CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

MEMOIR 297

TRURO MAP-AREA, COLCHESTER AND HANTS COUNTIES, NOVA SCOTIA

By

I. M. Stevenson

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1958

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PLATE I

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The mill and barite deposit at Brookfield, Colchester county, N.S. Deposit forms hill in top centre of picture. View looking northwest.

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PREFACE

The geological formations of the Truro map-area range in age from pre-Carboniferous sedimentary and intrusive rocks of the Cobequid Mountains in the north to the relatively undisturbed Triassic sedimentary rocks bordering either side of Cobequid Bay.

The latest previous detailed mapping of the area was carried out by officers of the Geological Survey of Canada in the late 1890s. Although much of this work remains unchallenged, palæontological data accumulated since that time have necessitated revision of the previously published map.

The present report deals in considerable detail with all known mineral deposits of possible economic interest within the area. Special attention is given to the barite deposit at Brookfield and also the lead-zinc deposit at Smithfield. In addition, field and laboratory work by the author has shed new light upon the origin, structure, and age relations of many of the geological formations.

GEORGE HANSON,
Director, Geological Survey of Canada

OTTAWA, October 1, 1956

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TRURO MAP-AREA, COLCHESTER AND HANTS COUNTIES, NOVA SCOTIA

CHAPTER I

INTRODUCTION

The Truro map-area, Colchester and Hants counties, Nova Scotia, lies between latitudes 45° 15′ and 45° 30′ north and longitudes 63° 00′ and 63° 30′ west, and covers about 400 square miles in the north-central part of the province. The town of Truro, with a population slightly in excess of 11,000, is situated in the approximate centre of the map-area.

Cobequid Bay, the east end of which has a tidal difference of about 50 feet, divides the western half of the map-area into north and south parts.

The climate is temperate and humid, with few temperature extremes. The mean annual temperature is 42° F., the average rainfall 35·15 inches, and the average annual snowfall 89·1 inches. The average total precipitation in terms of rain is 44·06 inches.

The chief economy of the area consists of mixed farming. Dairy produce and market gardening are of major importance. Hay and forage crops occupy the largest acreage, but potato growing is of importance in restricted areas. The sale of lumber provides an added source of income for many of the farmers, although very little timber of merchantable value remains except in the more inaccessible areas. The greater part of the region is covered by second growth pulp wood.

The 1950 and 1951 field seasons were spent in mapping the geology of the Truro map-area, particular attention being paid to mineral prospects that might prove of economic value.

The writer was capably assisted during the 1950 field season by Messrs. C. G. Winder, D. G. Kelley and W. H. Dobson, and during the 1951 season by J. R. Nixon, R. D. Howie and W. B. Dunlop. The advice and criticisms of Professor T. H. Clark of McGill University, under whose guidance the laboratory work was carried out, were much appreciated. Mr. C. O. Campbell, Manager of Brookfield Barytes Limited, kindly provided unpublished maps and information during the investigation of the barite property at Brookfield, N.S. The writer is also indebted to Mr. J. P. Messervey, Deputy Minister of Mines for Nova Scotia, for his assistance in supplying much unpublished information of economic nature relating to mineral deposits in the area.

With the exception of the more remote wooded sections in the northern part of the region, the entire district is readily accessible by automobile, but during periods of heavy rainfall many of the secondary dirt roads become impassable. Numerous logging roads, many of which are deteriorating through disuse, cross the timbered areas.

Access to the region may be had by No. 2 paved highway, which follows the north shore of Cobequid Bay, passes through Truro, and then proceeds south to Halifax. A paved highway that joins Truro and New Glasgow, crosses the northeast quarter of the map-area. The main line of the Canadian National Railways cuts across the northwest corner of the area, and then parallels the highway from Truro to Halifax. A branch line of the same railway follows Salmon and Black Rivers northeast to Sydney. The Dominion Atlantic Railway, a branch of the Canadian Pacific Railway, links South Maitland to Truro. Access to that part of the map-area west of Shubenacadie River may be had by means of this railway, or by a circuitous route by secondary road via the town of Shubenacadie.

Previous Geological Work

The earliest scientific description of the rocks of Nova Scotia is found in a paper presented to the *American Journal of Science* by Messrs. Jackson and Alger in 1828 (26)[1]. In the article reference is made to the beds of gypsum that occur along the west bank of Shubenacadie River.

Dr. Abraham Gesner, in his "Geology and Mineralogy of Nova Scotia" (19), produced the first comprehensive study of the rock formations and mineral occurrences of Nova Scotia. He attempted to classify the different rock types of the province by districts. Though he was a physician by profession and had to carry out his geological work in conjunction with his own arduous duties, his writings remain a masterpiece to this day. He was a firm believer in the future of Nova Scotia, and his work undoubtedly proved of great value in the subsequent geological examination and development of the province.

In 1843 he read a paper before the Geological Society of London, England, in which he set forth additional information compiled subsequent to 1836. Again in 1849 he published "The Industrial Resources of Nova Scotia" (20). The description of the material and the statements of views given in this book are couched in nomenclature similar to that of today.

