GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MEMOIR 325

WOLFVILLE MAP-AREA, NOVA SCOTIA (21 H 1)

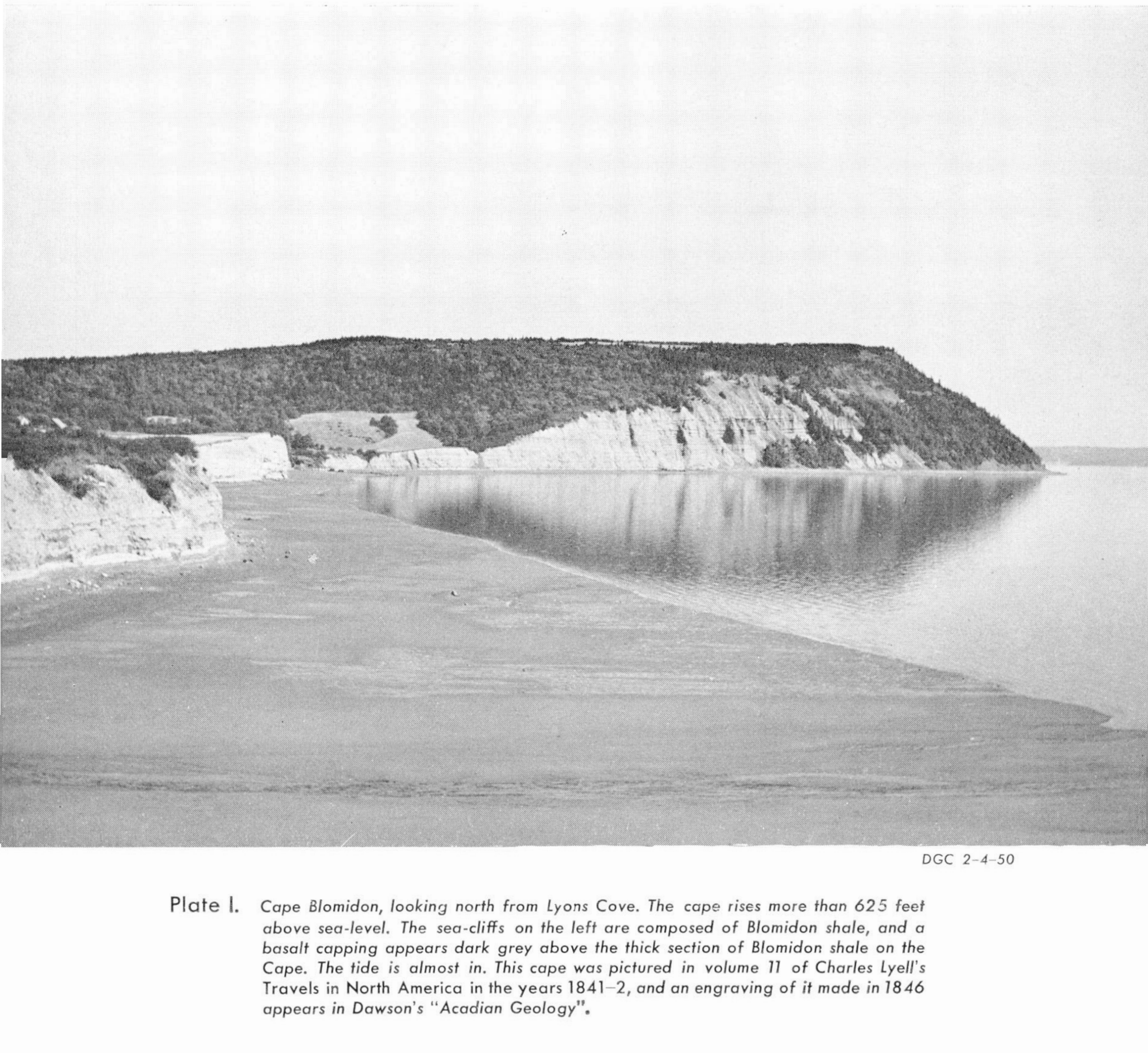
D. G. Crosby

Price, $1.25

1962

WOLFVILLE MAP-AREA,
NOVA SCOTIA
(21 H 1)

3,000—1962—2021
57670-2—1½



DGC 2-4-50

Plate I. *Cape Blomidon, looking north from Lyons Cove. The cape rises more than 625 feet above sea-level. The sea-cliffs on the left are composed of Blomidon shale, and a basalt capping appears dark grey above the thick section of Blomidon shale on the Cape. The tide is almost in. This cape was pictured in volume 11 of Charles Lyell's* Travels in North America in the years 1841–2, *and an engraving of it made in 1846 appears in Dawson's "Acadian Geology".*

GEOLOGICAL SURVEY
OF CANADA

MEMOIR 325

WOLFVILLE MAP-AREA, NOVA SCOTIA (21 H 1)

By
D. G. Crosby

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1962

Price $1.25 Cat. No. M46-325

PREFACE

Much of the area covered by this report was mapped geologically early in the present century, or even before. Because geological concepts have changed and mapping methods have improved considerably since then, remapping on a scale of 1 inch to 1 mile was undertaken. Earlier work had been devoted largely to the Carboniferous and Triassic rocks but in this study much attention was given to the early Palæozoic rocks. As a result the controversial Halifax Formation, long considered either Precambrian or Silurian, is now known to contain Lower Ordovician graptolites.

Field work was conducted in 1949 and 1950, but publication of the report has been unavoidably delayed. As a result the text has been partly revised to include advances in geological knowledge since the manuscript was submitted, especially the dating of the fossils in the Halifax Formation. The report should do much to clarify the stratigraphy of this region.

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

OTTAWA, January 12, 1961

Memoir Nr. 325
Kartenblatt Wolfville (Neuschottland)
von D. G. Crosby

Beschreibt die Geologie eines Gebietes an der Nordwestküste von Neuschottland, das aus ordovizischen und silurischen klastischen Sedimenten, devonischem Granit, karbonischen klastischen und kalkigen Sedimenten und Evaporiten und aus triassischen klastischen Sedimenten und basischen vulkanischen Gesteinen besteht.

Мемуар 325 — Геологическая карта — Лист Вульфвиль, Новая Шотландия. Д. Г. Кросби.

Описание геологии одного района на северо-западном побережье Новой Шотландии сложенной кластическими осадками ордовика и силура, гранитами девона, карбоновыми кластическими и известковыми осадками и эвапоритами, а равно триасовыми кластическими осадками и основными эффузивами.

CONTENTS

CHAPTER I

PAGE

Introduction 1
- Acknowledgments 1
- Previous geological work 1
- Methods of mapping 5

CHAPTER II

General character of the region 6
- Topography 6
  - The south highlands 7
  - The north highlands 7
  - The Carboniferous uplands 8
  - The Triassic lowlands 9
- Geomorphology 10
  - The Atlantic upland 10
  - Stream capture 10
  - Evidence of coastal emergence 12
  - Evidence of coastal submergence 13
  - Salt marshes 14

CHAPTER III

General Geology 16
- Table of formations 16
- Ordovician 17
  - Halifax Formation 17
- Silurian or older 21
  - White Rock Formation 21
  - Kentville Formation 24
- Silurian 25
  - New Canaan Formation 25
- Devonian 29
  - Granite 29
- Mississippian 31
  - Horton Group 31
  - Windsor Group 35
    - Macumber Formation 35
    - Pembroke Formation 37
    - Undivided Windsor rocks 39

	Page
Pennsylvanian (?)	41
Scotch Village Formation	41
Triassic	43
Annapolis Formation	43
North Mountain basalt	46
Scots Bay Formation	48
Pleistocene and Recent	49

CHAPTER IV

Structural geology	52
Folds and faults	52

CHAPTER V

Economic geology	57
Gypsum	57
Barite	59
Manganese	62
Petroleum	64
References	66

Illustrations

Map	1128A.	Geological map of Wolfville map-area	*In pocket*
Plate	I.	Cape Blomidon, looking north from Lyons Cove	*Frontispiece*
	II.	The North Mountain escarpment	8
	III.	A large sink-hole in a gypsum bed of the Windsor Group	9
	IV.	Sandbar at Woodside, Kings county	11
	V.	Meander scar along the tidal part of Oakland Brook	12
	VI.	Stumps in situ on the shore of Avon River	13
	VII.	Pine stumps buried by marsh growth, on the bank of Avon River	14
	VIII.	Marine breccia of the New Canaan Formation containing elongated, vesicular fragments	26
	IX.	Marine breccia of the New Canaan Formation containing dense fragments	27
	X.	Lenticular strata of the Horton Group	32
	XI.	Upper Horton shale channelled by arkose grit	33
	XII.	Close-up of fold in Horton strata	34
	XIII.	Angular unconformity separating the Wolfville sandstone from Horton rocks	45
	XIV.	Colloform texture in sphalerite partly replaced by galena	61
	XV.	Galena, pyrite, and sphalerite replacing barite	62
Figure	1.	Topographic divisions of Wolfville map-area	6

WOLFVILLE MAP-AREA, NOVA SCOTIA

Abstract

The Wolfville map-area contains rocks ranging in age from Ordovician to Triassic. The four oldest formations are apparently conformable and consist of some 15,000 feet of eugeosynclinal slates, siltstones, quartzites, and marine breccia. These four formations have been closely folded as a single unit. Lower Ordovician graptolites occur in the lowest (Halifax) formation, and Silurian fossils have been found in the uppermost (New Canaan) formation.

Porphyritic granite, a part of the large batholith that underlies much of central Nova Scotia, has intruded the Ordovician-Silurian rocks in the southwest corner of the map-area.

Carboniferous sedimentary rocks unconformably overlie both the lower Palæozoic strata and the granite. These include the Horton Group (about 4,000 feet of grey and red shales and sandstones of fluviatile origin), the conformably overlying Windsor Group (some 2,000 feet of red shale, limestone, gypsum, anhydrite, and salt of marine origin), and the apparently conformably overlying Scotch Village Formation (some 800 feet of feldspathic sandstone, of fluviatile origin). The Horton Group contains abundant plant and fish remains, and the Windsor Group contains marine fossils, all of Mississippian age. The Scotch Village Formation contains abundant plant remains of probable Pennsylvanian age.

Triassic rocks include several hundred feet of red conglomerate, sandstone, shale, and basaltic lavas, topped by about 16 feet of arenaceous limestone and calcareous sandstone. Late Triassic (Newmark) ostracods and plant and fish remains occur in these continental deposits. The Triassic rocks lie with marked angular unconformity on Horton and older rocks.

Major folds conform to the northeast Appalachian trend. Pre-Carboniferous folds were accentuated by forces that folded the Carboniferous strata, but fold axes of both correspond. Although many of the minor folds conform to the regional northeast trend, there are many east-west folds as well. Except for minor irregularities, Triassic rocks dip gently to the northwest. High-angle faults occur in many parts of the area.

The Walton mine, one of the world's largest deposits of barite, lies in the northeast part of the map-area. Argentiferous sulphides are associated with the barite. Considerable tonnages of gypsum are recovered annually from quarries in the Windsor and Cheverie districts.

Résumé

La région de Wolfville comprend des roches dont l'âge varie de l'Ordovicien au Trias. Les quatre formations les plus anciennes sont apparemment en concordance. Elles se composent de quelque 15,000 pieds de roches eugéosynclinales, à savoir d'ardoises, de siltstones, de quartzites et de brèche marine. Elles ont été plissées comme un tout en plis serrés. Il existe des graptolites de l'Ordovicien inférieur dans la formation Halifax qui se trouve à la base et l'on a découvert des fossiles siluriens dans la formation New Canaan qui est la plus haute.

Du granite porphyritique, qui fait partie d'un gros batholite qui recouvre une bonne partie du centre de la Nouvelle-Écosse, a fait intrusion au sein des roches ordoviciennes-siluriennes du coin sud-ouest de la région.

Des roches sédimentaires carbonifères recouvrent en discordance tant le granite que les strates du Paléozoïque inférieur. Elles se composent du groupe Horton (environ 4,000 pieds de grès et schistes gris et rouges, d'origine fluviatile), recouvert en concordance par le groupe Windsor (quelque 2,000 pieds de schiste rouge, de calcaire, de gypse, d'anhydrite et de sel d'origine marine), sur lequel repose, apparemment en concordance, la formation Scotch Village (quelque 800 pieds de grès feldspathique, d'origine fluviatile). Le Horton contient de nombreux vestiges de plantes et de poissons et le Windsor, des fossiles marins, tous d'âge mississipien. La formation Scotch Village contient beaucoup de vestiges végétaux qui remontent probablement au Pennsylvanien.

Les roches triasiques sont rouges et comprennent plusieurs centaines de pieds de conglomérat, de grès, de schiste et de laves basaltiques, sur lesquels reposent environ 16 pieds de calcaire arénacé et de grès à ciment calcaire. Ces sédiments terrestres contiennent des restes de plantes et d'animaux de même que des ostracodes de la fin Trias (Newark). Le Trias repose sur le Horton et les roches plus anciennes et présente une discordance angulaire bien marquée.

Les principaux plis sont vers le nord-est ou suivant la direction appalachienne. Les plis antérieurs au Carbonifère ont été accentués par les forces qui ont provoqué le plissement des strates carbonifères, mais les axes de plissement des deux séries se correspondent. Même si plusieurs des petits plis sont suivant la direction régionale vers le nord-est, il existe également un bon nombre de plis orientés d'est en ouest. Sauf dans le cas d'irrégularités peu importantes, les roches triasiques s'inclinent légèrement vers le nord-ouest. Bien des parties de la région contiennent des failles à angle très fort.

La mine Walton, où se trouve l'un des gîtes de barytine les plus étendus au monde, se trouve dans la portion nord-est de la région étudiée. Des sulfures argentifères se trouvent associés à la barytine. De grosses quantités de gypse s'extraient chaque année de carrières des régions de Windsor et de Cheverie.

Chapter I

INTRODUCTION

The Wolfville map-area lies between north latitudes 45°00′ and 45°15′ and west longitudes 64°00′ and 64°30′, and covers about 420 square miles including the eastern end of the Annapolis-Cornwallis Valley, commonly referred to as "the garden of Nova Scotia". On the north it is bounded, predominantly, by that part of the Bay of Fundy known as Minas Basin. About 120 square miles of the area is covered with water twice a day at high tide. High and low tide levels differ by more than 50 feet at the head of the Bay of Fundy, which is subjected to the highest tides in the world, and by more than 47 feet, on the average, in the map-area. Geological mapping was done by the writer during the field seasons of 1949 and 1950.

The Dominion Atlantic Railway, under lease to the Canadian Pacific Railway, connects the area with Yarmouth and Halifax, and the Halifax-Yarmouth highway, which passes through the area, follows the Avon River in the east half and the Cornwallis River in the west half. Secondary roads permit access to most other parts.

Acknowledgments

The writer was ably assisted by J. D. MacAlary, G. P. Williamson, and R. J. Stevenson during the field season of 1949; and by R. J. Stevenson, D. E. Smith, and W. B. Brady during the field season of 1950. W. A. Bell, a former Director of the Geological Survey of Canada, identified plant remains from the Scotch Village Formation, and Alice E. Wilson of the Survey identified fossils from the Halifax and New Canaan Formations. Mr. G. L. Harrington of Stanford University identified foraminifera from the tidal flats of Minas Basin.

Appreciation is expressed to the General Manager, Mr. G. G. Campbell, and employees of the barite mine near Walton for their assistance; to Professors M. F. Bancroft and H. L. Cameron, Acadia University, for pointing out localities of interest and for allowing the writer the use of university facilities; and to Dr. C. F. Park, Jr., and Dr. S. W. Muller of Stanford University for critical reading of the doctorate dissertation upon which this report is based.

Previous Geological Work

Easily accessible gypsum deposits on the shore of Avon River were worked as early as the beginning of the nineteenth century. Haliburton (1829)[1] described

[1] Names and dates in parentheses are those of references cited at the end of the report.

the exportation of this mineral as the chief item of trade at Windsor, Hants county, at that time. He also described deep, circular "kettle holes" in the ground underlain by gypsum beds.

In 1827, Alger made the first attempt to interpret the geology of the Annapolis Valley. He defined three rock-units: (1) clay slate, (2) red and white sandstone, (3) greenstone.

Jackson and Alger presented a description of the rocks of Nova Scotia and the first coloured geological map of the province in 1828-1829. The map is surprisingly accurate. They recognized and mapped six main rock-units: (1) primitive granite, (2) quartz rock alternating with clay slate, (3) transition clay slate, (4) red and grey sandstone alternating with black and red shale containing impressions of vegetables, beds of coal, etc., (5) red sandstone dipping under the trap, (6) columnar greenstone. These rock-units may be compared with the modern divisions: (1) porphyritic granite, (2) Goldenville Formation, (3) Halifax Formation, (4) Horton and Windsor Groups, (5) Annapolis Formation, (6) North Mountain basalt. Jackson and Alger also mentioned gypsum beds near Windsor, as well as sink-hole topography characteristic of ground underlain by unit 4.

Sir William Logan examined sedimentary rocks in various parts of the province in 1841 and made his famous discovery of fossil footprints, *Hyalopus logani* Dawson, at Horton Bluff in the Wolfville map-area (Dawson, 1882). This was the first evidence of the existence of air-breathers in Carboniferous times. Fossils that Logan collected at Windsor were considered to be of Permian age by European workers, and Murchison (1843) described the gypsiferous strata of Nova Scotia as of Permian age in his Presidential Address before the Geological Society of London in 1843.

Sir Charles Lyell visited Nova Scotia in 1842, and in 1843 published his correct conclusion that the gypsiferous strata belong to the Lower Carboniferous. Subsequent work by others, including Logan, has substantiated Lyell's conclusion.

In 1847, Sir William Dawson (1848) tentatively referred sandstones overlying Carboniferous beds to the Triassic, and described their distribution about the eastern arm of the Bay of Fundy. A geological map accompanies that text. In an appendix to the same paper, Dawson subdivides the gypsiferous strata into an upper marine part (later known as the Windsor Group), and a lower estuarine or lacustrine, plant-bearing part (later known as the Horton Group).

In 1855, Dawson published results of work in Nova Scotia up to that date, together with a geological map of the province. He mapped the metamorphic rocks of the uplands as Devonian and Silurian. Among these are slates and quartzites along the Atlantic coast that were considered by him to be of early Silurian age (later known as the Meguma Group, supposedly of Precambrian age). In the Wolfville map-area, the metamorphic rocks were mapped as Upper Silurian (much was later placed in the Halifax Formation, the upper division of the Meguma Group); Carboniferous rocks were subdivided in the text but were shown collectively on the geological map; Triassic rocks were subdivided into two divisions (later known as the Annapolis Formation and the North Mountain basalt), and were well delimited on the map.

In 1860, in a supplementary chapter to the previous volume, and in subsequent editions in 1868, 1878, and 1891, Dawson described *Dictyonema*-bearing slates of the New Canaan district, Kings county. He considered them to be of Niagaran age on the basis of Hall's determinations on fossils found in associated "coarse laminated magnesian and ferruginous limestone". Dr. Webster had earlier found specimens of *Dictyonema* in slates about 2 miles southeast of Kentville, which was the first discovery of fossils in the metamorphic rocks of the area. The graptolite was named *Dictyonema websteri* for its finder, and was described and figured in Dawson's publication (1860, 1868, 1878, 1891).

In 1879, Honeyman subdivided the pre-Carboniferous rocks of the Wolfville district into two rather vague divisions. He considered *Dictyonema*-bearing slates to be of early Silurian age, and designated most of the metamorphic rocks of the area as the Wolfville Formation of that age; most of these rocks were later placed in the Halifax Formation. His second division, the Greenfield Formation, which he considered to be of Cambrian age, lay in the southern part of the area; these rocks were later included in the Halifax Formation.

In 1900, Ami proposed the name Kentville for Silurian rocks in this district, and vaguely defined the Kentville Formation as follows:

> Near Kentville, the Kentville formation is seen as well on Angus Brook in the Gaspereau Valley, also at New Canaan, with *Dictyonema websteri* Dawson, and at Wolfville in Kings County where coralline limestones, red and green graptolitic slates, and other strata at times highly cleaved, squeezed and metamorphosed form conspicuous ridges, and constitute the oldest sedimentaries in the vicinity of the Bay of Fundy and the Blomidon region in the 'Land of Evangeline'.

The name has been used so often since then that today it is practically synonymous with Silurian rocks exposed near Kentville. In the same article, Ami proposed the name Halifax for "the slate group of the gold-bearing series", and the name Guysborough for the quartzite part of the series. The former name acquired popular usage, but the latter was discarded.

In 1902, Ami concluded that the graptolite *Dictyonema websteri* Dawson was closely related to *D. flabelliforme* Eichwald and, therefore, assigned slates containg *D. websteri* to the Upper Cambrian. However, three years later, Ruedemann (1908) identified *Dictyonema websteri* Dawson with a Niagaran form, *D. retiforme* Hall, and stated that there was no "difference sufficient for specific distinction" between the two. Thus these slates were again assigned to the Silurian.

In 1904, Woodman established the nomenclature now used for the Goldbearing Series. He named the entire rock-unit the Meguma Series and subdivided it into an upper formation, predominantly slate, for which he adopted the earlier proposed name Halifax, and a lower formation, predominantly quartzite, to which he gave the name Goldenville. He did not commit himself to the age of the rocks. However, in 1908 he concluded that they were of Precambrian age.

