axes of the other folds shows a change in plunge. The plunges of most of the axes show considerable variation from one part of the outcrop to another. The cleavage is nearly parallel to the adjacent axial plane throughout the entire outcrop. The complexity of this exposure is probably repeated many times throughout the map-area, but it cannot be observed in the smaller outcrops.

On Fall Brook, unit "b" sedimentary rocks are folded into an open anticline and syncline followed by a tight anticline, which is faulted across the crest. Part of this structure is shown in Plate VI. A small asymmetrical-plunging anticline is ex-

D.G.B., 3-7-61

PLATE VI. Syncline and faulted anticline in Horton unit "b" wacke on Fall Brook, showing broad open fold to the right and fractured tight fold at left.

posed on Big Stewiacke River about 500 feet north of the mouth of Little Stewiacke River. Near Burnside a syncline plunging steeply to the southwest and an anticline plunging more gently to the southwest are exposed in the bed of Pembroke River. Unit "c", exposed in Pembroke River east of Graham Hill, displays two nearly horizontal synclines in separate outcrops that have minor folds about a foot high on the flanks of the larger folds. These and other complexly deformed exposures cautioned the author against making a detailed structural interpretation of the Horton

Group and against stating anything more than that this group is highly folded and that slaty cleavage is developed in the argillaceous beds.

The overlying Windsor sediments and the other younger rocks are considerably less deformed than all older strata in the map-area. The Windsor rocks display several gentle open folds on West Branch of East River of Pictou (Pl. VII) and in several other localities in the map-area.

PLATE VII. Gently folded Windsor strata on west branch East River of Pictou near Eureka. D.G.B., 2-13-61

Faults

The faults in the map-area may be broadly divided into two classes—those that affect only the Ordovician and Silurian rocks and those that affect the Carboniferous rocks. The only observed faults are those with a displacement of a few feet that occur in single outcrops.

The northeasterly trending faults in the Antigonish Highlands have caused pronounced fracture zones. In Glencoe Brook one such zone is easily observed in outcrop in the bed of the stream where the rocks are intensely fractured and veined with barite. As the rocks in Holmes, Sam Cameron, and Blanchard Brooks are fractured for about half a mile, the fault location is based on the intensity of the fractures and the contrasting rock type. Near the fault zone on Sam Cameron Brook there are two distinctive fracture sets and a third poorly developed one. Although the rocks near Brookville are intensely fractured, the two faults that form the boundary of the large Arisaig syncline are located on the basis of the rock types on either side of the fault. None of the faults affecting the Ordovician and Silurian rocks can be observed in the overlying Windsor rocks. A small outlier of nearly flat lying massive limestone overlies highly fractured Arisaig rocks on Holmes Brook. The faults are thus apparently post-Downtonian and pre-Namurian (upper Lower Carboniferous).

No faults of regional significance were observed within the Meguma Group. The Meguma-Horton contact, however, was probably partly a fault during the deposition of the Horton Group. There is a pronounced scarp in Lochaber map-area to the east, which decreases to a slight hill in Hopewell map-area. It is of interest to note that two lead showings, the Pembroke in Hopewell map-area and the Glenelg in Lochaber map-area (Benson, 1963), lie in the west and east projections of this fault zone. As the sedimentary rocks are not in fault contact with the Meguma Group, there has been no appreciable movement of this fault since Horton unit "C" sediments were deposited (late Tournaisian or early Viséan).

Most outcrops of Carboniferous rocks display minor faults with movement of a few inches to a few feet. These faults appear to be local adjustments to large scale deformation. Many of these minor faults, shown in Figure 1 and seen elsewhere in unit "b", are high-angle reverse faults.

Four important boundary faults continue into Hopewell map-area from Truro map-area (Stevenson, 1958); their locations are indicated by fracturing in adjacent outcrops. The relative movement on these faults is the same in both map-areas. The Cobequid, North River, and Riversdale faults all terminate at their intersection with the West River fault. The Riversdale fault dips to the south between 60 and 75 degrees on Calvary Stream near the western boundary of the map-area. As the Riversdale strata are down-faulted in respect to Horton strata, the Riversdale fault is a high-angle reverse fault.