In 1842, Sir Charles Lyell made a visit to Nova Scotia. In his book, "Travels in North America" (29), he set forth in a very precise manner the results of his observations in the province. One of his most interesting descriptions of the stratigraphy of the area deals with a trip that he made in a small boat up Shubenacadie River in the company of Sir William Dawson and a Mr. Duncan of Truro. Lyell first assigned a Carboniferous age to the rocks of the area by a study of fossils collected from limestones

[1] Numbers in parentheses are those of references listed in the Bibliography.

along Shubenacadie River and the quarry east of Brookfield. Although a Permian age was assigned to the gypsum of Nova Scotia by Murchison in 1843, Lyell had correctly observed that gypsum constituted a regular part of the Carboniferous series.

The foundation of Carboniferous stratigraphy in Nova Scotia was laid by Sir William Dawson in four editions of his "Acadian Geology". The first edition was published in 1855, the second in 1868, with supplements in 1878 and 1891. "Acadian Geology" has remained a standard work on Maritime stratigraphy since that time (15). Dawson's description of his trip along Shubenacadie River with Lyell in 1842 (15, p. 266) gives a comprehensive description of the gypsum deposits and rock formations outcropping along the banks of this river. He recognized the presence of numerous faults, and realized the difficulty of assembling all the minor sections into a complete series. He also considered it probable that many of the contortions of the gypsiferous rocks of Nova Scotia were due to the growth of gypsum veins in the rock by the addition of material to each end of the prisms of gypsum by the water permeating the rock, thereby pressing the sides of the fissure apart as the prisms grew in length. Dawson was the first to assign a Triassic age to the unfossiliferous, limy sandstones of the area.

A series of fossil collections was made prior to 1864 by Charles Frederick Hartt, Professor of Geology at Cornell University, from exposures of Windsor limestones along the Shubenacadie River (23).

The first detailed mapping of the area was carried out by Hugh Fletcher during the period 1887 to 1891 (17). To this day his maps have proved to be accurate in detail, and the extreme skill with which these maps were prepared indicates the scientific knowledge that their author possessed. Special attention was given to all mineral showings, and all pertinent facts carefully recorded. As Fletcher's maps were prepared by chain and compass traverses, he was able to reproduce minute drainage details that are commonly lacking on modern maps produced from aerial photographs. His contacts are accurate, but as he expressed little faith in the use of fossils for age determination, the Union formation that lies below the marine Windsor group was incorrectly given a Devonian age. This started a controversy that waged for several years, for lithologically the Union is indistinguishable from the overlying Riversdale group in many localities, and fossils in the Union formation are extremely scarce. Several solutions to this problem are offered in reports by Ami (4), Young (38), and Hyde (25).

Sydney Powers (32) in his report on the Acadian Triassic, undertook a detailed examination of the rocks of that age in Nova Scotia. He dealt briefly with the Triassic rocks in the Truro area.

The first comprehensive report on the Carboniferous stratigraphy of Nova Scotia was published by Bell (7) in 1927. Since that time he has published several memoirs dealing chiefly with the fossil floras and faunas of Nova Scotia. In his memoir on the Horton-Windsor District (8, p. 84) he recorded the equivalence of the Union series and the exposures of Horton rocks in that area.

Weeks (35) undertook a detailed examination of the Londonderry Iron Mines, and established a type sequence for the Carboniferous rocks in that area. As the Londonderry-Bass River map-area lies immediately to the west of the Truro map-area, the present writer has endeavoured wherever possible to adopt the classification of formations worked out by Weeks.

Daly (12) dealt in a general manner with the physiography of the province, and compared the topographical features with those of New England. His work was later extended by Goldthwait (21), who published a more detailed memoir on the surface features.

No other province of Canada has been so thoroughly mapped as has Nova Scotia, and the accessibility of the Truro area has rendered it especially susceptible to detailed examination. Mineral prospects in particular have been thoroughly examined.

CHAPTER II

SURFACE FEATURES

Approximately two-thirds of the map-area is composed of relatively soft Carboniferous shales and sandstones. A small section in the extreme northwest corner of the area is made up of the more resistant crystalline rocks of the Cobequid complex. Along either side of Cobequid Bay, and extending up Salmon River almost to Union station, the bedrock consists of soft red sandstones of Triassic age. Differences in the erosive characteristics of these three rock types lead to well defined topographical boundaries along the contacts.

The area may best be divided topographically into three parts; the Cobequid Highlands, the Carboniferous uplands, and the Triassic lowlands.

Cobequid Highlands

The Cobequid hills, together with the Southern Plateau, North Mountain, the Pictou-Antigonish Highlands, and the highlands and northern tableland of Cape Breton Island, form the upland districts of Nova Scotia. These areas, and the highlands of Gaspé, Newfoundland, and New Brunswick, form part of an uplifted and dissected peneplain that Daly (12, p. 93) correlated with the Cretaceous peneplain of New England. He grouped the individual remnants and termed it the "Atlantic Upland". The Cobequid hills have played a decisive role in maintaining the general level of the Atlantic Upland, which slopes gently from sea-level along the southeast coast of Nova Scotia to the highlands of Cape Breton, Newfoundland, New Brunswick, and Labrador.