In the 1870's, Fletcher began mapping Nova Scotia on a scale of 1 inch to 1 mile. He correctly mapped strata of the Windsor Group (then termed Windsor Series) as Carboniferous, but mistakenly referred strata of the Horton Group (then termed Horton Series) to the Devonian, even though A. S. Woodward, David White, and others had confirmed Dawson's earlier assignment of the plant-bearing strata of the Horton Group to the Carboniferous. Fletcher's Walton area (1905), Kingsport area (1911), and Faribault's and Fletcher's Windsor area (1909), together cover the Wolfville map-area except for a quadrangle in the southwest corner extending about 15½ miles east and about 5¼ miles north, which is underlain almost entirely by metamorphic rocks. These maps are surprisingly excellent in detail when it is remembered that the field work was carried out under conditions far more difficult than those of today. Fletcher also published reports on the Kentville area (1906, 1907) and Faribault (1909) reported on the Gaspereau area. No maps were included with these reports and Faribault's manuscript maps were, unfortunately, lost. In his text, however, Faribault (1909) correctly located major synclines and anticlines in the southwestern part of the Wolfville map-area, assigned the slates of Black River to the Halifax Formation, and stated that "whin rock" of the Goldenville Formation is exposed for a width of a quarter of a mile along the crest of the anticline that crosses Black River "between the two bridges". He further stated that 11,700 feet of the strata exposed along Black River, measured from the base of the "two bands of Whiterock quartzite" to the "conformable" contact with the "whin rock" between the two bridges on Black River, "correspond in character and thickness to the upper or Halifax division of the gold-bearing series of the Atlantic coast". Three years later he stated that the "Whiterock quartzite" bands "apparently overlie conformably" the Halifax slates and are conformably overlain in turn by higher slates (Faribault, 1912).

In 1916, Powers established the nomenclature now used for the Acadian Triassic.

In 1929, Bell proved that both the Horton and Windsor Groups are of Mississippian age. He subdivided the Windsor Group into zones on the basis of faunal content and the Horton Group into two formations, the lower, Horton Bluff Formation, and the upper, Cheverie Formation. He described the Black River section of Meguma rocks as "the most complete section of the Halifax slates within the province" and concluded that they were of Precambrian age. By this time a Precambrian age had been accepted for the Meguma Group by most workers in Nova Scotia. Bell referred to slates believed to be of Silurian age as the Kentville Formation in accord with many other reports since 1900. The lower band of White Rock quartzite, and stratigraphically higher rocks, were also considered to be of Silurian age; rocks below the White Rock quartzite were assigned to the Halifax Formation.

Later in 1929, Malcolm, in a memoir compiled largely from the results of investigations by Faribault, stated "In a study of that area lying south of a line stretching from Wolfville to Kentville in Kings county, and west as far as the Aylesford road, Faribault has shown that with the exception of the small body of the Niagaran series of New Canaan nearly all the rocks are of the Gold-bearing series. The slates are very similar to those of the Gold-bearing series in other parts of the province, and the quartzite which is exposed along some of the anticlines is the same as the whin of the Goldenville formation." On the geological map of Nova Scotia accompanying that memoir, the rocks underlying the White Rock Formation were shown as Precambrian Gold-bearing Meguma Series, the White Rock Formation and overlying metamorphic rocks as Silurian.

Numerous geological reports dealing with the Wolfville area have been written since 1929, but in each instance the writers have accepted the regional geology as outlined by their predecessors and have restricted their reports to description of mineral deposits or other local geological phenomena.

Methods of Mapping

All outcrops along roads, railroad tracks, shoreline, and streams were examined by the writer, and locations were established by means of aerial photographs and pace-and-compass traverses. Special attention was given to the Horton-Windsor contact, the position of which was established by means of a plane-tabled baseline cut along its general location, as indicated on Fletcher's (1905) map, and pace-and-compass traverses made approximately at right angles to the baseline at 500-foot intervals. Although outcrops are scarce in those areas underlain by Horton and Windsor rocks, a gratifying number were encountered by this method.

Additional information was obtained from the limestone ridges and sink-holes in limestone and evaporite beds. Along-strike tracing of the quartzite beds of the White Rock Formation, which proved to be the best horizon marker in the southwestern part of the map-area, provided valuable information on the structure of that district.

57670-2—2

Chapter II

GENERAL CHARACTER OF THE REGION

Topography

The map-area may be divided into four topographical divisions (Fig. 1): (1) the south highlands, (2) the north highlands, (3) the Carboniferous uplands, (4) the Triassic lowlands. Each of these divisions is closely related to the underlying rock divisions and structures.

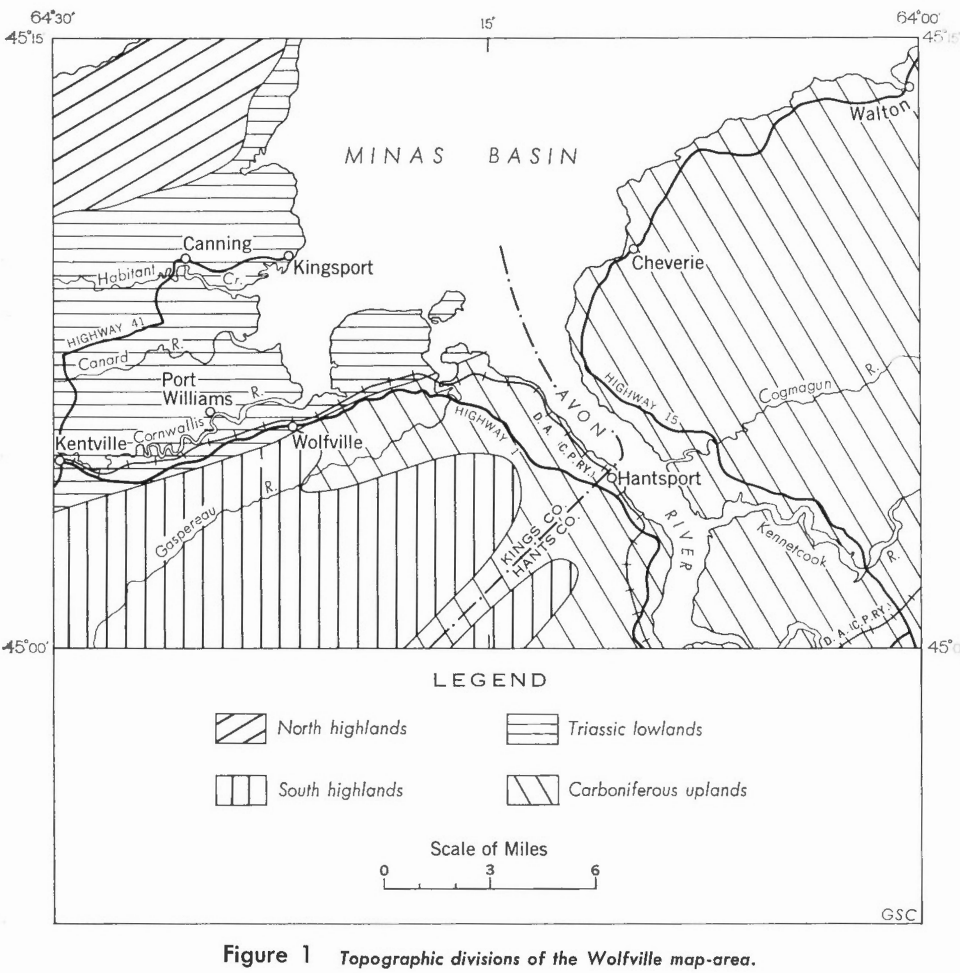


Figure 1 ***Topographic divisions of the Wolfville map-area.***

The South Highlands

The south highlands form the northern border of an upland region that extends along the southern and central parts of the Nova Scotia peninsula and contains the main watershed of the province. They are underlain by metamorphic rocks—principally those of the Meguma Group—and granite, and in the map-area commonly reach 700 feet in elevation, with a few small areas above this figure.

The highlands are locally subdivided, from north to south, into (1) Wolfville Ridge, which extends from Wolfville southwesterly for about 3 miles; (2) South Mountain, which begins about 2½ miles northwest of Hantsport and extends westerly and southwesterly; and (3) Grey Mountain, which begins about 2½ miles southwest of Hantsport and extends southwesterly along the south side of Halfway River.

The top of South Mountain is a gently rolling and almost featureless surface that truncates the underlying, closely folded metamorphic rocks and granite. It contains many broad, shallow, swampy stream valleys, which are choked with black alders. Down the flanks of the mountain, particularly the northern, steeper flank, these stream valleys become deep, V-shaped ravines characteristic of a youthful stage of stream development. Falls are numerous and the floors of the valleys are completely occupied by the streams, the valley of Black River being an excellent example.

Dense evergreen growth predominates on the south highlands, but there are many patches of mixed deciduous and evergreen trees.

The North Highlands

The north highlands constitute that part of the map-area underlain by North Mountain basalt. They locally rise above 700 feet, but most of the gently undulating summit level is at elevations between 650 and 675 feet. North Mountain, as this highland has been called for three centuries, extends 120 miles along the southeast side of the Bay of Fundy, from Cape Blomidon to Brier Island, Annapolis county.

Its gently undulating summit level is somewhat similar to that of South Mountain in appearance. It truncates basalt flows that dip, on an average, about 5 degrees to the northwest. Stream valleys are shallow and choked with alders on the summit, but become deep and V-shaped down the flanks of the mountain. Most of the drainage is to the north. The youthful aspect of north-flowing streams is enhanced by numerous falls, some of which are more than 50 feet high near the seashore. Streams flowing to the south and east descend the steep North Mountain escarpment (Pl. II).

Evergreen vegetation predominates, and trees are generally larger than those on the south highlands.

57670-2—2½

DCG 1-8-50

Plate II. *The escarpment along the south edge of North Mountain, looking southwest. Note the abrupt drop in elevation from North Mountain, which is underlain by basalt, to the Cornwallis Valley, which is underlain by soft Annapolis strata.*

The Carboniferous Uplands

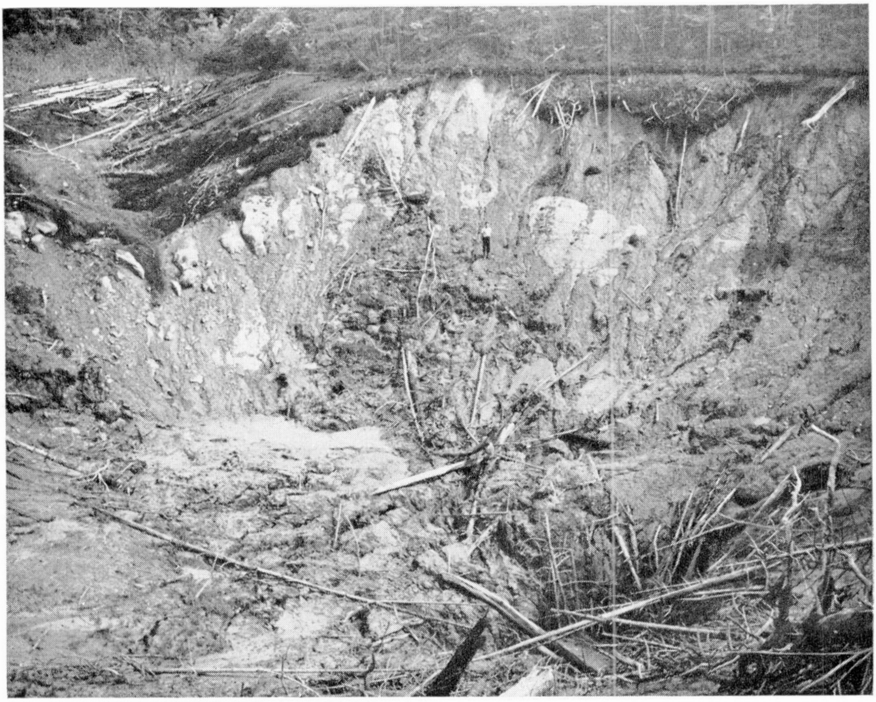
The Carboniferous uplands comprise much of the central and almost all the eastern parts of the map-area, and include that part underlain by Carboniferous strata except for the northeast extension of the south highlands. These uplands are lower than the north and south highlands and higher than the Triassic lowlands, and are characterized by great local variations in elevation. They continue east of the map-area for some 130 miles to the northeast extremity of the Nova Scotia peninsula; to the west they merge into the Triassic lowlands.

The area underlain by Horton strata attains elevations of more than 500 feet on the flanks of South and Grey Mountains; the maximum relief in the east at Cheverie Mountain is about 435 feet. The average elevation is between 200 and 250 feet.

That part of the uplands underlain by the less resistant Windsor strata does not generally rise above 150 feet elevation.

Swamps, both open and wooded, are numerous, particularly where underlain by rocks of the Windsor Group or the Scotch Village Formation. These, together with the shallow stream valleys and undulating hills, give rise to a monotonous type of topography. The most striking landforms are the sea-cliffs, commonly more than 50 feet high.

Those parts of the uplands underlain by gypsum are characterized by deep, funnel-shaped sink-holes, which have no surface outlet and may contain water (Pl. III).



DGC 12–4–50

Plate III. *Large sink-hole in the gypsum-anhydrite bed that overlies the Pembroke Formation, $1\frac{1}{3}$ miles northeast of the Walton barite mine. Note the size of the man standing in the sink.*

The Triassic Lowlands

The Triassic lowlands lie between North and South Mountains, and include that area underlain by the Annapolis Formation (*see* Pl. II). Their average elevation is between 50 and 75 feet.

That part of the lowlands included in the map-area is the Cornwallis Valley, on the west side of Minas Basin. It continues to the west for about 40 miles, where it becomes the Annapolis Valley, which extends to the head of St. Mary Bay. The Annapolis-Cornwallis Valley, with a total length of about 100 miles, is the most productive farming district in Nova Scotia. The Triassic lowlands continue to the northeast of the Wolfville map-area for 50 miles, forming a border around the eastern arm of the Bay of Fundy.

Sea-cliffs in the lowland area commonly are more than 40 feet high. Streams in the lowlands are in the stage of late maturity.

Geomorphology

The Atlantic Upland

The name Atlantic upland was proposed by Goldthwait (1924) for a level surface that was probably continuous throughout the maritime region. This surface gradually rises northwesterly from sea-level at the southern coast of Nova Scotia to the elevation of the south highlands in the Wolfville map-area. The uniform summit level of North Mountain indicates that the mountain is a detached fragment of this upland.

Structure-section C-D (*see* Map 1128A) illustrates the relationship between basement rock structure and topography in the northeastern part of the south highlands. Topographical prominences are directly related to anticlinal structures in the underlying rocks, and valleys correspond with synclinal folds. For example, Gaspereau River has eroded headward along the Gaspereau River syncline. At White Rock Mills its valley is localized by the resistant White Rock Formation, but farther southwest it follows the synclinal slates of the Kentville Formation, which are less resistant than rocks of the adjoining New Canaan Formation. The writer found no evidence of extensive faulting along the north side of Gaspereau River, as has been postulated by some workers to explain surface features. Downstream from the resistant White Rock Formation at White Rock Mills, the valley of Gaspereau River broadens and loses its youthful features. The lower part of Halfway River is similarly localized by a synclinal structure.

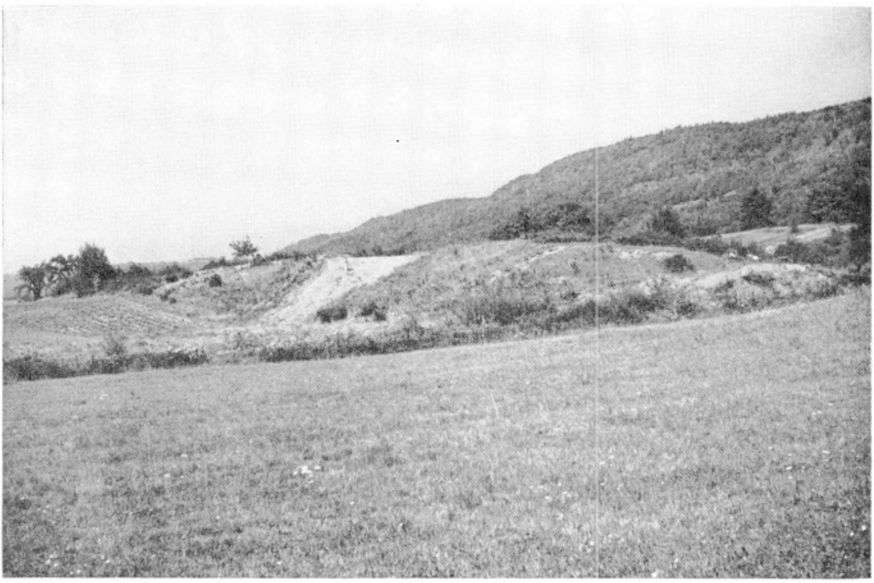
Structure-section A-B (*see* map) illustrates the relationship between basement rock structure and topography in the north highlands. North Mountain is a cuesta capped with lava flows. The steep south flank of the mountain is an escarpment slope; the gently descending north flank is essentially a dip slope.

No trace of the formerly continuous Atlantic upland surface is found in the Carboniferous uplands or in the Triassic lowlands of the map-area. These lower areas were formed by erosion after upwarping of the Atlantic upland. The variability of rock types underlying the Carboniferous uplands—limestones, shales, and sandstones of differing degrees of hardness, conglomerates, gypsum, and anhydrite—caused the formation of a terrain equally as variable. In the area underlain by soft strata of the Annapolis Formation, the Annapolis-Cornwallis Valley was carved out between the resistant basalt flows on the north and the resistant metamorphic and intrusive rocks on the south.

Stream Capture

The valley of Black River is aligned with the deep valley occupied by a small tributary of Cornwallis River and by Deep Hollow road. Both valleys cross the structural trend of the map-area, and have incised meanders near White Rock Mills. Black River, apparently a superimposed or consequent stream, once flowed through Deep Hollow. Headward erosion by Gaspereau River, which is a subsequent stream at least near and upstream from White Rock Mills, has apparently captured and diverted the waters of Black River.

This stream capture probably came about in the following manner. When Black River cut down to near its present level in the resistant quartzite of the White Rock Formation at what is now White Rock Mills, it encountered a considerably thickened section of the formation, because of the local folding (*see* structure section G-H, Map 1128A). This extra thickness of quartzite constituted an erosional deterrent, so that downcutting by the river must have been greatly retarded. Meanwhile the headward-eroding Gaspereau River advanced along the southern syncline and breached the White Rock Formation at the somewhat shattered trough of the syncline, and was able to cut down more rapidly than Black River. Ultimately it intersected and captured Black River.



DGC 7-1-50

Plate IV. *Sandbar at Woodside, looking northwest. The bar is more than 3 miles from the coast, and is about 20 feet high (note size of man standing where the sand is exposed). Hill in background is the North Mountain escarpment.*

The above explanation is simplified in that possible effects due to glaciation, regional tilting, etc., are not considered. Its validity is substantiated by evidence of capture of other streams that flow northerly into Gaspereau River, such as Duncanson, Harding, and Curry Brooks, whose valleys can be projected through gaps across the northeast extension of Wolfville Ridge. It seems evident that these smaller streams were captured by Gaspereau River as it cut its way headward, just as was Black River.

Evidence of Coastal Emergence

Two sandbars were observed on the south side of the road at Woodside, about 2 miles northwest of Canning, 3½ miles from the present shoreline (*see* Pl. IV). The larger bar is about 20 feet high, with the top just over 75 feet above mean sea-level. Both bars are composed of sand and minor amounts of rounded pebbles and argillaceous material, and are aligned along the northeast-trending valley in which they occur. The grassy floor of the valley is composed of mud similar to that of the present shore. Pereau Creek occupies this valley to the northeast, but it contains too little water to have formed the sandbars and large meander scars in the sides of the valley. Comparison of this valley with tidal channels at the mouths of streams elsewhere in the area leaves little doubt that it was formed by tidal currents. Assuming a difference between high- and low-tide levels equal to that of today (about 50 feet) and that the top of the larger bar was just awash at high tide, the evidence indicates a relatively recent emergence of at least 50 feet.

DGC 10-3-50

Plate V. *Meander scar on the tidal channel part of Oakland Brook, at Avonport, looking north from the Wolfville-Kentville highway. The channel contains little water at low tide.*

In 1920, Churchill described a number of small hills and hummocks at Woodside, including the two referred to in the preceding paragraph, and concluded that these were formerly marine sandbars.

In 1896, Coldwell described "an old beach formation" at Wolfville, "extending along the line of Acadia Street, parallel to the present water frontage. The rounded stones in this old beach are mainly trap." He concluded that the sea was at one time "nearly 50 feet higher than at present". During the summer of 1950, highway workers used truck loads of gravel from a similar raised beach at Scots

Bay village, for surfacing the Blomidon shore road along the foot of the North Mountain escarpment.