The outcrop in the West River of Pictou valley below West River Station is highly sheared and contains numerous veinlets of ankerite and specular hematite. The rock is generally a massive or faintly laminated argillite. Farther away from the river these rocks are shale and mudstone. This shear zone and change in lithology marks the location at the West River fault. This fault is extended to the eastern edge of the map-area along a well-defined shear zone. On Big Brook along the line of the fault there are numerous tension fractures from an inch to 2 inches long in black shale, and on McDonald Brook there are ankerite and quartz veinlets and a few graphitic shear surfaces.

These boundary faults affect all the Carboniferous rocks so that no age for the movement other than post-Upper Carboniferous can be determined.

Chapter IV

HISTORICAL GEOLOGY

This account of the historical geology of Hopewell map-area is based on an interpretation of the field data and the assumption that the suggested ages for the various rocks are correct.

During the Ordovician period fine-grained argillaceous and arenaceous sediments with minor greywacke were deposited in the Meguma basin. The sediments were derived from a possible land mass lying to the south and deposited in a marginal geosyncline (miogeosyncline) that may have lain to the south of the present Atlantic Upland. Farther north, near the site of the present Antigonish Highlands, interbedded pyroclastic and volcanic rocks and greywacke were deposited in an eugeosyncline. These rocks were not derived from the postulated southern land mass but from an island arc system within the geosyncline.

By Silurian time, uplift had begun in the active eugeosyncline, and thus marine Silurian sediments were deposited, with local unconformities, on top of the folded Ordovician rocks. The Arisaig Group is an irregular succession of thinly bedded, fine-grained argillaceous sediments with a few interbeds of coarse-grained siliceous rocks. Most of the rock types are grey, but red beds are more common near the top of the section. The enclosed fauna is shelly (almost entirely brachiopods but also including minor gastropods, pelecypods, ostracods, crinoids, trilobites, fish plates, and vermes). The Silurian was thus laid down in a shallow marine sea with minor subaerial deposition in the upper part.

The Meguma rocks and those of the Antigonish Highlands were affected by the Acadian orogeny, which began in late Silurian time and culminated in the intrusion of the Devonian granite. It is suggested that the Meguma rocks were thrust northward into their present position at this time, thus accounting for the different facies of Ordovician rocks now observed in close proximity.

The trough now occupied by the Carboniferous sediments developed as a fault basin during the Acadian orogeny, with possible slight movement continuing until mid-Lower Carboniferous. The Horton Group consists entirely of continental sediments ranging from the well-sorted, coarse-grained Craignish Formation to the fine-grained argillaceous Strathlorne and the Ainslie red beds. The Craignish sediments were probably derived from a regolith lying on the deeply weathered Meguma quartz-rich rocks and the Devonian granite. The fossil content of these rocks is almost wholly land plants with a fresh-water conchostracans. The Horton rocks were deformed prior to deposition of the marine Windsor Group, whose basal unit in Hopewell map-area is conglomerate in the southwest and limestone in the northeast. The Windsor Group was deposited in shallow marine waters adjacent to the land masses, and a few restricted basins were developed in which the anhydrite and gypsum were precipitated. The conformable contact between the upper Windsor red beds and the interbedded red and grey Canso beds indicates a gradual transition from marine to non-marine conditions. The Canso contains considerable red beds, but the overlying Riversdale and Pictou and/or Cumberland Groups are predominantly grey.

Deformation of the Carboniferous rocks continued from early Horton time. At first the rocks yielded by folding, but as the sedimentary cover thickened, the north-south compressive forces produced several east-west thrust faults. The deformation may have resulted from renewed movement of the suggested Meguma fault block. After relaxation of these forces, the block of Pictou and/or Cumberland rocks became a downthrown block. The lack of any evidence of faulting between the upper Horton, unit "c", and Meguma rocks indicates that gravity sliding may have been the mechanism that produced this deformation.

The diabase dykes were emplaced in post-Namurian time. Diabase dykes and basalt flows about 100 miles to the west on the south side of the Bay of Fundy (Crosby, 1962, p. 47) are of Triassic age. Possibly those in Hopewell map-area are also of Triassic age.

There is no record of post-Carboniferous deposition except the extensive Pleistocene glacial deposits and the Recent river sand and gravel. Continental Triassic sediments, however, were deposited in Truro map-area to the west and around Chedabucto Bay to the east (Stevenson, 1958, 1959b). The present drainage system follows the structure of the underlying bedrock in a few places, but generally the streams cut through thick glacial deposits and are thus of post-Pleistocene origin.