Goldthwait (1924, pp. 148-154) has described raised estuarine flats, marine beaches, and deltas along the Bay of Fundy shore of Nova Scotia that are 60 to 128 feet above mean sea-level. His isobase diagram (p. 150) showed the elevations of these landforms above mean sea-level, and demonstrated that the extent of post-Pleistocene emergence decreases southeasterly at about 2 feet per mile. The 100-foot isobase follows the Annapolis-Cornwallis Valley.

Assuming a difference between high- and low-tide levels similar to that of today during the formation of these landforms (about 50 feet in the Minas Basin), and that the landforms mark the high-tide level, the Cornwallis Valley must have emerged at least 75 feet since the Pleistocene. As there is evidence of a later submergence, however (*see* following paragraph), this figure is not the total emergence but only the apparent emergence. To obtain the total post-Pleistocene emergence it is necessary to add the amount of apparent emergence to the amount of more recent submergence.

Evidence of Coastal Submergence

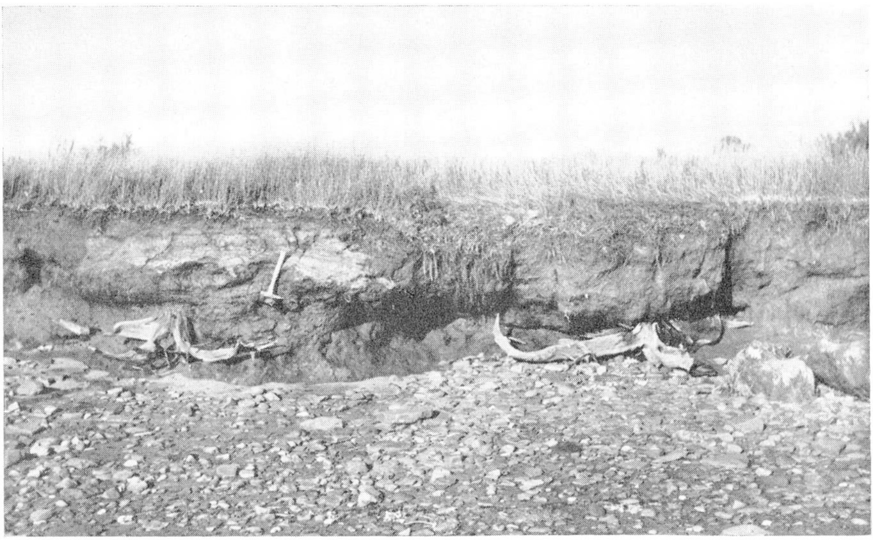
Goldthwait (1924, p. 158) described the "forest primeval" covered by the "famous marshes of Grand Pre". It is exposed on the mud flats behind Boot Island, about a mile east of Evangeline Beach. Pine stumps stand upright and commonly measure 2 feet in diameter. Goldthwait found the lowest visible stump to be 33 feet below the high-tide level, and described the underlying boulder clay as containing "birch bark, twigs, leaves, and other debris common in the woods".

DGC 14-4-50

Plate VI. *Pine stumps in situ on the shore 1,500 feet northwest of the wharf at the mouth of Kennetcook River with a salt marsh in the background.*

Another group of stumps occur on the mud flats 2 miles southeast from Boot Island (op. cit., p. 159). The lowest stump at this locality is 32 feet below the high-tide level.

Pine stumps measuring as much as 2 feet in diameter rest upon a stony surface on the shore 1,500 feet northwest from the wharf at the mouth of Kennetcook River (Pl. VI). Mr. M. Card, who lived nearby[1], could remember when the stumps were far more numerous. Tides and shore-ice steadily deplete the "forest", but the wood is extremely well preserved. The lowest stump observed is at least 20 feet below the high-tide level. A cross-section of marsh exposed along the shore shows upright stumps buried by layers of salt marsh deposits (Pl. VII). The "forest" extends laterally for an unknown distance underneath this covering.



DGC 14–7–50

Plate VII. *Pine stumps buried by marsh growth, at the edge of the salt marsh in the background of Plate VI. Note the stony surface upon which the stumps rest.*

The trees in these "forests" are characteristic of dry upland rather than of low or swampy ground. They therefore must have been growing above high-tide level, and have subsequently been drowned by shoreline submergence, increase in tidal range, or both.

Salt Marshes

The salt marshes of the map-area merit brief mention, because since dyking reclaimed them from the sea they have become fertile farm land. The Acadian French began this reclamation project in 1670, and cultivation has continued to the present.

[1] At the time of the author's visit in 1950.

These marshes are the flood plains of tidal streams, and the fine sand, silt, and clay that compose them were deposited by incoming tidal currents. The organic content is less than 10 per cent, the water content from 2 to 4 per cent (Goldthwait, 1924, p. 135). The main sources of the sediments are the nearby sea-cliffs composed of soft, red strata of the Annapolis Formation, and till. These cliffs recede rapidly during storms.

Gates in the dykes, known as aboteaux, keep out the sea, but allow the removal of freshwater from the land. When an aboteau is torn out by shore-ice, red deposits of fine sand, silt and clay, sometimes more than an inch thick, are laid down by a single tide. The deliberate breaching of dykes and subsequent flooding by tides is a process utilized to renovate land that has degenerated through usage or through bog growth.

The reclamation of bogs is a practice of similar nature. Canals dug from tidal streams into bogs allow them to be flooded by tides, and the bogs thus become filled with mud and are transformed into rich marsh land.

Chapter III

GENERAL GEOLOGY

The rocks examined in the map-area range from Ordovician to Recent. The oldest, metamorphosed sedimentary rocks, underlie the southwestern part of the area, the Carboniferous strata the eastern part, and the Triassic rocks the northern part. Glacial drift covers much of the area. A complete list of formations is given in the following table.

Table of Formations[1]

Era	Period or epoch	Group or formation	Formation or member	Lithology	Thickness (feet)
Cenozoic	Recent			Stream alluvium, tidal alluvium, beach sands and gravels, sand bars	0–(?)
	Pleistocene			Till; some stratified drift	0–75
			Unconformity		
Mesozoic	Triassic	Scots Bay Formation		Arenaceous limestone, calcareous sandstone	16+
			Disconformity		
		North Mountain basalt		Basalt flows	900 ±
		Annapolis Formation	Blomidon shale	Red shale and argillaceous sandstone	800 ±
			Wolfville sandstone	Red conglomerate and sandstone; minor red shale	2,400 ±

[1]Prior to publication of this report, part of this Table of Formations was reproduced in Geol. Surv., Canada, Memoir 314, Mississippian Horton Group of Type Windsor-Horton District, Nova Scotia, by W. A. Bell, 1960. (*Ed.*)

Era	Period or epoch	Group or formation	Formation or member	Lithology	Thickness (feet)
	Angular unconformity				
Palæozoic	Pennsylvanian(?)	Scotch Village Formation		Buff-weathering, grey sandstone	800+
	Mississippian	Windsor Group	undivided	Red shale, limestone, gypsum, anhydrite, salt	1,500+
			Pembroke Formation	Limestone conglomerate and limestone; minor sandstone and shale	0(?)-100
			Disconformity		
			Macumber Formation	Thinly bedded, arenaceous limestone	0(?)–25
		Horton Group		Grey and red shales, siltstone, sandstone; minor conglomerate	4,000 ±
	Angular unconformity				
	Devonian			Porphyritic granite	
	Intrusive contact				
	Silurian	New Canaan Formation		Marine breccia; minor siltstone and slate	1,000+
	Silurian or Older	Kentville Formation		Slate and minor siltstone	1,600 ±
		White Rock Formation		Quartzite and interbedded slate	100–500 ±
	Ordovician	Halifax Formation		Slate and minor siltstone	11,700+

Ordovician

Halifax Formation

Slates in the Wolfville map-area have long been correlated with those of the 'Gold-bearing series' to the southeast which are lithologically similar. As early as 1879, Honeyman remarked upon the similarity of slates in the Wolfville district to the "slates of Halifax", and concluded that, in part, those of the Wolfville district belong to the "great Cambrian series of our Gold fields". Since 1904, they have been regarded as the upper slate division of the Meguma Series[1] (Woodman, 1904).

[1] Now the Meguma Group (Stevenson, I.M., 1959, Shubenacadie and Kennetcook map-areas, Colchester, Hants and Halifax Counties, Nova Scotia; Geol. Surv., Canada, Memoir 302) (*Ed.*).

Faribault (1909) stated that 11,700 feet measured from the base of the "two bands of Whiterock quartzite" to the "conformable" contact with the "whin rock" between the two bridges on Black River, "correspond in character and thickness to the upper or Halifax division of the gold-bearing series of the Atlantic coast." The "whin rock" is identified by Faribault as belonging to the Goldenville Formation, and comprises siliceous beds exposed along the crest of the major anticline that crosses Black River between the two bridges. The section along Black River was subsequently declared the most complete section of the Halifax slates within the province (Bell, 1929).

Distribution and Thickness

Slaty sedimentary rocks of the Halifax Formation underlie the southwest part of the map-area, but are covered in the extreme southwest by connected synclines of younger rocks. An inlier of Halifax rocks occurs along the crest of Grey Mountain at the south border of the map-area, about 5 miles west of Windsor.

Although Faribault (1909) determined a stratigraphic thickness of 11,700 feet for the Halifax Formation, as exposed in the northeast-trending anticline that crosses Black River about 7,000 feet downstream from the south border of the map-area, the writer could not recognize a clear division between the underlying Goldenville quartzite and the Halifax slate in this Black River section. However, since Faribault examined the area, a power dam has been built on the river and the resultant lake has drowned the old stream bed. If the "whin rock" regarded by Faribault as part of the Goldenville quartzite is actually part of the Halifax Formation, the thickness of the Halifax Formation may be more than 12,000 feet.

Lithology

The Halifax Formation is mainly interbedded slate and minor siltstone. The slates are sericitic and characterized by bedding preserved as thin, continuous, uniform bands, rarely parallel to the cleavage. The banding is usually alternating light and dark grey layers but varicoloured slates with green, fawn, and red banding were noted. The bands vary in thickness from a fraction of an inch to over an inch. Carbonaceous and graphitic parts of the formation are dark grey to black with banding generally indistinct or absent. Finely laminated, truncated lenses, evidently caused by currents, are common in the lighter coloured, more siliceous layers. Crystals of pyrite are plentiful and through weathering may impart a rusty colour to exposures. The siltstone is grey to greenish grey, tough, fine grained, and may be finely laminated. Siltstone beds are generally less than a foot thick and are useful for strike and dip determinations in places where banding is absent or indistinct. Minute cross-laminations were noted in several exposures.

As seen in thin section, the slates are composed predominantly of sericite. Angular to subangular quartz grains are most abundant in the lighter coloured layers. The siltstones comprise angular to subangular grains of quartz and feldspar in a matrix of small sericite flakes. Biotite, if present, occurs as small anhedral flakes and is a minor part of the matrix. Quartz is the dominant constituent of the siltstones. Feldspar (albite or sodic oligoclase) rarely forms as much as 10 per cent of the rock, except in the siliceous beds along the crest of the anticline crossing the upper part of Black River. These beds may be termed feldspathic siltstone.

Structural Relations

Rocks of the Halifax Formation have a marked regional cleavage parallel to the northeast trend of the folding.

Attempts to trace horizons on the basis of colour were successful to a limited extent, but such a procedure was found to be misleading because many of the slates change colour along strike. Much of the colour variation is apparently of secondary origin and caused by superficial agencies such as weathering or downward migration of iron leached from overlying material. Faribault (1909) remarked upon this phenomenon as exhibited by the slates immediately underlying the White Rock Formation. At the power dam on Gaspereau River, 4,500 feet downstream from the Black River-Gaspereau River junction, the slates immediately underlying the White Rock Formation are dull red to fawn. However, less than a mile to the southwest, at the power house on Black River near its junction with Gaspereau River, slates of the same horizon are dark grey. The change in colour between the two localities is gradual. Faribault (op. cit.) described a transition phase of mottled red and dark grey slates between these two localities, in which the red colour is confined mostly to lines of cleavage and joints. Bell (1929, p. 28) described greenish and purplish slates grading into dark grey slates in Duncanson Brook, and noted that the slate fragments in basal Horton beds are "dominantly made up of these greenish and purplish slates, which suggests that the lighter colours may be explained by pre-Horton oxidation and weathering".

Such changes in colour have caused some doubt that the Halifax and the White Rock Formations are conformable. However, the conformable Halifax-White Rock contact is well exposed at the power dam on Gaspereau River, so there can be little doubt that these variations in colour are, in part at least, of secondary origin.

The base of the Halifax Formation may be, as Faribault described (1909), near the crest of the anticline crossing the upper part of Black River. The sequence becomes progressively more siliceous towards the crest of the anticline, and Faribault identified those siliceous beds exposed for a width of a quarter of a mile along the crest as part of the underlying Goldenville Formation. He described the contact between the Goldenville and Halifax as conformable. Some uncertainty still exists, however, as to whether or not these siliceous beds are part of the Goldenville Formation.

Origin and Age

The graptolitic *Dictyonema websteri* was first found about the middle of the nineteenth century (*see* p. 3). Subsequent discoveries have been made, and in 1906 Fletcher stated "*Dictyonema* has been found in nearly all the brooks from Harding (Angus) brook below Gaspereau village to Sharpe brook south of Cambridge station".[1]

[1] Cambridge is about 4 miles west of Kentville.

It was not, however, until Faribault (1909) worked out the structure of the district that the stratigraphic positions of the *Dictyonema*-bearing slates became evident. On the basis of his report, these slates can be placed about 6,700 to 7,700 feet stratigraphically *below* the White Rock Formation. Faribault's observations were evidently overlooked by his successors, for the slates underlying the White Rock Formation have been repeatedly referred to as of Precambrian age.

Fossil localities mentioned by Fletcher (1906) were visited by the writer during the field season of 1950. Specimens of *Dictyonema* were found at two of them, Harding (Angus) and Duncanson Brooks. To prove that the *Dictyonema*-bearing slates were stratigraphically *below* the White Rock Formation and consequently in the Halifax Formation, the writer examined the Black River section for places where the cleavage and bedding of dark grey slates are almost parallel, for only in such places are the graptolites likely to be preserved. Such a place was found in the by-pass on the upstream, west, side of the Lumsden power dam, and there, in less than an hour, specimens of *Dictyonema* were found. The slates at this locality are about 7,750 feet stratigraphically below the White Rock Formation.

A second new graptolite(?) locality was found on the west side of the Kentville-New Canaan highway, just south of a thick diorite dyke 1½ miles south from Kentville. The slates there are about 2,800 feet stratigraphically below the White Rock Formation. Fossils from his locality cannot be generically identified.

As a result of these fossil discoveries, graptolite fossils are now known to occur in slates of the Halifax Formation at horizons ranging from 2,800 to 7,750 feet stratigraphically below the White Rock Formation. The slates in which the graptolites are found are of various colours. On Harding Brook, they are fawn, red, grey, purple, and green; on Duncanson Brook, dark grey; on Black River, dark grey to black; and on the New Canaan-Kentville highway, light greenish grey.

Fossils collected by the writer at the following three localities were identified as *Dictyonema* sp., probably *D. websteri* Dawson, by Dr. Alice E. Wilson of the Geological Survey of Canada:

(1) Harding Brook, 85 feet upstream from the Halifax-Horton contact;

(2) Duncanson Brook, just below the water reservoir dam;

(3) Black River, in the by-pass on the upstream, west, side of Lumsden power dam.

These specimens were re-identified in 1955 as *Dictyonema flabelliforme* (Eichwald) *sensu lato* by Dr. D. E. Thomas, Chief Government Geologist for Victoria, Australia. Dr. Thomas placed these fossils stratigraphically at the base of the Ordovician system.

In 1960 the Geological Survey graptolite collections from the above localities, together with three specimens of *Dictyonema websteri* Dawson from the Redpath Museum, McGill University, Montreal, were sent for further examination to

Professor O. M. B. Bulman of the University of Cambridge, England. The type specimens of *Dictyonema websteri* cannot be located, but the three specimens from the Redpath Museum were collected at the type locality of the species, near New Canaan. Professor Bulman verified that the Geological Survey specimens were *Dictyonema websteri,* but added the following comment:

> Preservation of the *Dictyonema* specimens is poor, and unfortunately there is no proximal end visible on any of them; but they very closely resemble *D. flabelliforme sensu lato* and I am inclined to support Dr. Thomas in identifying them as this species, with the implication that the strata involved are of Lower Tremadoc age.

Of the *D. websteri* specimens from the Redpath Museum, Professor Bulman reported:

> These are considerably better preserved, and several proximal ends are visible. It can now be asserted that the rhabdosome is undoubtedly siculate. In general form, dimensions and spacing of the stipes, and number of thecae, the material is not unlike *D. flabelliforme,* but the dissepiments appear to be rather stouter and less frequently spaced. Furthermore, in this material, the initial branching of the rhabdosome seems to be more rapid and the rhabdosome appears to develop from more than three initial branches. Four initial branches are believed to occur in *D. flabelliforme parabola,* but the New Canaan material does not resemble that variety in other respects. I confirm my previous identification of it as *D. flabelliforme sensu lato.*

Professor Bulman examined the specimens collected from the west side of the New Canaan-Kentville highway, 1½ miles south from Kentville, and concluded that the fossil form was probably fucoidal, with nothing indubitably graptolitic about it. These fossils are not associated with *Dictyonema.*

On the strength of the fossil determinations, the Halifax Formation is now regarded as of Early Ordovician age.[1]

The above fossils indicate that most, if not all, of the Halifax Formation was deposited under marine conditions. *Dictyonema* forms probably led a pseudoplanktonic mode of existence attached to floating objects such as seaweed. The fossil evidence, together with the common cross-lamination of beds, the thickness and uniformity of the formation, and the clastic nature of the slates and siltstones, lead to the conclusion that the Halifax Formation was deposited in fairly shallow and commonly muddy water in a marine, geosynclinal basin. The alternating layers of fine and coarse material may have been due to seasonal deposition.

Silurian or Older

White Rock Formation

The name 'Whiterock quartzite' was used by Faribault (1909) for the quartzite rocks immediately above the Halifax Formation in the Gaspereau map-area. The writer has changed this to White Rock Formation, because the village from which this rock-unit derives its name is White Rock Mills rather than Whiterock,

[1] Subsequent field work to the southwest has substantiated this age assignment (Smitheringale, W. G., 1960, Nictaux-Torbrook Map-area, Annapolis and Kings Counties, Nova Scotia; Geol. Surv., Canada, Paper 60-13). (*Ed.*)

and the unit commonly includes more slate than quartzite. White Rock Mills was named for the quartzite upon which it was built.

Distribution and Thickness

The White Rock Formation outlines two connected synclines of younger rocks overlying the Halifax Formation in the southwest part of the map-area. The formation was easily traced throughout most of its mapped extent. In two places, however, its presence on the geological map is entirely interpretive, as the formation is not exposed. The first of these is 2 miles southwest of the Black River-Gaspereau River junction. The formation thins to the southwest as it approaches this locality, and is presumed to continue thinning until cut off by the granite batholith. The rugged topography and dense vegetation of the youthful valley of Gaspereau River have so far prevented tracing the formation to the granite contact. The second place where the formation has not been traced is along the north limb of the northern syncline east of the Deep Hollow road. The formation is assumed to continue from Deep Hollow road northeasterly under overburden and to pass beneath Annapolis strata, thus matching the south limb of this syncline, which has been traced beneath the Annapolis strata.

The writer traced the White Rock Formation beyond the western border of the Wolfville map-area. Both quartzite beds in the formation were observed at a locality 3 miles southwest of New Canaan, about 1,000 feet west of the Kentville-New Ross highway. There the formation is about 180 feet thick; the upper quartzite bed is about 30 feet thick, the lower, about 15 feet.

Known thicknesses of the formation vary within the map-area from about 100 feet to more than 450 feet. It probably nowhere exceeds 600 feet, although this thickness may be closely approximated east of Deep Hollow road. Sections suitable for measurements of thickness are not numerous and may be summarized as follows:

	Thickness (feet)		
	Upper bed	Lower bed	Whole formation
(1) in the ditches along the Kentville-New Canaan road	75	14	107
(2) along the road trending southeasterly from New Minas	92	33	345
(3) on the east side of Deep Hollow road, 700 feet from the road		87	
(4) at the Gaspereau River dam, 4,500 feet downstream from the junction of Black and Gaspereau Rivers		83	
(5) at the lower power station on Black River, just upstream from Gaspereau River		45	

The formation is approximately 500 feet thick, 2,000 feet southwest of the third locality. It is about 200 feet thick, 6,000 feet southwest of the junction of Black and Gaspereau Rivers, but in a small stream 5,000 feet farther southwest, only one 15-foot bed of quartzite is exposed, and no outcrops of the formation were recognized farther to the southwest.

Lithology

The White Rock Formation consists of two massive quartzite beds separated by slate; the slate commonly is thicker than the quartzite. The lower quartzite bed is thinner than the upper, at least in those sections where both beds are exposed. Locally, thin beds of slate occur in the quartzite.

The slate is lithologically indistinguishable from that of the Halifax Formation. The quartzite is white, pale yellow to pale brown, or pinkish, well indurated, even and medium grained, and very tough.

In thin section, the quartzite is seen to be an even- and medium-grained mosaic of quartz, with little sericite and even less hematite in the matrix. Minor chert grains were noted in a few thin sections. Most of the rock is pure, but it becomes dark grey and more sericitic at the slate-quartzite contacts. It is most highly metamorphosed at White Rock Mills, where it is more closely folded than elsewhere. There, quartzite specimens obtained from small, close folds are composed of elongated and aligned quartz grains, with small amounts of sericite and mylonitized quartz in the matrix. Specimens from several localities, particularly those from outcrops on the slightly travelled road trending southeasterly from New Minas, contain quartz grains showing authigenic overgrowths. The original, well-rounded outlines of such quartz grains are preserved by minute, dark particles that were on the original grain surfaces before formation of the overgrowths. Quartzite of the White Rock Formation differs from siliceous beds in the underlying sequence by its lack of feldspar and the small amount of sericite matrix.

Structural Relations

Current ripple-marks were noted in quartzite exposed on the east side of Deep Hollow road 5,000 feet north of White Rock Mills. Similar structures were noted in quartzite exposed in the small north-flowing brook 4,000 feet east of Deep Hollow road.

The conformable Halifax-White Rock contact is best exposed on the south side of Gaspereau River dam. There, two thin beds of slate occur within the lower quartzite, near the base, and the quartzite at the contact is darker in colour than normal. The sequence is as follows, from the top downward:

Description	Thickness (feet)
White Rock Formation	
Slate, predominantly dark grey	(not measured)
Quartzite, pale yellow to pale brown	68
Slate, varicoloured	4
Quartzite, light grey	4
Slate, varicoloured	2.5
Quartzite, grey	4
Halifax Formation	
Slate, varicoloured	(not measured)

The conformable contact between the lower quartzite bed and overlying White Rock slates is well exposed on the east side of Deep Hollow road 5,000 feet north of White Rock Mills. The quartzite has an interbedded thin layer of slate, 2 to 3 feet thick near the contact, and is much darker there—as at its lower contact—than in the middle of the bed. The overlying slates are dark grey and do not exhibit colour banding, but differential weathering has exposed the bedding.

No good exposure of the contact between the upper quartzite bed and the overlying slates of the Kentville Formation was found, but the overlying slates are believed to be structurally conformable to the White Rock Formation, as stated by Faribault (1909).

Origin and Age

The current ripple-marking, the well-rounded shape and well-sorted nature of quartz grains in the quartzite where overgrowths are discernible, the presence of slate lithologically indistinguishable from the underlying marine slates, and the conformable relationship to underlying marine strata lead to the conclusion that the White Rock Formation was laid down under marine conditions in fairly shallow water. During deposition of the quartzite beds some sorting action was operative that reduced the amount of fine or angular material. The quartzite beds are probably not continuous over a large area as is indicated by the southwesterly thinning. They were probably deposited on a shelf over which the water was shallowest during times of quartz sand formation, giving rise to better sorting than in deeper water where muds and silts were depositing. Each quartz sand bed was probably deposited nearer a shore to the east than were the finer sediments of the formation, and current action probably played an important role in distributing these coarser clastics.

No fossils have been reported from the formation and none was found by the writer. The formation is of Ordovician or Silurian age, inasmuch as underlying Halifax slates are Ordovician and stratigraphically higher New Canaan beds are Silurian.

Kentville Formation

The name Kentville was proposed by Ami (1900) for Silurian rocks near that town. His description left much to be desired, for if interpreted literally, it meant that the Kentville Formation included all pre-Carboniferous sedimentary rocks in the region around Minas Basin.

Since Ami's report, detailed field work has led to the recognition of the Halifax slates and the White Rock quartzite. Faribault (1909) was the first to realize that the *Dictyonema*-bearing slates that Ami had included in his Kentville Formation are within the Halifax Formation, stratigraphically below the White Rock Formation. Geologists who followed Faribault in the Wolfville district incorrectly assigned *Dictyonema*-bearing slates to the Kentville Formation on the assumption that the slates stratigraphically below the White Rock quartzite were Halifax, unfossiliferous, and belonged in the Precambrian.

Despite the ambiguity and vagueness of Ami's original description of the Kentville Formation, the name has been used repeatedly by succeeding writers in numerous geological reports and maps including many published by the Geological Survey of Canada, and its usage has made it practically synonymous with slates near Kentville. It is therefore considered inadvisable to discard the name, but the formation is here redefined.

Distribution and Thickness

The Kentville Formation is exposed only in the southwest quarter of the map-area, from 2½ to 5 miles south of Kentville, and lies within the outcrop area of the White Rock Formation. On the southwest it is cut off by granite and covered by the New Canaan Formation. The formation is about 1,600 feet thick.

Lithology

The interbedded slate and minor siltstone are lithologically indistinguishable from those of the Halifax Formation. The slates vary in colour and are characterized by prominent banding except where dark grey or black. Siltstones are grey, tough, and fine grained, similar to those stratigraphically above the "whin rock" on Black River. Detailed descriptions of Halifax rocks apply equally well to Kentville rocks.

Structural Relations

Structural features of Kentville rocks are similar to those of Halifax rocks.

The Kentville Formation lies apparently conformably upon the White Rock Formation. The writer found no locality where the White Rock-Kentville contact was exposed for more than a few feet, and its nature was not definitely established. The Kentville is conformably overlain by the New Canaan Formation.

Origin and Age

The similarity between Kentville and Halifax rocks leads to the conclusion that both formations were deposited under similar conditions, that is, in fairly shallow water, in a marine, geosynclinal basin.

No fossils have been found in Kentville slates. However, if localities could be found in these slates where the bedding and cleavage are parallel, or nearly so, intensive splitting of the rocks might yield specimens of graptolites.

The formation is probably of Silurian age, inasmuch as immediately overlying conformable New Canaan beds are apparently Silurian.[1]

Silurian

New Canaan Formation

The name New Canaan is proposed by the writer for a formation of marine sedimentary breccia containing fragments predominantly of volcanic origin, and

[1] Silurian graptolites have since been reported from Kentville slates to the southwest (Smitheringale, W. G. Nictaux-Torbrook Map-area, Annapolis and Kings Counties, Nova Scotia; Geol. Surv., Canada, Paper 60-13). (*Ed.*)

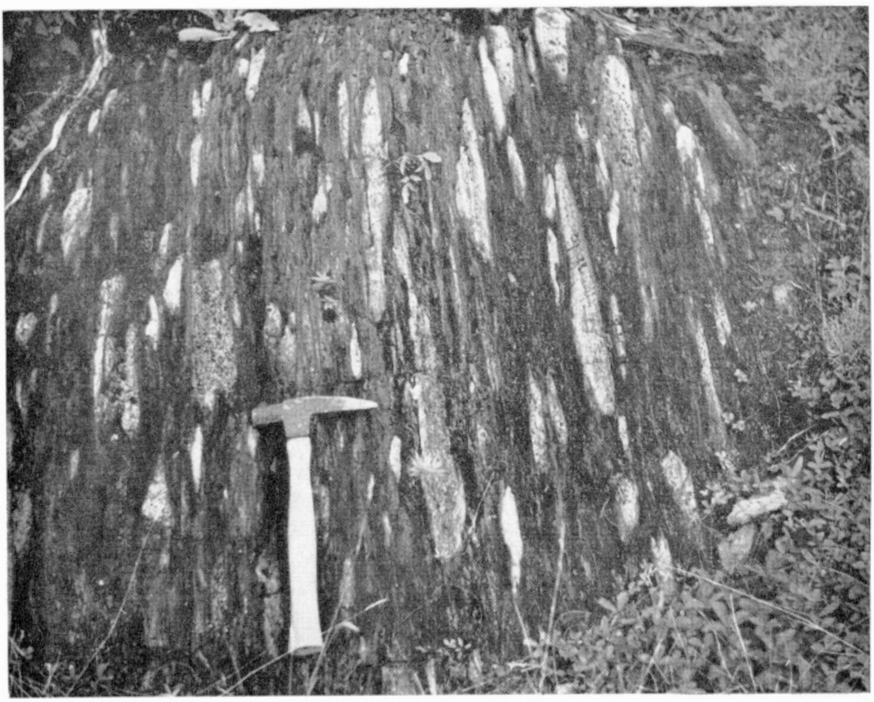
minor dark grey siltstone, slate, and possibly lava, conformably overlying slates of the Kentville Formation in the New Canaan district. The top of the formation is not exposed within the map-area.

Distribution and Thickness

New Canaan rocks form two connected southwest-pitching synclines extending from a mile northeast of New Canaan southwesterly beyond the west border of the map-area. The formation is cut off in the southwest corner of the map-area by granite of South Mountain. The synclines are about 1½ miles wide at the west border of the map-area. The thickness of the formation probably exceeds 1,000 feet.

Lithology

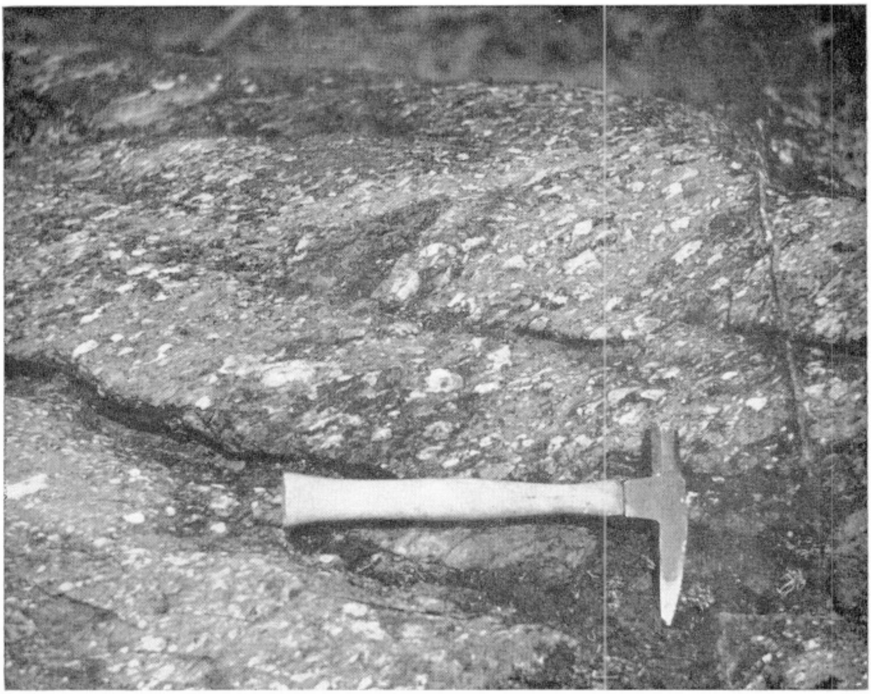
New Canaan rocks are predominantly breccias composed of volcanic detritus with associated beds of siltstone, slate, and probably limestone. The fragments included in the breccias may be subdivided into: (1) lava with abundant amygdules, usually calcite, less commonly of quartz or chalcedony (*see* Pl. VIII); and (2) dense, in part lava and in part very fine grained sedimentary rocks or tuff (*see* Pl. IX). The tuff commonly resembles chert. Exposures as a rule have either



DGC 9-2-50

Plate VIII. *Marine breccia of the New Canaan Formation, containing amygdaloidal fragments elongated parallel to the foliation. New Canaan, 7,000 feet south and slightly east of the school house.*

one or the other of these types of fragments, rarely both. They are rounded to angular, mostly subangular, and although the amygdaloidal fragments are commonly elongated parallel to the northeast-trending foliation, those that are fine grained rarely exhibit much distortion. Fragments are conspicuous on the weathered surface of exposures because of their lighter colour against the dark matrix. The matrix is calcareous, dark grey, and exhibits a foliation that is rarely as well developed as that of slate beds. In places, a medium to coarsely crystalline matrix of calcite comprising about 50 per cent of the rock was noted.



DGC 7-7-50

Plate IX. *Marine breccia of the New Canaan Formation, containing dense fragments. Quartz veinlet on right of hammer. New Canaan, 5,000 feet northwest of the school house.*

In thin section, all amygdaloidal and some fine-grained fragments are seen to contain innumerable small feldspar laths that impart a felt-like appearance characteristic of lavas of an intermediate composition. Irregular masses of chlorite and actinolite, apparently replacements of ferromagnesian minerals, and innumerable blebs of opaque oxides are also present. Thus, although the fragments are now altered and feldspars are albitic in composition, they were undoubtedly derived from volcanic rocks of an intermediate, perhaps andesitic, composition.

In thin section, most of the fine-grained fragments appear to be very fine grained sedimentary rocks, perhaps of pyroclastic origin. Their matrix commonly contains small altered rock fragments, apparently of volcanic origin, in part at least. In some specimens the matrix is almost entirely composed of crystalline calcite.

A smaller part of the New Canaan Formation consists of siltstone and slate. The former is a very fine grained, dark grey rock exhibiting poorly developed foliation. As seen in thin section, it is composed of quartz and sericite with small amounts of biotite and chlorite. The slate is dark grey and sericitic.

Only one outcrop that may be part of a flow was noted in the formation. This was a small exposure of greenstone cut by narrow veinlets of chrysotile on the west side of the road running southwesterly past the New Canaan school.

Rocks of this formation have undergone the same low-grade metamorphism as the underlying Halifax, White Rock, and Kentville Formations, and have developed a foliation parallel with that of the underlying strata.

Structural Relations

There are no good sections of the New Canaan Formation in the Wolfville map-area from which an accurate stratigraphic sequence can be established. Field work to the west may reveal such information.

Bedding is commonly discernible as slaty bands near the base of the sequence, but attitude determinations are difficult to obtain in the overlying coarser grained beds.

The New Canaan Formation is structurally conformable with the underlying Kentville. That it is also stratigraphically conformable is indicated by the increase in amount of slate in the lower part of the formation downwards to the contact with the Kentville Formation.

Origin and Age

Fossils found in New Canaan beds disclose much information about the conditions under which the rocks were deposited. The following identifications were made by A. E. Wilson, Geological Survey of Canada:

Locality	Fossils
4,800 feet slightly east of south from the New Canaan school, 400 feet northeast from the small bridge over the headwaters of Moore Brook, on the northeast side of the driveway leading to Mr. Tetzlaff's farmhouse.	Crinoid stems; pentamerid brachiopod apparently of *Conchidium*-type; brachiopod fragment; tabulate coral, too worn to show pores if present; several other obscure fragments.
3,300 feet northwest from the above locality, 50 feet east from the bridge over Moore Brook that is on the highway running southwesterly past New Canaan school.	Crinoid stems; pentamerid brachiopod apparently of *Conchidium*-type.

These fossils are evidence that New Canaan strata were deposited in marine, fairly shallow, warm water. The rock at the first locality is breccia with dense fragments, that at the second locality is dark grey slate. The coral may have been carried by currents into this area of deposition from farther off shore.

Future work to the west of the map-area will probably establish what can now only be postulated, namely, that the sequence of New Canaan rocks in the Wolfville map-area grades southwesterly into marine limestone and lava flows. Present evidence strongly suggests that the source of the volcanic material in New Canaan breccias was to the southwest, and the fragmental nature of the rocks probably reflects shallow-water, near-shore deposition in a sea that deepened in that direction.

The fossils recovered from the New Canaan Formation are badly deformed, but the presence of brachiopods apparently of *Conchidium*-type would indicate a Silurian age.

The above fossils are similar in type and age to those reported by Dawson (1891, p. 571) from limestones in the general vicinity of New Canaan, and the containing beds were considered by Hall as equivalents of the Niagara Formation of New York State. The New Canaan Formation is, therefore, regarded as a marine sequence of Silurian, probably Niagaran, age.

Devonian

Granite

Granite outcrops over large areas in the upland region of south and central Nova Scotia, and the granite batholith that projects into the map-area is by far the largest in the province. The youngest rocks intruded by it are Early Devonian; the oldest rocks overlying it are of Early Mississippian age.

Distribution

Granite occupies a small triangular area of one quarter square mile in the southwest corner of the map-area. The batholith of which it is a part extends southeasterly for 60 miles to the Atlantic coast in Lunenburg and Halifax counties, and southwesterly for 94 miles into Yarmouth and Shelburne counties.

Lithology

The granite is porphyritic, with large euhedral to subhedral phenocrysts of white to salmon-red potash feldspar, averaging between 2.5 and 5 cm long, in a coarse-grained matrix of quartz, potash feldspar, plagioclase, and biotite crystals, averaging about 0.5 cm in diameter. The rock has a reddish or whitish appearance depending upon the colour of the potash feldspar. The potash feldspar phenocrysts show excellent contact Carlsbad twinning.

In thin section, the matrix is seen to be a hypidiomorphic aggregate of quartz, potash feldspar, oligoclase, and biotite. A few garnet crystals are locally present. Potash feldspar crystals in the groundmass have a poikilitic texture as a result of inclusions of plagioclase and biotite. Oligoclase crystals exhibit contact Carlsbad twinning as well as albite twinning. The mineral composition of the granite varies from place to place, but is approximately potash feldspar (45%), quartz (20%), oligoclase (20%), and biotite (15%).

Structural Relations

The contact between the granite and surrounding rocks is covered, in the map-area, with glacial drift and swamps. Just south of the area, however, along Gaspereau River, steep cliffs of granite partly hidden by dense evergreen growth and slumped overburden give way northerly to similar cliffs of slate. Even here the exact contact is difficult to recognize because the slates are metamorphosed to siliceous gneisses and are cut by innumerable, irregular, granitic dykes.

Contact Metamorphism

For about 3,000 feet downstream from the contact on Gaspereau River, the slates show contact metamorphic effects and contain irregular apophyses of the granitic batholith. However, similar effects and apophyses are not present in slates to the west that are only half this distance (horizontally) from the contact. The greater width of the contact-metamorphosed zone along Gaspereau River may indicate (1) a closer position to the top of the granitic batholith because of the 250-to-300-foot youthful river valley in which the contact is exposed, or (2) the top of the batholith may dip northward more gently near the river valley than farther west, so that the top is nearer the surface.

At and near the contact, the slates are metamorphosed to siliceous gneiss, a banded rock with laminae averaging about 0.1 inch thick but varying in thickness from several times the average to a fraction of it. Dark grey, medium-grained layers containing abundant mica alternate with light grey, fine-grained, more siliceous layers. In thin section, the dark grey layers are seen to be medium grained and consist of subhedral to anhedral muscovite and biotite flakes with subordinate anhedral quartz and albite. Poikilitic, subhedral to anhedral andalusite crystals are common. The light grey layers are composed of a mosaic of fine-grained quartz and albite, predominantly the former, with minor amounts of anhedral biotite and muscovite. The mica in the gneiss is commonly chloritized in part. The apparent lack of disturbance of the attitudes of the metamorphosed slates at and near the contact was noted long ago by Dawson (1891, p. 501) and Bailey (1898, pp. 105, 107, 123).

Origin and Age

The manner in which granite cuts off closely folded Early Devonian rocks southwest of the map-area and Silurian and Ordovician rocks within the map-area without apparently disturbing their attitudes suggests that the granite was intruded quietly, probably after most of the post-Early Devonian, pre-Early Mississippian folding took place.

Early Devonian rocks in several structural basins along the north border of the batholith, west of the map-area, in Kings, Annapolis, and Digby counties, are intruded by the batholith. The nearest of these basins is about 25 miles southwest of Kentville. The granite is overlain by sedimentary rocks of the Lower Mississippian

Horton Group south and west of Windsor. From field relationships, therefore, a Devonian age is well established for the granitic batholith.[1]

Mississippian

Horton Group

The Horton Group is a succession of grey and red shales, sandstone, grit, and minor conglomerate. It is separated from older rocks by an angular unconformity, and is conformably overlain by the lowest strata of the Windsor Group.

Bell (1929, pp. 30-45) divided the Horton Group into two formations: the lower, the Horton Bluff Formation; and the upper, the Cheverie Formation. He estimated the Horton Bluff Formation to be from 1,000 to 3,400 feet thick and the Cheverie Formation at least 600 feet thick. The writer was not able to use these formations as map-units, due primarily to the scarcity of outcrops and marker horizons.

Distribution

Horton strata outcrop over the eastern and central parts of the map-area, west of a line running southwesterly from Walton to Hantsport and continuing southwesterly along the southeastern foot of Grey Mountain. An outlier of Windsor strata, extending from Bramber to Kempt Shore, overlies Horton strata in the Cheverie district. The western limit of Horton rocks is along the northeast flanks of South Mountain and Wolfville Ridge. An inlier of older rocks is exposed along the crest of Grey Mountain. To the north, Horton rocks pass under strata of the Annapolis Formation near the shore of Minas Basin.