Chapter V

ECONOMIC GEOLOGY

Several mineral occurrences are known to exist in Hopewell map-area, some of which supported mines in the past, but none of them is at present being worked.

Antimony

References: Fletcher, H., and Faribault, E. R., Geol. Surv. Can., Map 593, Map Sheet 42 (Trafalgar Sheet) Nova Scotia, 1901.
Geol. Surv. Can., Ann. Rept., vol. 6, 1892 (1893), p. 59 A.

Fletcher's map shows the presence of antimony associated with a small granitic stock about 2 miles east of Trafalgar. The annual report states only that the mineralization is similar to the stibnite found at West Gore, 50 miles to the southwest.

Coal

Reference: Fletcher, H., Report on geological explorations and surveys in the counties of Pictou and Colchester, Nova Scotia; Geol. Surv. Can., Ann. Rept., vol. 5, Part P, p. 174, 1892.

Several small pits were dug in the search for coal prior to 1900. Most of these pits were in black graphitic or carbonaceous shale in the Riversdale Group. There is no recorded reference to the actual finding of coal.

Copper

References: Ells, R. D., Bulletin on the ores of copper in the provinces of Nova Scotia, New Brunswick and Quebec; Geol. Surv. Can., Mineral Resources Bull. 882, p. 10, 1904.
Fletcher, H., Geol. Surv. Can., Ann. Rept., vol. 5, Part P, p. 185, 1892.
Messervey, J. P., Copper in Nova Scotia, Pamphlet No. 7; Dept. Pub. Works and Mines, Nova Scotia, 1929.
Piers, H., Economic minerals of Nova Scotia; Dept. Pub. Works and Mines, Nova Scotia, 1906.

Malachite staining and minor chalcopyrite occur in Canso strata near an old copper prospect 3 miles north of Lansdowne Station. The Copper Crown Mining Company attempted to develop the property in 1899. They drove two horizontal adits 30 feet apart, one 60 feet long and an upper one 80 feet long. At the top of the hill a vertical shaft 40 feet long was sunk and in 1899 it was extended at an angle for 75 feet. The copper mineral encountered was chalcopyrite, irregularly disseminated in quartz sandstone and quartz veins.

Minor amounts of chalcopyrite and malachite occur in intraformational Windsor conglomerate below the bridge over West Branch East River of Pictou at Hopewell and near Eureka.

Gypsum and Anhydrite

The largest exposures of gypsum and anhydrite are southeast of Eastville, north of Glenbervie, and south of Bridgeville. In these outcrops the white specimens were determined to be nearly pure gypsum, whereas the anhydrite-rich material is very light grey. Local inhabitants have used these deposits and other small ones as a source of plaster, but there has been no attempt at commercial development.

Iron

References: Can. Dept. Mines Tech. Surv., Mineral Resources Div., Resources File, M.R. Fe 300.00.07, 300.08, and 301.00.07.
Cole, E. J., and Grant, R. I., Report on metalliferous mines; Nova Scotia Dept. Mines, Ann. Rept. 1949, pp. 56 and 96, 1950.
Fletcher, H., Geol. Surv. Can., Ann. Rept., vol. 5, Part P, pp. 176-186, 1892.
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Lindeman, E., and Bolton, L. L., Can. Dept. Mines, Mines Br. Rept. 217, vol. 2, pp. 174-176, 1917.
Messervey, J. P., Iron ore occurrences, Bridgeville area; Nova Scotia Dept. Mines, Ann. Rept. 1943, pp. 71-81, 1944.
Weeks, L. J., Bridgeville limonite deposits; Nova Scotia Dept. Mines, Ann. Rept. 1948, pp. 121-125, 1949.

The Bridgeville area was the site of several small iron mines that supplied limonite ore to a smelter at Ferrona. The iron occurs as discontinuous botryoidal limonite masses and nodules in Silurian slates and shales at the contact with the overlying Windsor limestone. Minor hematite, siderite, ankerite, manganite, and psilomelane were observed.