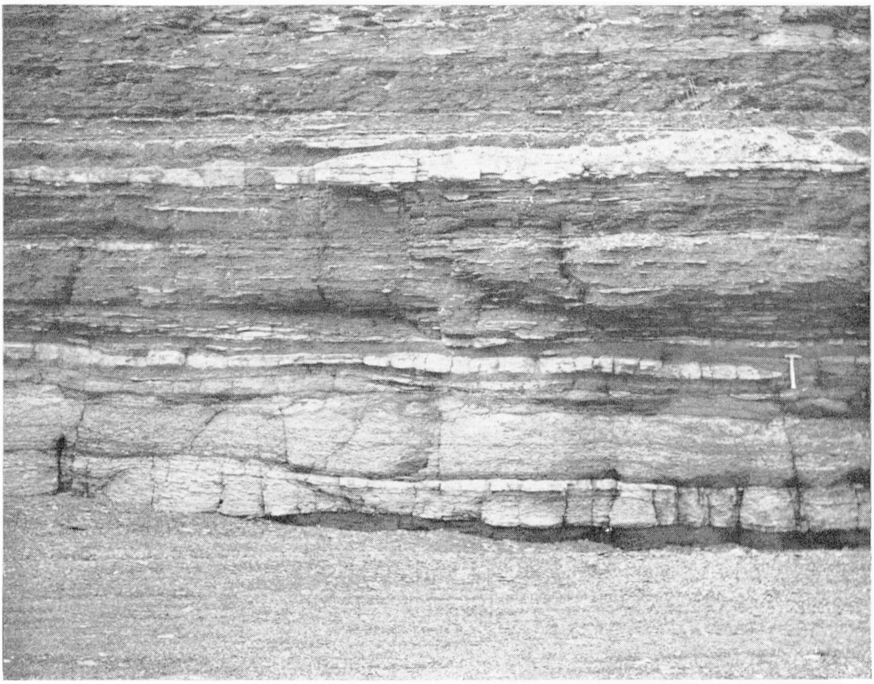
Lithology

The lower one third to one half of the Horton Group consists of interbedded light grey to reddish feldspathic quartz conglomerate, grit, and sandstone interbedded with lesser amounts of grey to dark grey siltstone and shale, and minor red shale. The conglomerate comprises rounded pebbles—vein quartz, quartzite, and dark slate—in a matrix composed predominantly of angular quartz grains. The grits and sandstones are similar but for the absence of water-worn pebbles. These coarse rocks are commonly silicified to quartzites. The sandstone is commonly crossbedded. The fine-grained rocks (siltstone and shale) are notable for the development of sericite on bedding planes, current ripple-marking, crossbedding, and the thinness of beds—less than 2 inches on the average. This part of the Horton Group is well exposed on Harding and Duncanson Brooks, which join Gaspereau River at Melanson, 2 miles southeast of Wolfville.

The middle one quarter to one third of the group consists predominantly of dark grey, commonly slaty, shale. Flat, nodular masses of iron sulphide are found

[1] Since this manuscript was submitted, several specimens from this granite batholith within 30 miles of the Wolfville map-area have been dated isotopically at the Massachusetts Institute of Technology and the Geological Survey of Canada. The potassium-argon ages they have yielded range between 350-370 m.y. (*Ed.*)

along bedding planes; calcareous concretions, usually restricted to soft, calcareous beds, are numerous. Much of the shale is arenaceous and an increase in silica content gives rise to siltstone, little different in appearance from the shale. Thin, lenticular beds of calcareous siltstone and sandstone, averaging less than 6 inches thick, are interbedded with the shales. The calcareous beds are composed of subrounded to angular (predominantly the latter) quartz grains in a matrix of fine calcite. They are conspicuous in outcrops because of their lighter colour and because they stand out above the enclosing shale on the weathered surface. A few thin beds of medium-grained orthoquartzite were noted. This part of the Horton Group is well exposed in sea-cliffs at Horton Bluff, on the west shore of Avon River (Pl. X).



DGC 11-4-50

Plate X. *Dark grey shale and thin beds of calcareous siltstone in the Horton Group at Horton Bluff. Note lenticular nature of strata. Hammer near the base of the cliff gives scale.*

The upper one fifth to one third of the group consists predominantly of brown to red shales, arkose grit, and grey sandstone. Grey arkose grit with subordinate brown to red shale and arkose in the lower half of this part of the Horton, gives way to brown to red shale and minor grey shale and sandstone in the upper half. The arkose grit is composed predominantly of angular fragments of quartz and pink potash feldspar, both commonly more than half an inch across. Pebbles are scattered throughout the grit, but are of importance only in conglomeratic lenses. They are rounded and include vein quartz, quartzite, and slate. The shales are soft and commonly non-laminated, and their weathered surface is hackly. The sandstone consists of subrounded to subangular grains of quartz with subordinate amounts of chert, quartzite, and slate fragments. It is evident that authigenic overgrowths, noted on a few quartz grains, account in large part for the angularity of detrital grains as is shown by original rounded outlines discernible in some quartz grains and by the rounded outlines of many rock fragments. The lower beds of this part of the Horton Group are well exposed in sea-cliffs 2 miles northwest of Hantsport, on the shore of Avon River (Pl. XI). The upper beds are well exposed in sea-cliffs and along the shore from Kempt Shore northerly to the fault at Johnson Cove, a mile north of Cheverie. Some of the sea-cliffs between these points are of overlying Windsor strata.

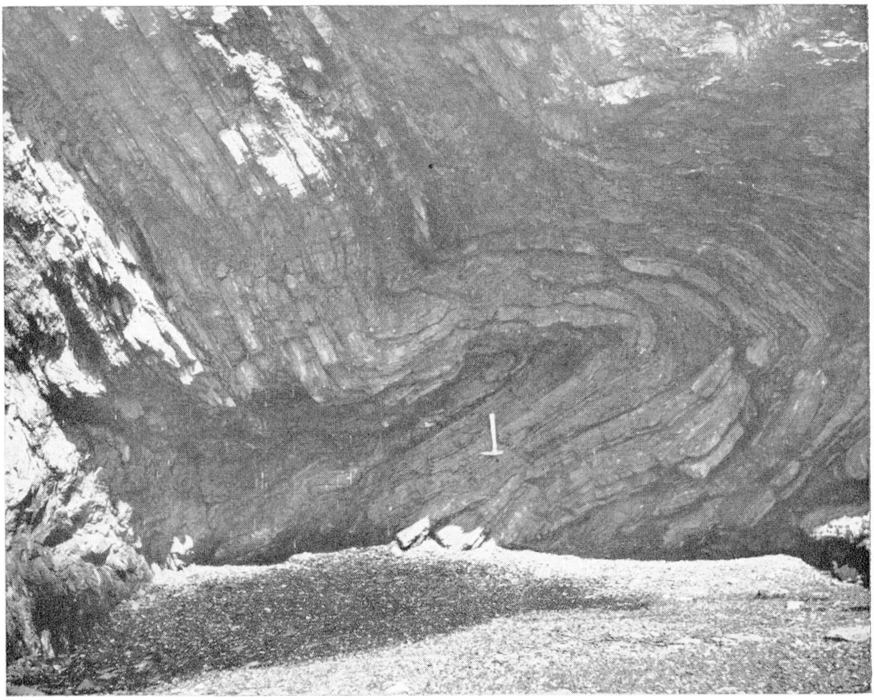
DGC 9-6-50

Plate XI. *Upper Horton shale channelled by overlying arkose grit, west shore of Avon River, 2,300 feet southeast of Blue Beach. Hammer on shale near channelling shows scale.*

Structural Relations

Current ripple-marking is a prominent feature of the Horton rocks, whereas oscillation ripple-marks are relatively rare. Crossbedding is characteristic, on a minute scale in fine beds and on a larger scale in coarser beds. Bell (1929, pp. 36, 42) recognized numerous poorly stratified argillo-arenaceous deposits containing upright tree stems and rootlets as fossil soils. Strata are lenticular and can be used as horizon markers only for short distances. They change in lithology along the strike and are commonly indistinguishable from others of different stratigraphic positions. Channelling phenomena are particularly well developed in the lower half of the upper part of the group (Pl. XI). Grit beds are channelled into underlying shales and, to a lesser extent, vice versa. Balls and angular fragments of shale are included in arkose grit, and fragments of arkose grit and arkose are isolated in shale.

The structure of the Horton Group is more complex to the northeast. On the west side of Avon River, strata are gently folded, whereas to the northeast at Walton, strata have been thrown into sharp-angled recumbent folds (Pl. XII) and are displaced by innumerable faults. It is difficult to ascertain whether the faults are normal or thrust in displacement because of their ill-defined nature and the similarity of strata on either side. Drag-folds are useful aids in some places.



DGC 13–2–50

Plate XII. *Close-up view of a tight fold in Horton beds near the Walton lighthouse.*

An angular unconformity separates the Horton Group from older rocks. The basal bed of the group is a breccia composed of angular to subrounded fragments of underlying slaty rocks cemented with argillaceous material. Some fragments are several inches long. The unconformity is best exposed on Harding Brook, 3 miles southeast of Wolfville, where the basal breccia is about 5 feet thick.

Origin and Age

The lenticular nature of strata, current ripple-marking, crossbedding, channelling phenomena, and other properties common to the Horton Group are characteristic of fluviatile deposits.

Abundant plant remains, commonly in situ in fossil soil beds, and the unoxidized nature of the iron present in the lower part of the group indicate that these strata were not subjected to intensive, subaerial, oxidizing conditions. The above observations substantiate the conclusion of Bell (1929, pp. 37-38) that the lower part of the group was formed as fluviatile deposits in a climate of abundant rainfall. The coarse, feldspathic nature of the lowest part is evidence of an intermontane environment of deposition.

Fish remains and ostracod-bearing, laminated shales in the middle part of the group indicate there was a subordinate amount of deposition in bodies of water. Flood plains of rivers would supply the conditions necessary for formation of the fine-grained middle part of the group, that is, a fluviatile environment with temporary bodies of water.

Excellently developed channelling phenomena in the lower half of the upper part of the group, together with the freshness of feldspar and biotite grains, and the coarse nature of the rocks, indicate rapid deposition by torrential currents in an intermontane environment. The low carbon content and the oxidized condition of the iron in the shale and sandstone in the upper half of the upper part of the group indicate a greater amount of subaerial exposure under oxidizing conditions than that experienced by lower strata. The evidence leads to the conclusion that the climate became progressively more arid during deposition of the upper part of the group.

Much of the material comprising the coarser beds of the group can be traced to older rocks to the south. In addition, current ripple-marking and crossbedding throughout the group agree in indicating that the sediments were deposited by northeasterly flowing currents.

Plant and fish remains and ostracod fossils prove that the Horton Group is of early Mississippian age.

Windsor Group

The Windsor Group, of late Mississippian age, is a succession of relatively soft calcareous and arenaceous rocks with interbeds of calcium sulphate. In the northeast part of the map-area, Windsor rocks have been divided into three map-units; elsewhere they are undivided.

Macumber Formation

Macumber is the name given by Weeks (1948, p. 20) to the lowest formation of the Windsor Group. It conformably overlies the Horton Group, and is disconformably overlain by the Pembroke Formation.

Distribution and Thickness

This formation was readily traced in the northeast quarter of the map-area; it could not, however, be traced on the west side of Avon River. The lack of these basal Windsor beds to the south may be apparent rather than real. In the sea-cliffs and along the shore between the wharf at Summerville and the mouth of Cogmagun River, thinly bedded limestone strata similar to those of the Macumber Formation were observed underlying a thin limestone breccia bed that in turn underlies gypsum. This sequence is similar to that of the thicker Macumber, Pembroke, and Windsor gypsum strata in the northeast quarter of the map-area, where each division is prominent and can be easily mapped. It is probable that the thinly bedded limestones are the Macumber Formation and that the limestone breccia represents the Pembroke Formation. If so, both formations decrease in thickness to the southwest. In the sea-cliff on the south side of the mouth of Big Creek, 1,700 feet southeast from the Summerville wharf, these beds dip steeply to the northeast (i.e. shoreward), and the Macumber is about 12 feet thick, the limestone breccia about 2 feet thick. About 235 feet seaward from the cliff, below high tide, 12 feet of thinly bedded limestone occurs again, dipping steeply northeast as in the sea-cliff. Shoreward, the limestone is overlain by 3 feet of limestone breccia, and the breccia is in turn overlain by gypsum. Many faults, apparently thrusts, cause repetition of beds along the shoreline to the south of this place. In summary, it is likely that the Macumber Formation, and the overlying Pembroke Formation, continue to the south, but their decrease in thickness, complexity of structure, and the general paucity of outcrops make recognition doubtful and mapping difficult.

The known maximum thickness of the Macumber Formation in the map-area is about 25 feet at the Stephens manganese mine, which is three quarters of a mile southwest of Walton.

Lithology

The Macumber Formation is easily recognized in the northeast quarter of the map-area as buff to light grey, fine-grained, arenaceous, well-bedded limestone. Where the uppermost beds of the underlying Horton Group happen to be thinly bedded, fine-grained grey sandstone, Horton and Macumber strata are very similar in appearance, but can be readily distinguished by testing with hydrochloric acid.

Structural Relations

The conformable Horton-Macumber contact is best exposed on the shore a mile north of Cheverie, on the north limb of the anticline at Johnson Cove. There, the following sequence, from top to bottom, is exposed:

Description	Thickness (feet)
Johnson Cove Fault Zone	
Pembroke Formation	
Limestone breccia	24
Macumber Formation	
Limestone, light grey, fine, arenaceous, thinly and well bedded	9.2
Horton Group	
Sandstone, light grey and mottled maroon-grey, fine grained, slightly calcareous, well bedded, beds 1 inch to 1.5 feet thick, thinly bedded at top	21
Sandstone, pink, medium grained, slightly calcareous, thinly bedded, beds average about 1 inch in thickness, crossbedded, containing plant remains	11
Argillites, etc	(not measured)

Origin and Age

The conformity of the Horton-Macumber contact, the fact that underlying Horton sandstones and shale contain abundant plant remains whereas overlying Windsor limestones abound in marine fossils, and the well-bedded nature of the Macumber Formation lead to the conclusion that Macumber strata formed as initial limestone deposits from a transgressing Windsor sea. The sea advanced over a flat alluvial plain underlain by earlier continental sediments so that no conglomerate was formed.

Bell (1929, p. 46) previously referred to this rock unit as the lowermost member of subzone A of the Windsor Group. Although it is unfossiliferous in the Wolfville map-area, and in the Londonderry and Bass River map-area to the northeast, the Macumber Formation is both underlain and overlain by fossiliferous Mississippian strata.

Pembroke Formation

Pembroke is the name given by Weeks (1948, p. 21) to a formation of reddish limestone-conglomerate and massive limestone, locally interbedded with reddish calcareous sandstone and shale, within the Windsor Group.

Distribution and Thickness

This formation has been readily distinguished only in the northeast quarter of the map-area. Limestone beds that probably constitute the Macumber and Pembroke Formations along the shore south of Summerville have been previously described (*see* p. 36).

The basal Windsor strata, particularly those of the Pembroke Formation, commonly form ridges. Where exposures are absent, small sink-holes distinguish such ridges from those underlain by Horton sandstones and are helpful in locating the Horton-Windsor contact.

The known maximum thickness of the Pembroke Formation in the map-area is about 100 feet, which occurs in D.D. hole No. 15 at the Walton mine, 2½ miles southwest of Walton townsite. This hole included the upper contact of the formation, but did not go deep enough to include the base. The total thickness of the formation there has been calculated by Weeks (1948, p. 22) as 115 feet, utilizing sections in three adjacent holes that did include the base of the formation, and assuming that the beds dip 30 degrees. As the beds dip from 40 to 45 degrees, 100 feet is regarded as a more accurate figure for the thickness at this locality.

Lithology

The basal part of the Pembroke Formation is well exposed at the Stephens manganese mine, 4,000 feet southwest of Walton, Hants county. There, reddish limestone-conglomerate, which weathers from red to buff, contains angular fragments of Macumber limestone, and water-worn pebbles and grains of vein quartz, grey quartzite, granite, grey slate, red arenaceous shale, and sandstone. The red shale and sandstone were probably derived from the Horton Group, and the slate, quartzite, and vein quartz from the low-rank metamorphic rocks to the south. The granite may have originated in the south also. The calcite matrix of the conglomerate is predominantly megascopically crystalline.

The largest fragments of Macumber limestone in the Pembroke Formation are found in the exposure in the sea-cliff a mile southwest of Cheverie, where angular fragments as much as 10 feet across are cemented by limestone near the base of the Pembroke Formation. These fragments appear to be practically in situ. Stratigraphically upward from the base of the formation, the fragments of Macumber limestone decrease to the size of pebbles.

At the Walton mine, the formation is chiefly arenaceous, red to brown limestone-conglomerate, but it also includes some red to red-brown, calcareous sandstone and red shale which is more plentiful there than elsewhere. Most of the shale is calcareous and there are minor amounts of arenaceous limestone.

Structural Relations

The Pembroke Formation is structurally conformable with the underlying Macumber Formation, but the abundance of fragments of the latter in basal Pembroke beds indicates a disconformable contact. These relationships are well displayed on the shore a mile north of Cheverie, on the north limb of the anticline at Johnson Cove. The sequence at that locality has been described (*see* p. 37).

The Pembroke Formation is overlain apparently conformably by the lowermost of the Windsor gypsum-anhydrite beds.

Origin and Age

The large angular blocks of Macumber limestone cemented by red crystalline limestone in the basal part of the Pembroke Formation led Weeks (1948, p. 21) to conclude that violent and short-lived forces, possibly occurring beneath the surface of the Pembroke sea, were responsible for the breccia. Older rocks, which are exposed even today to the south, were the probable source of the many rounded rock fragments in the formation.

Bell (1929, p. 46) previously included strata of what is now called the Pembroke Formation, and the overlying gypsum-anhydrite bed, in his subzone A of the Windsor Group. The formation is unfossiliferous so far as known, but is underlain and overlain by fossiliferous strata of Mississippian age.

Undivided Windsor Rocks

This section deals with that part of the Windsor Group that could not be further subdivided for field mapping, and probably includes both Lower and Upper Windsor beds. The strata comprise a sequence of marine limestones interbedded with shale, gypsum, anhydrite, and salt. The lowermost of the gypsum-anhydrite beds is the basal part of this subdivision, and overlies the Pembroke Formation. The uppermost beds, the Kennetcook limestone, are overlain by the Scotch Village Formation.

Distribution and Thickness

Except for a synclinal basin of younger rocks in the Avon-Kennetcook River district, Windsor strata occur throughout the area east of a line running southwesterly from Walton. These strata form part of a basin that extends for about 25 miles northeast of the map-area. An outlier of Upper Windsor strata occurs west of this line, preserved as a northeast-trending structural basin extending from Kempt Shore to Bramber.

The total thickness of the Windsor Group in the Windsor district has been estimated by Bell (1929, p. 45) as not less than 1,550 feet. Taking into account the many covered or partly covered intervals and the presence of rock salt in the subsurface, the thickness of the undivided upper part of the Windsor is probably about 2,000 feet.

Lithology

As exposed in the Wolfville map-area, strata of the Windsor Group above the Pembroke Formation are soft, brick-red predominantly to green-grey shales, which comprise over half the unit; limestone, which is about one quarter; gypsum and anhydrite, which together are about one fifth; and minor calcareous sandstone. The shale is commonly calcareous, and much of it could better be called mudstone. The limestone is generally very fossiliferous. Oolite beds, averaging less than 3 feet thick, account for a minor amount of the limestone. Exposures of evaporite beds are commonly composed of gypsum, but some are an intimate mixture of gypsum and anhydrite.

Rock salt is present in the subsurface. Two shallow bore-holes drilled about a mile west of Windsor in 1922 each penetrated a thin rock salt bed at a depth of about 550 feet. Numerous salt springs in the area underlain by Windsor beds further confirm the presence of rock salt in the subsurface (Wright, 1931, pp. 131-2).

Bell (1929, pp. 46-54) subdivided the Windsor Group into subzones on the basis of fossils in limestone beds, and discussed the stratigraphy of the group in detail in his memoir on the Horton-Windsor district. In the Wolfville map-area, the group is exposed only in sea-cliffs, along the larger rivers, and in a few railway-cuts, and the complexity of structure and paucity of outcrops have prevented the writer from subdividing that part of the group above the Pembroke Formation.

The following generalized section of the group above the Pembroke Formation is adapted from Bell's memoir. Because of structural complexities, it is necessary to piece together parts of sections from several localities to obtain a more or less complete section of the Windsor. Thicknesses are approximate with two exceptions, as indicated. The limit of error is particularly high for shale and evaporite beds.

Description	Thickness (feet)
Scotch Village Formation	(not measured)
Upper part of the Windsor Group	
Kennetcook limestone, blue-grey to dark shaly limestone containing cup corals, bryozoans, brachiopods, and trilobites	100
Red shale, etc.	227+
Gypsum, with fossiliferous, calcareous beds	40 ±
Red shale, etc.	102+
Avon limestone, grey, platy limestone containing brachiopods	17
Red shale, etc.	129+
Gypsum, with fossiliferous, calcareous beds carrying foraminifera and ostracods	100+
Red shale, etc.	122+
Dolomitic and calcareous shale, arenaceous, fossiliferous limestone, oolitic limestone, *Modiola* and algal bands	57+
Red shale	unknown
Gypsum	unknown
Miller limestone, consisting predominantly of brachiopods, bryozoa, pelecypods, gastropods	35 ±
Red shale	6+
Gypsum	35 ±
Red shale, etc.	110+
Maxner limestone, similar to Miller limestone	80 ±
Gypsum	55 ±
Pembroke Formation	(not measured)

Structural Relations

The contact between the Pembroke Formation and the overlying gypsum-anhydrite bed is exposed at only a few localities, and not too well at those. Strata adjacent to gypsum are brecciated and such brecciated zones are commonly several feet wide.

The contact is exposed in the largest sink-hole in the map-area, 7,500 feet northeast of the Walton barite mine (*see* Plate III). There gypsum along the south side of a ridge is underlain by south-dipping Pembroke red shale. The shale is best exposed in the north side of the sink-hole.

The structural picture as concerns the Windsor is considerably complicated by expansion effects of sulphate beds during hydration and probably by salt solution effects as well.

Origin and Age

The types of sediments, their sequence, and their faunal content in that part of the Windsor Group above the Pembroke Formation indicate that these sediments formed in an arid climate as deposits in a tectonically active basin, or basins, periodically isolated from the sea.

Field evidence favouring the deposition of the evaporite beds as anhydrite and later conversion to gypsum along with a volume increase is as follows: (1) thin limestone beds in gypsum are commonly crumpled and microfaulted; (2) strata adjacent to gypsum are brecciated; (3) the ratio of anhydrite to gypsum increases with depth in the gypsum quarries; (4) some outcrops consist of an intimate mixture of gypsum and anhydrite; and (5) some exposures exhibit a wavy lineation that is apparently a flow structure.

Sedimentary rocks of the undivided Windsor Group are of Mississippian age on the basis of their faunal content. Bell (1929, p. 56) correlated these strata palæontologically with the Visean of northern Europe and "in general with the Chesterian of the United States".

Pennsylvanian (?)

Scotch Village Formation

The name Scotch Village has been used by the writer (1952) for a formation of buff weathering, light blue-grey, medium-grained, feldspathic sandstone, overlying, apparently conformably, the uppermost limestone of the Windsor Group in the Avon-Kennetcook River district, Hants county. The name was chosen because the best exposure of this formation in the map-area is along the north bank of the Kennetcook River, ½ mile north of the settlement of Scotch Village.

Distribution and Thickness

The Scotch Village Formation forms a northeast-pitching syncline that extends from the east shore of Avon River, southwest of Centre Burlington, beyond the east border of the Wolfville map-area.

The top of the formation is missing but the total thickness probably exceeds 800 feet. A stratigraphic thickness of about 20 feet is exposed one half mile north of Scotch Village, and 35 feet are exposed 2 miles east of Centre Burlington, on the north bank of Kennetcook River. These are the best outcrops in the map-area.

Lithology

The formation consists almost entirely of feldspathic sandstone. Its most striking feature is the bright buff colour of its weathered surface, which locally is obscured by a thin, brown or reddish brown layer. The weathered zone commonly extends into the rock for a few inches; the fresh surface underneath is a light blue-grey. The sandstone is even grained, friable, thickly bedded, blocky, and well cross-laminated. Some beds are more than 6 feet thick; laminae average less than an inch thick.

Shale, which constitutes less than 10 per cent of the exposures, is soft, greenish grey to grey, and occurs in beds from a foot to 3½ feet thick. Strata of the Scotch Village Formation contain abundant plant remains, and small seams of low-rank coal are common. Plant remains may cause laminae to resemble coarse breccias on the weathered surface.

As seen in thin section, the rock is not as even grained as it appears in hand specimen, but is still a well-sorted, medium-grained sandstone. Grains are angular to subrounded, usually subangular. Overgrowths were noted on a few quartz grains, which showed original rounded surfaces as outlined by minute inclusions. Such overgrowths may account in large part for the angularity of grains. Quartz grains predominate, with 10 to 15 per cent feldspar, mostly plagioclase. Rock fragments are less abundant than feldspar, and are predominantly quartzite and chert. Fragments of low-rank metamorphic rocks other than quartzite are rare.

Structural Relations

The sandstone is well bedded and markedly cross-laminated. Beds are commonly channelled into underlying beds. Current ripple-marks agree with cross-lamination in indicating that these sediments were deposited by currents flowing to the north and northwest.

The base of the Scotch Village Formation is exposed near the mouth of the Kennetcook River on the south bank, below high-tide level, where the contact with the Windsor can be traced for about 40 feet. There, competent Scotch Village sandstone beds are separated from lower, structurally conformable, competent beds of Upper Windsor (Kennetcook) limestone by a largely covered 60-foot interval of incompetent, somewhat contorted, shaly, Kennetcook limestone. The contorted nature of the beds in this interval is a reflection of a fault zone immediately to the south. The Scotch Village-Windsor contact appears to be gradational in that the basal part of the Scotch Village consists of about equal parts of carbonate cement and sand grains, with the carbonate content decreasing upwards until it is absent.

Origin and Age

The marked cross-lamination, intrastratal channelling phenomena, and current ripple-marking are evidence that strata of the Scotch Village Formation are of fluviatile origin. The abundant plant remains, the unoxidized condition of the iron content, and the freshness of the plagioclase feldspar indicate that the strata were not subjected to intensive, subaerial, oxidizing conditions. The well-sorted nature of the sandstone discredits the postulation of deposition from torrential currents. It is concluded, therefore, that the strata formed as fluviatile deposits in a climate characterized by abundant, but not torrential, rainfall.

It is not known with certainty whether the formation is of Mississippian or Pennsylvanian age. Plant fossils collected at four localities were identified by W. A. Bell, of the Geological Survey of Canada, as follows:

Calamites suckowi Brongniart
Cordaites principalis (Germar)
Calamites sp.
Neuropteris sp.

With respect to the age of the formation, Dr. Bell stated (personal communication):

> The fact that these sandstones lie with apparent conformity upon Windsor limestone would seem to suggest the probability of a Canso age. However, the lithology is unlike known Canso beds of the Minas Basin area, and the common presence of broad ribbed *Calamites*, some specimens of which are considered to be *C. suckowi*, together with the presence of *Cordaites* and of a moderately large pinnule of a *Neuropteris* all militate against a Canso age. A Pennsylvanian age is therefore considered most probable.

Triassic

Annapolis Formation

Annapolis was the name given by Powers (1916) to the lowest formation of the Acadian Triassic. He subdivided the formation into two members: the lower, Wolfville sandstone; the upper, Blomidon shale. The Annapolis formation is separated from older rocks by an angular unconformity, and is overlain by the North Mountain basalt.

The few fossils found in the Annapolis Formation include ostracods and silicified and carbonized plant remains, which indicate a Late Triassic age for the rocks. Referring to the above evidence in conjunction with fish remains of the Scots Bay Formation, Powers (1916) stated: "The paleontological and paleobotanical evidence proves that the Acadian area is part of the Newark system, and further shows a pronounced similarity between the Newark and the Lettenkohle of Germany."

Wolfville Sandstone

Distribution and Thickness

Strata of the Wolfville sandstone outcrop over the southern part of Cornwallis Valley and underlie the larger part of Minas Basin. In several places they extend up to or beyond the shoreline in the northeastern part of the map-area. Northwest of Cambridge, there are two small outliers, and just north of the Johnson Cove fault, 3,000 feet southeast of Split Rock, there is a remnant bordered on the north by a fault downthrown to the south. The larger masses along the shoreline, however, are not isolated but extend seaward, as shown on the geological map accompanying this report.

The member is about 2,400 feet thick, and dips 5 to 10 degrees to the northwest.

Lithology

The Wolfville sandstone is remarkable for its heterogeneity. Interbedded conglomerate, grit, and sandstone are soft, brick-red to reddish brown, poorly sorted, lenticular, and markedly crossbedded. Pebbles consist of quartzite, vein quartz, sandstone, arenaceous shale, slate, felsite, granite, and crystalline limestone, in order of decreasing abundance. They are subangular to well rounded, being generally bounded by fracture faces with the corners well abraded. A few large crystals of Carlsbad-twinned potash feldspar, identical to phenocrysts in the porphyritic granite of South Mountain, occur in conglomerate lenses exposed in sea-cliffs between Kingsport and Paddy Island, but there is no arkose anywhere in the Wolfville sandstone.

As seen in thin section, the sandstone and grit consist predominantly of quartz grains, but fragments of quartzite, slate, and altered fine-grained igneous rocks are common. The quartz grains are mainly angular; some, however, are subround to round. The cement varies from predominantly hematite to predominantly calcite, with minor limonite, and is generally a mixture of carbonate and iron oxide. Small, isolated, light green patches in the strata derive their colour from irregular clusters of chlorite in the matrix.

Structural Relations

The most striking structural features of the Wolfville sandstone are the lenticular nature of the beds, the crossbedding, and the intraformational breccias composed of red shale fragments in a matrix of red sandstone. Isolated balls of shale in grit are also present. The member contains innumerable diastems, and intraformational channelling phenomena are common.

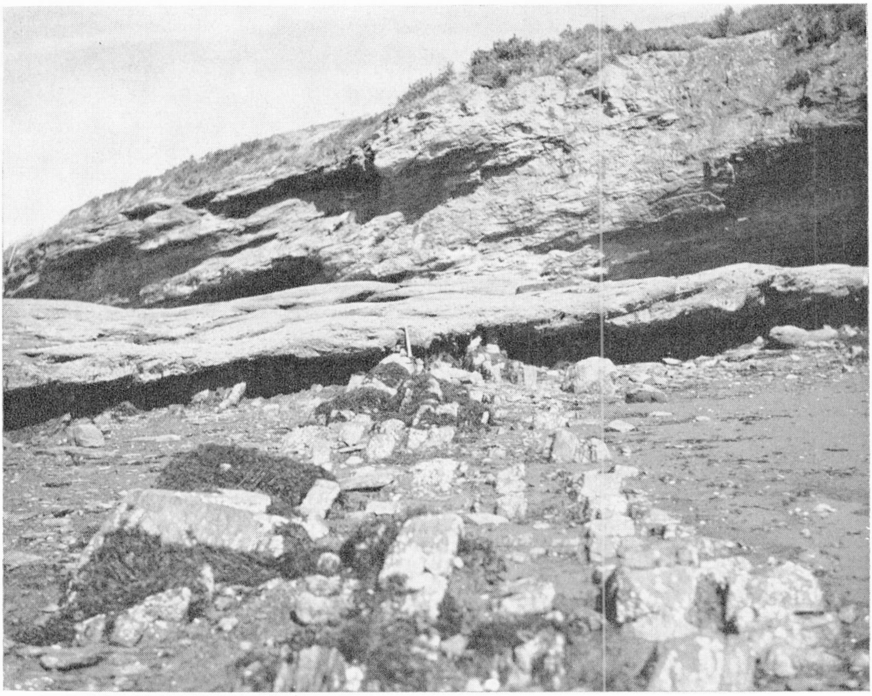
Numerous, steeply dipping, normal faults displace strata of the Wolfville sandstone. Most of the faults strike about S20°W; but some strike about east-west. Most have vertical separations of only a few feet.

A pronounced angular unconformity separates the Wolfville sandstone from older rocks (Pl. XIII). The basal part of the member is invariably a breccia composed predominantly of fragments from directly underlying rocks. The erosion surface abruptly truncates the closely folded, underlying strata, and is an even plane wherever exposed (except in minute detail), dipping 5 to 10°NW. The best exposures of the unconformity are: (1) along the northeastern shore from Cambridge Cove to Whale Cove, where underlying rocks belong to the Horton Group; (2) on Ridge Brook, where underlying rocks belong to the Halifax Formation; (3) off the northeast tip of Oak Island, where an inlier of Horton beds projects through basal Wolfville sandstone strata.

The Wolfville sandstone is conformably overlain by the Blomidon shale.

Origin

The textural and structural properties of the Wolfville sandstone—poorness of sorting, channelling phenomena, crossbedding, intraformational shale breccias, isolated shale balls—are indicative of deposition by torrential streams. The



DGC 12-5-50

Plate XIII. *Angular unconformity separating the gently dipping Wolfville sandstone from underlying, steeply dipping Horton strata. Photo taken on the shore at Whale Cove, 2,600 feet north of Walton. Hammer in the centre of the picture shows scale.*

ubiquity of iron oxide, the absence of arkose, and the paucity of carbon are evidence of intense, subaerial, oxidizing conditions. These factors, together with the wide range in composition of material and the presence of calcite cement, lead to the conclusion that these sedimentary rocks were formed in a semi-arid climate as intermontane, fluviatile deposits. Much of the material making up the strata can be traced to older rocks that outcrop to the south.

Blomidon Shale

Distribution and Thickness

Strata of the Blomidon shale outcrop over the northern part of Cornwallis Valley and extend under the western part of Minas Basin. The member is about 800 feet thick, and the strata dip about 5 degrees to the northwest.

Lithology

In contrast to the Wolfville sandstone, the Blomidon shale is notably homogeneous. Soft, brick-red shale and argillaceous sandstone make up the basal 60 feet. The shale comprises most of the overlying strata and is commonly arenaceous. Pebbles and rock fragments are rare, whereas angular quartz grains are common.

Thin, continuous beds with light green patches, caused by local clusters of chlorite, occur throughout the member. The spacing of the mottled beds is distinctive and allows their correlation. These beds contain appreciable amounts of calcite.

Structural Relations

Strata of the Blomidon shale are generally continuous and uniform, and the member is well bedded. There are many diastems, however, and close inspection of sections in sea-cliffs reveals that many beds pinch out. In the lower, sandy 60 feet, channelling phenomena are well developed and diastems are particularly numerous. Oscillation ripple-marks were noted.

Normal faults displace strata of the member, but are not so numerous as in the Wolfville sandstone.

The Blomidon shale conformably overlies the Wolfville sandstone. The contact is best exposed at the base of the sea-cliff on the north side of the Paddy Island fault. The lower part of the cliff face is composed of weakly resistant strata of the Wolfville sandstone and juts out several feet beyond the upper part, which is composed of less resistant strata of the Blomidon shale. The uppermost beds of the sandstone member contain many pebbles. The basal beds of the overlying shale member consist of 3 feet of banded, mottled light green and brick-red shale, with up to 5 inches of sandstone, overlain by 6 feet of intermixed, soft, reddish brown, argillaceous sandstone and red shale, overlain in turn by alternating beds of mottled sandstone and shale from 3 to 9 inches thick. The thin, continuous, mottled shale beds at the base of the Blomidon shale, together with the marked difference in resistance to erosion and composition of strata, make the contact between the two members easily recognizable.

The Blomidon shale is overlain with structural conformity by the North Mountain basalt.

Origin

Channelling phenomena characteristic of fluviatile deposits are well developed in the lower 60 feet of the Blomidon shale. The occurrence of ostracods, oscillation ripple-marks, and calcareous layers suggests lacustrine conditions. The ubiquity of iron oxide, chiefly hematite, and the paucity of carbon are evidence of intense, subaerial, oxidizing conditions. These factors, in conjunction with the well-bedded nature, homogeneity, and fineness of the strata, lead to the conclusion that the shales formed in a semi-arid climate as flood-plain deposits, with subordinate deposition in temporary lakes.

North Mountain Basalt

North Mountain was the name given by Powers (1916) to the basalt flows of the Acadian Triassic that overlie the Annapolis Formation, and are overlain by the Scots Bay Formation.

Distribution and Thickness

North Mountain basalt is the resistant cap-rock of North Mountain, a southwest-trending highland, 4 miles wide in the Wolfville map-area. The flows have a total thickness of about 900 feet, and dip about 5°NW.

Lithology

The basalt is dark grey to dark greenish grey, aphanitic to fine grained, and commonly exhibits a diabasic texture. It weathers to various shades of maroon and brown.

As seen in thin section, the rock is an aggregate of plagioclase feldspar laths, and anhedral augite, with accessory glass, magnetite, and, rarely, olivine. The texture is ophitic, augite enclosing feldspar laths. Feldspar crystals are zoned, varying from oligoclase at the borders to bytownite in the central parts, but the bulk of each crystal is of a composition more basic than An_{50}. Brown to dark brown glass constitutes about 20 per cent of the rock.

The variety of minerals in the amygdaloidal upper and lower parts of flows has attracted many mineralogists, professional and amateur. In the Wolfville map-area, heulandite, stilbite, clear quartz, amethyst, agate, and jasper are common as amygdules and coatings in large vesicules. Varieties of chalcedony also form veinlets and sill-like structures. Analcime and apophyllite have been reported from the map-area (Jackson and Alger, 1828, 1829), but were not recognized by the writer.

Powers (1916) stated that there were at least two, and probably three, thick flows in the section from Cape Blomidon to Cape Split, and that the top of the upper flow is exposed around the edge of Scotsman Bay. There are, in addition, several minor flows exposed in the cliffs along the north shore of the mountain, but these are neither continuous nor distinctive enough to be traced very far. Between flows, there are thin, discontinuous layers of green grit composed of material derived from the underlying flow. These layers formed in the intervals between extrusions. The grits are usually well indurated and may be accompanied by 'sills' of chalcedony.

Structural Relations

The basalt is characterized by well-developed columnar jointing. The joints have facilitated weathering processes, and in exposures where weathering has been extensive, spheroids or ovoids of rotten basalt may be easily removed from disintegrated lava.

There are several small synclinal structures, or basins, in the basalt. A few such basins contain strata of the overlying Scots Bay Formation (*see* p. 48). Small coves along the north shore of North Mountain, such as Bigelow Cove, are caused by such structures. At Bigelow Cove, basalt dips up to 25°NE on the west side of the bay. Dips to the northwest on the east side of the bay are gentler, as are dips in other coves.

The contact between the North Mountain basalt and the underlying Annapolis Formation was not observed, but the flows are structurally conformable with the underlying sedimentary rocks.

Origin and Age

The basalt evidently came from fissure eruptions, and crystallized extremely rapidly, as indicated by the abundance of glass in the groundmass. No pyroclastic breccias accompany the flows in the Wolfville map-area.

Being underlain and overlain by Triassic sedimentary rocks, the North Mountain basalt must be assigned to that period also.

Diabase sills intruded into strata of the Horton Group in the sea-cliff 1½ miles north of Cheverie probably belong to the same period of igneous activity.

Scots Bay Formation

Scots Bay was the name given by Powers (1916) to the uppermost formation of the Acadian Triassic.

Distribution and Thickness

Strata of this formation occur in two small structural basins along the north shore of North Mountain. The smaller basin is just east of the mouth of Woodworth Creek; the larger is 3,500 feet farther northeast, at the northern border of the map-area. Fletcher (1911) and Powers (1916) mapped these basins and also a third one between the two. Their third basin, however, is now only a well-exposed section of weathered basalt.

The top of the formation is missing because of erosion. The thickest section, 16 feet, is in the sea-cliff that cuts through the larger basin at the northern edge of the map-area.

Lithology

The formation is composed of interbedded arenaceous limestone and calcareous sandstone. The limestone is white, dense, and thinly bedded. Jasper concretions are numerous and average about a foot wide transverse to the bedding and about 2 feet long along the bedding. A few concretions are several feet long. The sandstone is light green, fine to medium grained, very calcareous, and thinly bedded.

As seen in thin section, the limestone is fine grained with crescentic structures resembling shell fragments. These structures may be ostracod fossils. Angular quartz grains constitute about 10 per cent of the rock. The sandstone contains about 40 per cent calcite as a cement for the detrital grains of quartz, plagioclase, altered ferromagnesian minerals, and lava derived from the underlying basalt. The light green colour is the result of chloritic alteration of ferromagnesian minerals and lava fragments. Detrital grains are angular to subrounded, most being subangular.

The section exposed in the sea-cliff that cuts through the larger basin northeast of Woodworth Bay may be summarized, from top to bottom, as follows:

Description	Thickness (feet)
Scots Bay Formation	
Limestone, white, dense, thinly bedded, with numerous jasper concretions	2.5+
Sandstone, light green, medium grained, calcareous, thinly bedded; minor brown, calcareous shale	1.0
Limestone, white, dense, thinly bedded, with numerous jasper concretions	2.5
Sandstone, light green, fine grained, calcareous, thinly bedded	6.0
Breccia, consisting of coarse, angular basalt fragments	4.0
North Mountain basalt	(not measured)

The basal breccia and overlying sandstone vary in thickness—the sandstone from 2.5 feet at the eastern border of the basin to a maximum of 6.0 feet in the centre. The described section is similar but not identical to that in the smaller basin to the southwest; however, the smaller basin contains 9 inches of mottled maroon-green shale near the base. Closer similarity would hardly be expected, for the basal beds were deposited on the irregular surface of a basalt flow.

Structural Relations

The Scots Bay Formation lies disconformably upon the North Mountain basalt. The disconformity is marked by a breccia composed of basalt fragments in a matrix of finer material of the same composition. Chert concretions occur in the upper part of the breccia. This basal bed averages about 4 feet thick. A weathered zone in the basalt immediately underlying the breccia averages about 3 feet thick. The top of the Scots Bay Formation has been removed by erosion.

Origin and Age

The calcareous composition, the well-bedded nature, and fragmentary fish remains indicate that strata of the Scots Bay Formation were deposited under lacustrine conditions.

The fish remains indicate a Triassic age for the enclosing rocks. Some of them have been tentatively identified as a form characteristic of the Newark Group (Powers, 1916).

Pleistocene and Recent

Pleistocene

The composition of Pleistocene boulder clay and till in the Wolfville map-area largely reflects the composition of the underlying rocks, which fact was utilized to a small extent in interpreting the nature of the basement rocks in concealed areas. Most of the boulders in the till were derived from local outcrops, but some were apparently brought south from the Cobequid Mountains, about 15 miles north of the map-area.