In 1828 the General Mining Association became the first company to be interested in this area. The most active period was in the late 1890's, when there were eight separate mines. The mine shafts and open pits have now all been filled in. There was a small blast furnace east of Bridgeville, but most of the ore was shipped to Ferrona, where a smelter operated until 1899. Production was about 50,000 tons each for the J. S. Cameron, McDonald, and Grant mines and about 10,000 tons each for the other five mines. The Grant mine ore assayed 42-47 per cent metallic iron, 12-17 per cent silica, 0.12-0.15 per cent phosphorus, and 0.08 to 0.2 per cent sulphur. Further exploration work consisting of prospecting, geophysical surveying, and diamond drilling was undertaken in 1942-43, 1948, and 1955.

At Websters some prospecting was carried out around 1895. The iron occurs as a hematite cement in a quartz arenite in two separate beds, one 2 feet wide and the other 8 feet wide. Assays of this material gave values of 23 to 28 per cent iron. Similar hematitic arenite occurs a mile and 3 miles northwest of Sunnybrae.

In 1949 Ironlake Exploration Limited drilled one hole at the northwest end of Piper Lake, and it intersected minor amounts of siderite in shale over a 10-foot width.

Lead

References: Alcock, F. J., Zinc and lead deposits in Canada; Geol. Surv. Can., Econ. Geol. Series, No. 8, p. 56, 1930.
Messervey, J. P., Lead and zinc in Nova Scotia; Nova Scotia Dept. Pub. Works and Mines, Ann. Rept. 1928, p. 405, 1929.
Messervey, J. P., Report on metalliferous mines; Nova Scotia Dept. Pub. Works and Mines, Ann. Rept. 1930, p. 122, 1931.
Messervey, J. P., Report on metalliferous mines; Nova Scotia Dept. Pub. Works and Mines, Ann. Rept. 1931, pp. 128-130, 1931.
Goudge, M. G., Report on government core drills; Nova Scotia Dept. Mines, Ann Rept. 1949, p. 69, 1950.

Veins of disseminated coarse-grained galena occur in Windsor limestone near the Horton contact at Glenbervie (Pembroke). This deposit was worked prior to 1877, and in 1931 the old shaft was dewatered and additional underground work was performed. Two bulk samples of 2.74 and 1.48 tons were assayed to give 13.7 and 8.9 per cent lead respectively. Surface trenching and some diamond drilling were done in 1949 and 1960.

Limestone

Reference: Goudge, M. F., Limestones of Canada, Part II, Maritime Provinces; Can. Dept. Mines, Mines Br. No. 742, pp. 95-99, 1934.

The limestone beds of the Windsor Group have been quarried in many places as local sources of agricultural limestone. In the iron smelter at Ferrona limestone from Springville was used as a flux. At Black Rock a quarry and pulverizing plant were operated from 1924 to 1930 by the Nova Scotia Department of Agriculture. The other deposits were worked prior to 1900, but except at Springville, the quarries are now difficult to recognize.

Analyses of Limestone

(Data from Goudge, 1934, p. 99)

Locality	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$
	%	%	%	%	%	%
Lorne	4.52	0.52	1.28	0.02	90.32	2.83
Centredale	3.08	1.01	1.55	0.11	90.32	2.86
Springville	2.32	0.57	0.77	0.04	94.46	2.03
Black Rock	6.36	0.78	1.88	0.07	89.60	0.94
Sunnybrae	7.10	0.77	2.11	0.07	89.30	1.30

Manganese

References: Fletcher, H., Geol. Surv. Can., Ann. Rept., vol. 5, Part P, p. 19, 1892.
Gilpin, E. Jr., Notes on manganiferous ores of Nova Scotia; Trans. Roy. Soc. Can., vol. 2, sec. 4, 1884.
Hanson, G., Manganese deposits of Canada; Geol. Surv. Can., Econ. Geol. Series No. 12, p. 65, 1932.

Ten occurrences of manganese minerals in Hopewell map-area are recorded by Hanson. The only appreciable concentration of manganese is associated with the limonite deposits at Bridgeville. Elsewhere the manganese is found as a surface coating on sedimentary rocks and in bog iron ore.

Miscellaneous

Numerous sand and gravel deposits of glacial origin are distributed over the entire map-area. There are no commercial deposits, but material for road construction is generally obtained from the land owner near the site.

The quartz arenite beds in the Craignish Formation, in particular near McKinnon Lake, could provide a relatively pure source of quartz.

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