The colour of the till is also dependent largely upon the nature of underlying rocks. In the low-lying west-central and eastern parts of the map-area, the till is brick-red to brown because the underlying rocks are red to brown. In the high areas of the west half—North Mountain and the south highlands—the till is commonly grey as it is derived from dark coloured rocks, basalt in the north and slate in the south.

Glacial drift covers much of the region, but is thickest in the low areas, being as much as 75 feet thick in the east half of the map-area. Thicknesses of till are much less in the high areas, but fairly thick deposits are found in a few topographically favourable localities, such as in undulations in the basement rock surface.

Some boulders in the till have been transported for several miles. For example, those of soft, red Triassic sediments occur in cliffs of till along the west shore of Avon River for 1.5 miles from the mouth of Hurd Creek to Hantsport. These boulders are 3 to 4 miles southwest of the nearest outcrops of Triassic strata. Bell (1929, p. 61) reported similar boulders in drift in Curry Brook 4 miles south of the nearest outcrops of Triassic strata. Boulders of amygdaloidal North Mountain basalt derived from the northeast are common along the shore from Hurd Creek to Hantsport and boulders of porphyritic granite derived from the south are also present. In addition, erratics of amygdaloidal North Mountain basalt were noted on South Mountain at several localities, and erratics of porphyritic granite, commonly several feet in diameter, were noted on South Mountain 2 miles north of the granite batholith, and as far north as the beds of streams flowing down the north flank of South Mountain, i.e., Harding Brook. Glaciation in this region thus was not simply a southerly movement of an ice-sheet, for the distribution of erratics indicates that ice advanced both southerly and northerly.

Minor amounts of stratified sands and gravels are interbedded with till. The sands and gravels are generally well crossbedded and evidently are stream deposits.

Recent

Recent deposits include stream alluvium, tidal alluvium, beach sands and gravels, and sand-bars.

Stream alluvium is best developed in the Gaspereau River Valley, where stratified gravels and sands form a terrace extending from Wallbrook to the shore. Tidal alluvium has built up the salt marshes around Minas Basin (*see* p. 15). These marshes are extensively developed near the mouths of Pereau Creek, Habitant Creek, Canard River, Cornwallis River, Gaspereau River, Halfway River, Ste. Croix River, Kennetcook River, and along the west shore of Avon River from Hantsport to Windsor. The most famous stretch of reclaimed marsh extends seaward from Grand Pré, which is about 3 miles northeast from Wolfville. Beach sands and gravels are present where sea-cliffs are composed of Horton and Annapolis strata. Sandbars occur in Minas Basin and in tidal channels; those at Woodside, more than 3 miles inland, have been described in Chapter I.

A sample of mud from the tidal flats was collected off Kingsport wharf by the writer's father at an elevation about 20 feet below high-tide level. This was subsequently studied for its foraminiferal content by G. L. Harrington, at Stanford University. Mr. Harrington reported the following species present in the mud sample:

Webbinella sp. or *Tholosina* sp.
Spiroplectammina biformis (Parker and Jones)
Haplophragmoides? sp. Juvenile and very small
Psammatodendron arborescens Norman
Eggerella advena (Cushman)
Quinqueloculina agglutinata Cushman
Quinqueloculina groenlandica Cushman
Quinqueloculina sp. Very similar to *Q. seminula* but faintly striated, may be var. *jugosa* of *Q. seminula*
Nonion sp. A small species, possibly juvenile
Nonion pauciloculum Cushman
Elphidium advenum (?) Cushman
Elphidium incertum var. *clavatum* Cushman
Elphidium spp. (At least two additional species)
Entosolenia lucida Williamson
Entosolenia catenulata Williamson
Entosolenia sp.
Lagena clavata d'Orbigny
Lagena vulgaris Williamson
Lagena gracillima var. *mollis* Cushman
Lagena substriata Williamson
Buliminella elegantissima (d'Orbigny)
Guttulina lactea? Walker and Jacob
Angulogerina angulosa? Williamson. Stubbier than normal *A. angulosa*
Bolivina cf. *variabilis* Williamson
Boliviana pseudoplicata Heron-Allen and Earland
Trochammina inflata Montagu
Trochammina spp. (Ventral side light coloured as is outer whorl above.)
Trochammina squamata var. *adaperta* Rhumbler
Trochammina sp. One or more var. related to preceding.
Eponides? sp.
Discorbis cf. *obtusa* (d'Orbigny)
Patellina corrugata Williamson
Cibicides lobatula (Walker and Jacob)
Globigerina bulloides d'Orbigny
Glomospira sp.

"Besides the foregoing there are one or two miliolids, and one or two arenaceous forms that it has not been possible to identify" (G. L. Harrington, personal communication).

Chapter IV

STRUCTURAL GEOLOGY

Folds and Faults

The Wolfville map-area is structurally complex as regards the Palæozoic rocks. This is especially apparent in those localized areas where exposures are common, along parts of the shore and in some stream valleys. The general scarcity of outcrops and marker horizons greatly hinders the tracing of structural features inland, particularly in the areas underlain by Windsor and Horton strata. The structural picture of the Windsor Group is further complicated by expansion effects of sulphate beds during hydration and probably by salt solution effects as well. The structure of the Horton Group is more complex to the northeast. On the west side of Avon River, Horton strata are gently folded, whereas to the northeast at Walton, strata have been thrown into sharp-angled recumbent folds (*see* Pl. XII) and are displaced by innumerable faults.

The geological map accompanying this report is designed to show the distribution and relationships of the rocks in the Wolfville map-area as clearly as possible. It is impractical to represent on this map all, or even most, of the many folds and faults apparent at some of the localities where exposures are common. In particular, strike and dip symbols have been omitted for areas of intense deformation underlain by incompetent Windsor strata and dark shales and siltstones of the Horton Group. Most of the shoreline from Walton to Split Rock falls into the latter category.

Major folds conform to the northeast Appalachian trend. Pre-Carboniferous folds were accentuated by forces that folded the Carboniferous strata, but fold axes of both correspond. Although many of the minor folds conform to the regional northeast trend, there are many east-west folds as well. Except for minor irregularities, Triassic rocks dip gently to the northwest. High-angle faults occur in many parts of the area, and those faults are plotted that affected construction of the map.

Folds

Northeast Folds

The map-area is a small part of the Appalachian region of eastern North America, and major folds in the area conform to the northeast Appalachian structural trend. Those prominent in the west half, named to facilitate recognition by the reader and listed from north to south, are: (1) Deep Hollow road syncline; (2) Deep Hollow road anticline; (3) Gaspereau River syncline; (4) South Mountain anticline; (5) Halfway River syncline; and (6) Grey Mountain anticline. In the east half of the map-area, the prominent northeast folds are (1) Cheverie syncline; (2) Walton anticline; and (3) Kennetcook River syncline. The Cheverie syncline is a continuation of Gaspereau River syncline. Walton anticline apparently bifurcates to the southwest into the South Mountain and Grey Mountain anticlines.

Pre-Carboniferous rocks have been affected by low-grade metamorphism and have a regional northeast-trending cleavage. They are more closely folded than the overlying Carboniferous strata, from which they are separated by an angular unconformity, and have, therefore, been subjected not only to the stresses that caused the folding in Carboniferous strata but to earlier orogenic forces as well.

Axes of folds in pre-Carboniferous rocks correspond with axes of folds in Carboniferous strata. Pre-Carboniferous folds were accentuated by later orogenic forces that folded the Carboniferous strata, that is, their closures were increased. Structure-section C-D (Map 1128A) demonstrates the results of the recurrent folding along pre-Carboniferous fold axes. It will be noted from the geological map that northeast folds in pre-Carboniferous rocks plunge to the southwest whereas those in Carboniferous strata plunge to the northeast. Thus the erosion surface that truncated the pre-Carboniferous rocks, now represented by the angular unconformity at the base of the Horton Group, has been tilted to the northeast in the map-area, and the southwest plunge of the folds in pre-Carboniferous rocks must have been greater before the tilting took place than at present.

East-west Folds

Although many of the minor folds in Carboniferous strata conform in trend to the major northeast folds, there are many east-west folds transverse to the regional northeast trend. Such folds almost invariably plunge gently from 10 to 25°E.

Perhaps the most important east-west fold is the Bay of Fundy syncline, whose axis passes through the village of Scots Bay just north of the Wolfville map-area. Triassic rocks are included in this structure. The plunge of this fold at Scots Bay is less than 10°W, which is in contrast to the easterly plunges on most of the east-west folds in the Carboniferous strata.

Faults

Faults in Pre-Carboniferous Rocks

The strike of the Deep Hollow road fault is slightly north of west at Deep Hollow road and curves to N70°W about 1,500 feet west of the road. According to subsidiary shear planes along the fault in quartzite beds, the dip is vertical. Striations on such shear planes are horizontal or plunge gently to the northwest indicating that at least the late movements along the fault were nearly horizontal. The normal horizontal separation, or offset, along the fault is about 800 feet.

57670-2—5

The Gaspereau River fault, near Gaspereau River power station, strikes slightly east of north. Neither the dip of the fault nor the direction of movements along it could be ascertained. The normal horizontal separation along the fault is about 300 feet.

Many minor faults with horizontal separations of only a few feet cut across the White Rock Formation. Such faults could not be traced in the slaty rocks underlying and overlying the formation, and their strikes could not be accurately determined.

Faults in Carboniferous Rocks

Movements along the Whale Cove fault, which intersects the shore about 2,000 feet north of Walton, have brought basal beds of the Windsor Group into juxtaposition with dark grey shales of the Horton Group. The fault strikes about east-west; the dip could not be determined. Assuming a stratigraphic thickness of 1,400 feet for the dark shales of the Horton Group, and a thickness of 600 feet for Horton strata overlying the dark shales, the stratigraphic throw[1] caused by movements along the fault is between 600 and 2,000 feet. The north side has moved down relative to the south side.

Basal Windsor beds have also been brought into juxtaposition with dark shales of the Horton Group at the Johnson Cove fault, which intersects the shore about 3,000 feet north from Cheverie. The fault is marked by a brecciated zone that extends for about 500 feet along the shore. It strikes about N80°E; the dip could not be determined. Numerous asymmetrical folds in the fault zone and on the north side of it, with axial planes dipping to the north, indicate compressive stresses. The fault is assumed to be a thrust. The stratigraphic throw caused by movements along the Johnson Cove fault like that of the Whale Cove fault is between 600 and 2,000 feet. The south side has moved down relative to the north side.

At Cheverie, uppermost strata of the Horton Group have been brought into juxtaposition with the lowest gypsum-anhydrite bed of the Windsor Group by movements along the Cheverie fault. The fault strikes N50°E; the dip is not apparent at Cheverie where the fault is represented by a brecciated zone about 500 feet wide, but is 75°SE to vertical where the fault intersects the shore 2 miles southwest of Cheverie. There, the fault consists of two well-defined brecciated zones, each about 20 feet wide, in which striations and drag-folds indicate that the southeast side moved down with respect to the northwest side. The relationships of Horton and Windsor strata at Cheverie indicate the same relative movement. The striations further show that the late movements, at least, followed the dip of the fault. The Macumber and Pembroke Formations are together about 40 feet thick in this vicinity, and the gypsum-anhydrite bed is about 55 feet thick. The stratigraphic throw at Cheverie, therefore, is between 40 and 95 feet. The southeast side has moved down relative to the northwest side.

---

[1] The total stratigraphic thickness missing between beds on either side of fault.

The Summerville fault system consists of three faults: two join near the Summerville wharf; the third, which intersects the shore 1,800 feet northwest of the wharf, probably joins the continuation of the other two under Avon River. The northern fault strikes about N50°E; the dip could not be determined. A gypsum quarry in the lowest gypsum-anhydrite bed of the Windsor Group borders the fault on the southeast. Overturned Horton strata were observed dipping from 40 to 70°NW near the top of the northwest side of the quarry, so the fault is evidently a thrust. The Horton strata bordering the fault on the northwest belong to the upper 600 feet of the Horton Group. The gypsum-anhydrite bed is about 55 feet thick. The Macumber and Pembroke Formations, if present in this vicinity, are together about 15 feet thick. The stratigraphic throw caused by movements along the fault is, therefore, between 70 and 670 feet. The southeast side has moved down relative to the northwest side.

The other two faults can be considered as branches of one fault, for they join about 700 feet southwest of Summerville wharf. The northern branch strikes about east-west; the dip is steep, but could not be accurately determined. Contorted Horton shales and the lowest gypsum-anhydrite bed of the Windsor Group are in fault contact in the sea-cliff, 1,100 feet southeast of Summerville wharf. The stratigraphic throw there, as in the northern fault, is between 70 and 670 feet. The south side has moved down relative to the north side. The southern branch strikes about N55°W. From 3,000 to 3,500 feet southeast of Summerville wharf, the sea-cliff coincides with this fault. There, Horton shale, which outcrops in the sea-cliff, has been brought into juxtaposition with northeasterly dipping, thinly bedded Windsor limestone, which outcrops on the shore. The limestone strata, which total about 15 feet thick, contain the brachiopod *Martinia,* and thus lie within the upper part of the Windsor Group (W. A. Bell, personal communication). Minor faulting has caused repetition of strata on the shore so that stratigraphic relationships are not clear. The 15-foot sea-cliff is composed of Horton strata that belong to the upper 600 feet of the Horton Group. The stratigraphic throw caused by movements along the fault is between 1,500 and 2,000 feet. The southwest side has moved down relative to the northeast side.

On the opposite side of Avon River, the Blue Beach fault, probably the extension of the Summerville fault system, intersects the shore about 2 miles northeast of Hantsport. On the shore at Blue Beach, the fault zone is about 175 feet wide. It consists of strata that dip deeply to the northwest to vertical and seven well-defined, steeply dipping gouges. The gouges vary from 4 to 35 feet wide and make up about 80 feet of the total width of the zone. The fault strikes N60°E. It is slightly convex to the northwest. Steep dips caused by movements along the fault permit it to be traced to the southwest from Blue Beach. At the latter locality, Horton strata that are stratigraphically about 300 to 600 feet below the top of the group have been brought into juxtaposition with Horton strata that are approximately 600 to 2,000 feet below the top of the group. The stratigraphic throw is, therefore, between 300 and 1,700 feet. The southeast side has moved down with respect to the northwest side.

57670-2—5½

Faults in Triassic Rocks

Movements along the Paddy Island fault, which intersects the shore about 1½ miles north from Kingsport, have brought strata of the Wolfville sandstone into juxtaposition with strata of the Blomidon shale. The fault can be easily traced on the shore and in the sea-cliff near Paddy Island. It strikes N85°E and dips 60°S. Drag-folds and the stratigraphic relationship of strata on either side of the fault indicate normal movements. The fault was responsible for the formation of Paddy Island. Wolfville sandstone on the north side of the fault was more resistant to wave action than Blomidon shale on the south side, and upon recession of the sea-cliff Paddy Island was left as a remnant of the more resistant rock. Thin, mottled shale beds of Blomidon shale in the sea-cliff can be correlated from one side of the fault to the other because of their distinctive spacing, and the stratigraphic throw caused by movements along the fault measured by utilizing these beds is 98 feet. As strata in the sea-cliff are horizontal, the stratigraphic throw is equal to the vertical separation. This is by far the greatest vertical separation measured on any fault in Triassic strata in the map-area. The south side has moved down relative to the north side.

Movements along the Cambridge fault have brought Horton strata into juxtaposition with Wolfville sandstone in the sea-cliff 1,500 feet northeast of Cambridge Cove. The fault strikes N35°E and dips 65°SE. The vertical separation is 6 feet, and the southeast side has moved down relative to the northwest side. Although the fault is of minor importance, it is plotted on the accompanying map because movements along it have exposed an inlier of Horton strata near the base of the sea-cliff and on the shore, and because the fault is representative of numerous steeply dipping, normal faults, with vertical separations of only a few feet, that displace strata of the Wolfville sandstone. Most of these faults strike northeasterly as does the Cambridge fault, the average strike being about N20°E. Almost all the remainder strike about east-west.

Although not exposed, a fault probably separates Halifax slates from Wolfville strata just south of Kentville. Strata of the Wolfville sandstone outcrop in the deep valley of Dodge Brook about a mile south of Kentville, at the intersection of the eastern and western branches of the brook and about 1,000 feet farther upstream on each branch. These exposures are from 125 to 150 feet lower in elevation than outcrops of Halifax slate on the Kentville-New Ross highway, about 2,300 feet west of the map-area. Halifax slate also outcrops in the Dodge Brook valley, 1,000 feet downstream from the intersection of its eastern and western branches. From this evidence, the Halifax rocks appear to have been faulted up relative to the Wolfville strata. The srike of this fault would be about N70°E, judging by the position of the above outcrops. The dip is unknown, but the fault may be steep and normal in nature as are the other faults that displace Triassic rocks within the map-area. The stratigraphic throw would be about 500 feet, with the south side moved down relative to the north side.

Chapter V

ECONOMIC GEOLOGY

Gypsum

References: Bell, 1929, pp. 81-88.
Goodman, N. R., Gypsum and Anhydrite in Nova Scotia; N.S. Dept. Mines, Mem. 1 (1952).
Haliburton, 1829, pp. 108-109.
Jackson and Alger, 1829, pp. 132-160 and 201-217.
Messervey, J. P., Gypsum in Nova Scotia; N.S. Dept. Mines, pamphlet, 1949.
Wright, 1931.

Thick gypsum beds within the Windsor Group form extensive and valuable deposits in the east half of the Wolfville map-area. Gypsum is currently being mined by Canadian Gypsum Company, Limited, in the Windsor district, and by National Gypsum (Canada) Limited in the Cheverie district.

The gypsum deposits of Nova Scotia, largest known in Canada, were the first discovered in North America, and those of the Windsor district were the first quarried. The exportation of gypsum was an item of trade at the time of the American Revolution, and, according to Haliburton (1829), was the chief item of trade at Windsor at the beginning of the nineteenth century.

The readily accessible areas underlain by gypsum are dotted with numerous abandoned quarries. Early quarry operators were mainly farmers who quarried gypsum from their own land and hauled it by horse and cart to the nearest seaport. These early operations are now replaced by modern large-scale quarrying, but the principal market is still in the United States, and most of the gypsum mined is still exported in crude form for processing elsewhere. The open-quarry method of mining gypsum in Nova Scotia, as well as the treatment, transportation, and uses of gypsum, are discussed in various publications, and will not be dealt with here. The reader is referred to "Gypsum in Nova Scotia", by Messervey (1949) for a brief but comprehensive treatment of the subject.

Windsor District

Canadian Gypsum Company Limited mines a large amount of gypsum from their quarries 2 to 3 miles east of Windsor. Their Miller Creek operation, near the southern boundary of the Wolfville map-area on the north side of Ste. Croix River, went into production in the summer of 1957; their Wentworth Creek quarries, just south of the map-area on the south side of Ste. Croix River, have been in operation for many years, and still supply much of the gypsum production of Nova Scotia.

In 1959, Canadian Gypsum Company Limited mined a little over half of the total gypsum production of Nova Scotia (5,058,561 tons) from their quarries in the Windsor district. Annual production figures, in short tons, for the last decade are as follows:

1950 - 1,759,456	1955 - 1,953,437
1951 - 1,788,345	1956 - 2,159,869
1952 - 1,639,390	1957 - 1,775,397[1]
1953 - 1,790,120	1958 - 213,114[1]
1954 - 1,732,354	1959 - 2,663,424

The company transports the crushed and screened gypsum via the Dominion Atlantic Railway to their tidewater storage and shipping facilities at Hantsport.

Cheverie District

National Gypsum (Canada) Limited commenced mining gypsum near Cheverie in 1957. The quarry is operated under contract by Mr. B. A. Parsons, and the broken gypsum is trucked to the company's tidewater storage and shipping facilities at Walton. Annual production figures, in tons, since this operation began are as follows:

1957 - 5,888
1958 - 74,181
1959 - 67,952

Production from the Cheverie quarry has been increasing whereas that from the company's Walton quarries, just beyond the northeast border of the Wolfville map-area, has been decreasing.

Gypsum had previously been mined in the Cheverie district for several years prior to 1948 by the Connecticut Adamant Gypsum Company.

Origin of Gypsum Deposits

A considerable amount of work has been carried out bearing on the nature and origin of the gypsum deposits of Nova Scotia (Bell, 1929; Goodman, 1952). In brief, the types of sediments, their sequence, and their faunal content indicate that Windsor sediments were formed in an arid climate as deposits in a basin, or basins, periodically isolated from the sea.

There seems little doubt that most of the calcium sulphate was deposited as anhydrite. Field evidences favouring the deposition of evaporite beds as anhydrite and later conversion to gypsum, along with a volume increase, is outlined in the section of this report dealing with the Windsor Group. The ratio of anhydrite to gypsum increases with depth in the gypsum quarries, and the floors of quarries are commonly composed mainly of anhydrite.

[1] Production reduced by a strike that lasted from October 1957 to November 1958.

Barite

Walton Mine

References: Cameron, A. E., Barytes Deposit at Pembroke, Hants County, Nova Scotia; N.S. Inst. Sci., Proc. and Trans., vol. 20, 1941, pp. 57-63.

Campbell, C. O., Barytes at Pembroke, Hants County, Nova Scotia; Can. Inst. Min. Met., Trans., vol. 45, 1942, pp. 229-310.

Crosby, D. G., The Wolfville Map-Area, Nova Scotia; doctoral dissertation, Stanford University, California, 1951.

Fletcher, 1905.

Garpner, E. U., Gravimetric Survey of Barite Deposit at Walton, Nova Scotia, Canada; unpublished report by C. H. Frost, Gravimetric Surveys, Inc., Tulsa, Oklahoma, 1945, 10 pp.

Randell, J. T., Report on the Geology and Geophysical Tests on the Walton Barytes Deposit, Nova Scotia; unpublished report by Geo-Technical Development Co., Ltd., Toronto, Ont., 1948, 28 pp. (plus 2 pp. appendix).

The Walton mine, the only barite property active at present (1960) in Nova Scotia, is operated by Magnet Cove Barium Corporation, a subsidiary of Dresser Industries Incorporated of Dallas, Texas. The barite ore was obtained from an open-pit for several years, but is now produced entirely from underground workings. It is trucked to the company's tidewater milling, storage, and shipping facilities at Walton townsite, 2½ miles northeast of the mine.

Recently, development activities have focussed upon the argentiferous sulphide mineralization associated with the barite.

Fletcher first accurately located the Walton deposit, and indicated it as an outcrop of barite on his map of the Walton area (1905). In 1940, the economic potentialities of the small exposure were recognized by Springer Sturgeon Gold Mines Limited. Diamond drilling proved an orebody of more than 3 million tons, one of the largest known barite deposits in the world, and in February 1941, Canadian Industrial Minerals Limited, a subsidiary of Springer Sturgeon Gold Mines Limited, commenced quarrying operations. Three months later a mill was completed at Walton, and on June 15, 1941, the first shipment left Walton for Trinidad. Underground operations began in early 1946. The present owners, Magnet Cove Barium Corporation, took over the operations of Canadian Industrial Minerals Limited on November 1, 1955. As the open-pit was near its maximum operating depth, the new owners concentrated on the development of underground mining facilities, and by 1958 most of the ore was being obtained from underground workings.

The total production of barite from the Walton mine to the end of 1959 was 2,578,754 tons. By comparison, the total Canadian output between 1885 and 1941 (when operations at Walton commenced) was only a little more than 41,000 tons. Annual production figures for the Walton mine range from the initial production of 12,840 tons in 1941 to a high of 292,145 tons in 1956. Production in 1959 was 207,386 tons.

Geology

Horton strata are exposed in the southern part of the Walton open-pit, Windsor strata in the northern part. Horton rocks are tough, impure sandstone and grey to red shale and argillite. Windsor strata include interbedded sandy, reddish brown limestone-conglomerate, red shale, red to reddish brown calcareous sandstone, and minor sandy limestone, which together constitute the Pembroke Formation. Exposures of the Macumber Formation were not observed, but pieces of Macumber limestone are present in Pembroke conglomerate. The Pembroke Formation is about 100 feet thick. A gypsum bed that is exposed as small outcrops along the northern edge of the open-pit overlies the Pembroke Formation.

The barite orebody appears to follow a normal fault zone that strikes about S75°E and dips steeply north in the vicinity of the mine. Horton beds border the orebody on the south and Windsor beds on the north. The vertical separation caused by movements along the fault zone is estimated to be at least 300 to 400 feet, north side down relative to the south side. Minor high-angle faults noted in underground workings and in the open-pit appear to have been of subordinate importance in controlling the orebody. The barite ore formed an elongate body plunging east at about the same angle as the enclosing strata, that is, about 25 degrees. The orebody is somewhat lens-shaped in cross-section with the long axis dipping steeply north. Post-barite movements have brecciated the barite and country rocks along the margins of the orebody.

Barite ore is fine grained, massive, and white to light grey, with reddish patches due to disseminated hematite. The specific gravity of the barite ore varies from 4.3 to 4.5, and a typical chemical analysis is as follows (Campbell, 1942):

BaO	63.90%
SO_3	33.85
SiO_2	1.84
Al_2O_3	0.75
Fe_2O_3	0.52
CaO	0.27
SrO	0.07
	101.20%

Some samples contain as much as 0.50 per cent MnO_2.

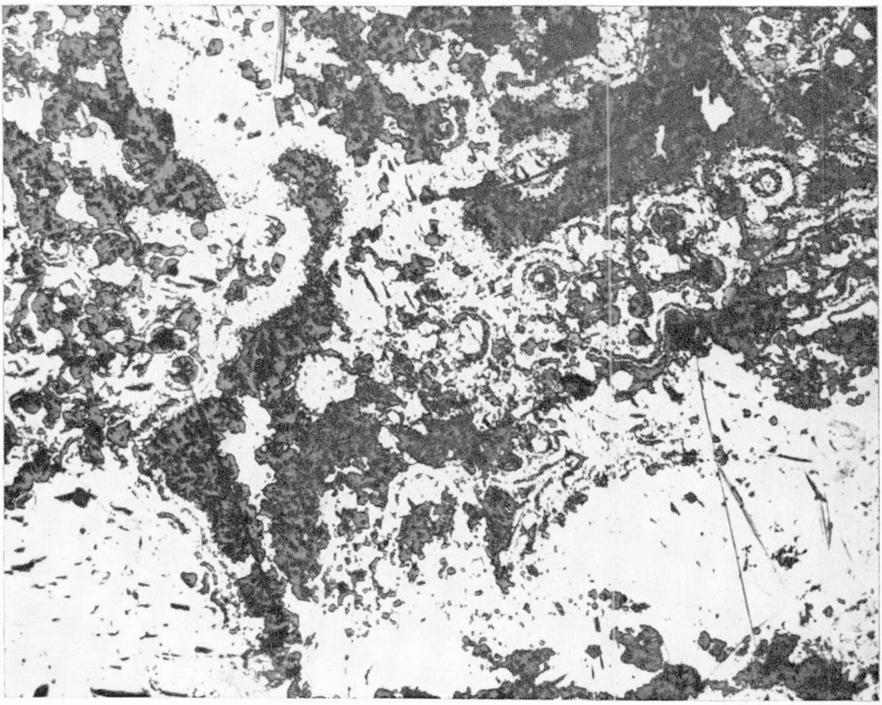
In thin section, most of the barite appears as elongated crystals arranged in radiating sheath-like forms. The crystals are basal tablets, elongated parallel to the "a" and "b" crystallographic axes and flattened at right angles to the "c" axis. A small amount of hematite accompanies radiate barite, being concentrated at the loci of individual sheaths, at the junctions of adjacent sheaths, and along the cleavages, particularly the 001 cleavage.

A short piece of diamond-drill core labelled "manganese", which was sampled during a visit to the Walton mine in 1949, proved upon examination in polished sections to consist almost entirely of sulphides, as shown by the following estimated percentages by volume (Crosby, 1951):

Galena	55%
Sphalerite	15
Barite	10
Pyrite	10
Tetrahedrite-tennantite	6
Chalcopyrite	4

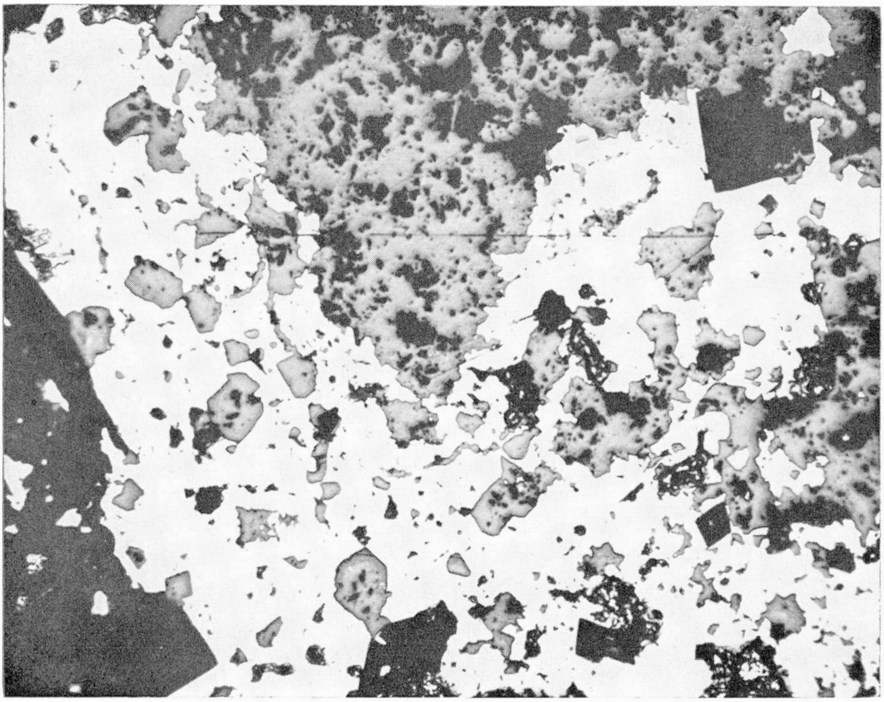
To the writer's knowledge, this was the first indication of the presence of sulphide minerals in the area.

Colloform sphalerite has been replaced by galena (*see* Pl. XIV). As seen under high magnification, pyrite occupies the central parts of many of the spheroidal structures. All the sulphides replace barite, and minute inclusions of sulphides occur in barite as replacement blebs (*see* Pl. XV). Barite, a common mineral in many metalliferous and non-metallic deposits of igneous origin, is



111930A

Plate XIV. *Photomicrograph of colloform texture in sphalerite (grey) partly replaced by galena (white). 117X.*



111930B

Plate XV. *Photomicrograph of galena (white) replacing barite (black, in lower left); pyrite (black with light spots) replacing barite in bottom centre; sphalerite (grey) replacing barite in upper right. Replacement blebs of sulphides in barite. 358X.*

usually late in the paragenetic sequence. A later rise of temperature during deposition may account for the reversal at the Walton mine.

Origin

The Walton barite orebody was formed by fissure filling and replacement processes, predominantly the latter. Barite replaces limestone and to a lesser extent sandstone and shale. Principal access for the mineralizing solutions appears to have been provided by an east-trending regional fault zone.

The occurrence of barite replacing rocks of different lithologies, accompanied by sulphides and slight wall-rock alteration, suggests that the Walton deposit is of hydrothermal origin, probably deposited from low-temperature telethermal solutions. Such solutions may have originated during the time of Triassic igneous activities, as did extensive basic extrusions and associated dykes and sills in the Wolfville map-area.

Manganese

References: Fletcher, H., Geol. Surv., Canada, Ann. Rept. 1892-93, pt. A, p. 64; Geol. Surv., Canada, Sum. Rept. 1902, pt. A, p. 390; also Walton sheet (1905) and Kingsport sheet (1911).

Flynn, A. E., Survey of Minas Basin Manganese Deposits; N.S. Dept. Mines, Ann. Rept. 1939, pt. 2, pp. 1 and 4.
Hanson, G., Manganese Deposits of Canada; Geol. Surv., Canada, Ec. Geol. Ser. No. 12, pp. 41 and 56 (1932).
Ingall, E. D., Manganese; Geol. Surv., Canada, Sec. of Mines, Ann. Rept. 1902, pt. S, pp. 155-156.
Smitheringale, W. V., Manganese Occurrences of the Maritime Provinces; unpublished doctoral thesis, Mass. Inst. Technology, 1928, copy on file, Geol. Surv., Canada.
Weeks, 1948, pp. 71-75.

A number of abandoned manganese prospects are present in the east half of the Wolfville map-area. All occur at or near the Horton-Windsor contact. They consist of the oxides pyrolusite and subordinate manganite and psilomelane, which occur mainly as replacement masses, lenses, and nodules, in Pembroke limestone-conglomerate. Lesser amounts are present as coatings on fragments in limestone-conglomerate and as fracture fillings in Pembroke and underlying Macumber strata. At some localities the manganese oxides occur along joints and bedding planes in Horton strata. The origin of the manganese is not known. On the basis of the character of the deposits they are probably of supergene origin, the manganese oxides being deposited from migrating meteoric waters.

None of the prospects has been active for many years, and none appears commercially attractive at this time. The Stephens mine near Walton and the Macumber mine near Cheverie have undergone more work than the other manganese prospects in the area. They have been described in considerable detail by Weeks (1948).

Stephens Mine

The Stephens mine is three quarters of a mile southwest of Walton, less than 2,000 feet south of the Walton-Windsor shore highway, and is readily accessible by means of a short wood road. J. Brown first worked the mine and obtained a few tons of ore during the period 1870 to 1875. R. J. Stephens mined 10 to 20 tons of ore about 1885; and William Stephens obtained about 20 tons of ore from 1902 to 1907. The total recorded recovery of ore is only about 40 tons, but there was probably some unrecorded production.

The mine workings are spaced along 1,800 feet of the outcrop band of the Pembroke and Macumber Formations. There are five open-cuts in low cliff faces of limestone, the largest of which is 230 feet long, and about half a dozen pits, some of which may actually be sink-holes. Eight shafts were sunk into limestone, but these are now either caved in, full of water, inaccessible, or otherwise unattractive for internal inspection. Weeks (1948) estimated that some 10,000 tons of rock were moved in excavating these workings.

The average dip of strata near the mine is about 45°S. Horton shale is exposed in the eastern part of the workings, and forms the foot-wall limit of possible ore. Most of the manganese ore produced from the property was from replacement masses in Pembroke limestone-conglomerate. The ore minerals, pyrolusite and lesser manganite, also occur as fracture fillings in Macumber limestone. No large body of ore was found on the property, and the tenor of the rock mined appears to have been very low.

Macumber Mine

The properties of the Macumber mine are three quarters of a mile southwest of Cheverie, west of the Walton-Windsor shore highway, and are readily accessible by means of a good farm road. The Lake property is at the shore, about 1,800 feet from the highway; the Brown property is about 500 feet from the highway, at the end of Manganese Hill. The Lake workings consist of an open-cut into the sea-cliff 80 feet long and 25 feet deep, partly caved. The Brown workings consist of an open-cut about 60 feet long into the side of a hill and several small pits on top of the hill. These properties were worked for a short time at the turn of the century, and yielded a total of about 100 tons of ore.

In 1936 or 1937 Leander Macumber, owner of the farm upon which the properties are located, sank a 19-foot timbered shaft just west of the Lake open-cut. Weeks (1948) estimated that about 66 tons of rock were excavated from the shaft with a recovery of a ton and a half of manganese oxides.

The Macumber deposits are on the west limb of a structural basin of Windsor rocks that extends from Kempt Shore to Bramber. Strata in the immediate vicinity of the workings are gently dipping to flat. Underlying Horton sandstone is exposed at the shore just west of the Lake workings and as an inlier just south of the Brown workings. The ore minerals, pyrolusite and manganite, occur as replacement masses in Pembroke limestone-conglomerate. A minor amount occurs as veinlets. Nodular masses of psilomelane a foot across are present in limestone-conglomerate on the shore. Manganese oxides there may have a considerable lateral extent, owing to the flatness of strata; however, the rock mined appears to have been very low grade.

Petroleum

References: Bancroft, M. F., Geology of the South Side of Minas Basin; unpublished report Nova Scotia Oil and Gas Company, on file, N.S. Dept. Mines, Halifax, p. 2 (1946).

Bell, W. A., Possibilities for Occurrence of Petroleum Reservoirs in Nova Scotia; N.S. Dept. Mines, Halifax, pp. 21 and 80 (1958).

Fletcher, H., Geol. Surv., Canada, Rept. Prog. 1902, p. 393A (1903).

Wright, 1931, pp. 119 and 126-127, maps 11 and 12, and sketch 11.

Oil and bitumen were first noted about 1872 in the Windsor gypsum that was quarried near Cheverie, and were described by Fletcher (1903) as follows, "Oil and bitumen have been found in cavities, joints and fissures of a mass of gypsum largely quarried in this neighbourhood . . ." Three holes were drilled in 1902 on the basis of this occurrence. No shows of petroleum were reported from any of the tests. The second and deepest hole, 1½ miles southeast of Cheverie, was abandoned at a total depth of 1,910 feet; it had penetrated about 500 feet into the Horton strata.

A hole was drilled in 1912, 1½ miles southwest of Windsor, in search of oil. It was abandoned at a total depth of 1,637 feet, about 300 feet into the Horton, after reportedly encountering a show of heavy black oil in Windsor gypsum. Three shallower holes were drilled in the same region 10 years later, two of which were located about a mile west of Windsor, the third just south of the hole drilled in 1912. No shows of petroleum were reported from any of these three holes.

References

Alger, F.
1827: Notes on the Mineralogy of N.S.; *Am. J. Sci.,* vol. 12, pp. 227-232.

Ami, H. M.
1900: Synopsis of the Geology of Canada; *Proc. and Trans. Roy. Soc. Can.,* 2nd ser., vol. 6, sec. 4, pp. 187-225.
1903: On the Upper Cambrian Age of the *Dictyonema* Slates of Angus Brook, New Canaan and Kentville, Nova Scotia; *Proc. and Trans. N.S. Inst. Sci.,* vol. 10, pp. 447-450.

Bailey, L. W.
1898: Report on the Geology of Southwest Nova Scotia; *Geol. Surv., Canada,* No. 628, 151 pp.

Bell, W. A.
1929: Horton-Windsor District, Nova Scotia; *Geol. Surv., Canada,* Mem. 155, 268 pp.

Churchill, F. C.
1923: An abandoned Marine Sand-bar in the Cornwallis Valley, Nova Scotia; *Proc. and Trans. N.S. Inst. Sci.,* vol. 15, pp. 65-69.

Crosby, D. G.
1952: Wolfville (East Half), Hants and Kings Counties, Nova Scotia; *Geol. Surv., Canada,* Prel. Map, Paper 52-18.

Dawson, J. W.
1848: On the New Red Sandstone of Nova Scotia; *Quart. J. Geol. Soc. London,* vol. 4, pp. 50-58, appendix, On the Lower Carboniferous Rocks of Windsor and Horton, p. 59.
1855: Acadian Geology; London, 1st. ed., 833 pp.
1868: Acadian Geology; London, 2nd. ed.
1878: Acadian Geology; London, 3rd. ed.
1882: On the Footprints of Batrachians observed in the Carboniferous rocks of Nova Scotia; *Trans. Roy. Soc. London,* vol. 173, pt. 2, pp. 651-654.
1891: Acadian Geology; London, 4th. ed.

Faribault, E. R.
1909: Southern Part of Kings and Eastern Part of Lunenburg Counties, Nova Scotia; *Geol. Surv., Canada,* Sum. Rept. 1908, pp. 150-154.
1912: Goldbearing Series of the Basin of Medway River, Nova Scotia; *Geol. Surv., Canada,* Sum. Rept. 1911, p. 336.

Fletcher, H.
1905: Walton Sheet No. 74, Hants County; *Geol. Surv., Canada,* Map 879.
1906: Geological Work in the Northwestern Parts of Nova Scotia; *Geol. Surv., Canada,* Sum. Rept. 1905.
1907: Surveys in Western Nova Scotia; *Geol. Surv., Canada,* Sum. Rept. 1906, pp. 140-141.
1911: Kingsport Sheet No. 84, Hants and Kings Counties; *Geol. Surv., Canada,* Map 13A.

Fletcher, H., and Faribault, E. R.
1909: Windsor Sheet No. 73, Hants County; *Geol. Surv., Canada,* Map 1037.

Goldthwait, J. W.
1924: Physiography of Nova Scotia; *Geol. Surv., Canada,* Mem. 140, 178 pp.

Haliburton, T. C.
1829: An Historical and Statistical Description of Nova Scotia; Halifax, vol. 2, pp. 108-109.

Honeyman, D.
1879: Nova Scotia Geology-Kings County; *Proc. and Trans. N.S. Inst. Sci.,* vol. 5, pp. 21-31.

Jackson, C. T., and Alger, F.
1828-1829: A Description of the Mineralogy and Geology of a Part of Nova Scotia; *Am. J. Sci.*, vol. 14, pp. 305-330; vol. 15, pp. 132-160, 201-217.

Malcolm, W.
1929: Gold Fields of Nova Scotia; *Geol. Surv., Canada,* Mem. 156, pp. 33-34.

Murchison, R. I.
1843: Presidential Address; *Proc. Geol. Soc. London,* vol. 4, p. 65.

Powers, S.
1916: The Acadian Triassic; *J. Geol.,* vol. 24, pp. 1-26, 105-122, 254-268.

Ruedemann, R.
1908: A report read by the President on three specimens of *Dictyonema websteri* Dawson from New Canaan, near Kentville, Nova Scotia; *Proc. and Trans. N.S. Inst. Sci.,* vol. 11, p. xlvii.

Weeks, L. J.
1948: Londonderry and Bass River Map-areas, Colchester and Hants Counties, Nova Scotia; *Geol. Surv., Canada,* Mem. 245, 86 pp.

Woodman, J. E.
1904: Nomenclature of the Gold-bearing Metamorphic Series of Nova Scotia; *Amer. Geol.,* vol. 33, pp. 364-370.
1908: Probable Age of the Meguma (Gold-bearing) Series of Nova Scotia; *Bull. Geol. Soc. Amer.,* vol. 19, pp. 99-111.

Wright, W. J.
1931: Reports on Cheverie, Windsor, and Shubenacadie Basins; *N.S. Dept. Mines,* Ann. Rept. 1930, pt. 2, pp. 114-142.