The topography of the Cobequid hills is due to the resistant character of the rocks of which they are composed. Following the formation of the Cretaceous peneplain, uplift occurred and the softer sediments of the lowlands to the south were worn down by the new cycle of erosion. These lowlands form a second and lower peneplain that dates from the Tertiary period (12, p. 94).

Although only a minor part of the Cobequid complex lies within the boundaries of the map-area, this resistant chain of igneous rock exerts a considerable influence upon the topography of the bordering lands which slope gently towards the south, for it is the Cobequid hills that form the watershed wherein the major south-flowing streams of the area arise.

The Cobequid belt of hills averages 12 miles in width and stretches from the head of the Bay of Fundy almost to Northumberland Strait, a distance of about 75 miles. The Cobequid area, though often spoken of as a mountain range, has few of the rugged features generally associated with that name. When viewed from the lowlands that lie to the south the range presents an irregular, jagged outline. Actually the summits display a roughly similar accordance in height that averages 900 feet above sea-level. The southern flank of the range, which approximately parallels the northern boundary of the map-area, rises abruptly, in places precipitously, above the softer Carboniferous rocks to the south. This steep slope is cut by numerous deep gorges that have been carved out by the major streams.

The writer made several traverses into the mountains immediately north of the map-area in order to examine the upper part of the watershed. Much of the highland is swampy and boggy, and covered with a heavy drift mantle. Due to the depth of glacial debris, very little bedrock is exposed in the interstream areas. Small lakes, many with no visible outlets, are numerous. The slopes of the individual hills are heavily wooded with birch, beech, and maple, and the poorly drained valleys support a thick growth of balsam, spruce, hemlock and tamarack.

In general, the summit of the range is flat and featureless, in contrast to the southern slope with its numerous waterfalls and steep cliffs.

Carboniferous Uplands

The rocks of the Carboniferous uplands consist of shales, sandstones, conglomerates, limestones, and gypsum beds. The resistance of these rocks to erosion varies but all are less resistant than the Cobequid crystalline rocks to the north.

The upland surface is one of numerous gently rolling hills with relatively deep valleys. Evidence of glaciation may be found on the hills, but the major topographic relief has been brought about by stream erosion. In many instances hills have the general form of drumlins, but upon examination are found to be elongated parallel to the general strike of the strata, which is often at right angles to the direction of ice-movement. Several of these hills have been penetrated by drilling and found to be composed of deeply decayed rock and not of glacial debris.

The Carboniferous uplands include approximately three-quarters of the map-area. Where Horton sedimentary rocks outcrop in the south half of the region, the average elevation is 450 feet, with a maximum elevation of 825 feet. The less-resistant Windsor strata have a more subdued relief, with an average elevation of about 200 feet.

The Pennsylvanian beds in the north half of the upland area rise gently from about 100 feet to a maximum elevation of 800 feet along the northern boundary of the map-area. The average elevation is approximately 550 feet. Most stream channels are deep and sharply defined.

Those sections of the uplands immediately underlain by gypsum are for the most part characterized by karst topography in various stages of formation. Funnel-shaped sink holes, with no surface outlet, occur with depths often exceeding 30 feet. Although gypsum should be easily susceptible to erosion such is not always the case, as in numerous instances well-exposed outcrops of gypsum project above the general level of the more resistant surrounding bedrock.

Some farming is carried out on the Carboniferous uplands, but generally the land is of a marginal nature. Dense second growth evergreen woods cover the larger part of the region. Due to poor drainage several large areas are boggy.

Triassic Lowlands

The head of Cobequid Bay marks the eastern limit of a syncline that stretches from Cape Blomidon, 15 miles north of Wolfville, N.S., to a point about 5 miles east of Truro. Cobequid Bay is bounded on either side by distinctive red sandstones and conglomerates of Triassic age. These rocks are softer than the Carboniferous rocks of the area and erosion has affected them much more severely.

The greatest width of Triassic rock lies north of Cobequid Bay. The eastern contact with the Carboniferous is well exposed on Salmon River midway between Valley and Union stations. The surface of the land underlain by Triassic rock is one of gently rolling relief, the average height above sea-level being less than 50 feet. The relatively soft Triassic rocks have been affected severely by glaciation and hills in them are extremely well rounded.

Truro is situated on a delta deposited by Salmon River. The materials that form the delta originated mainly from the red Triassic sandstones that lie to the east of the town.

The rich farming areas of the district are found almost exclusively in the fertile calcareous soils derived for the most part from the underlying Triassic bedrock.

Drainage

The two principal rivers are Shubenacadie River, which flows from the south, and Salmon River, which flows from the east; both empty into Cobequid Bay. Most of the brooks and streams drain into these two rivers. Much of the south half of the region is drained by small brooks that flow southward into Stewiacke River, a tributary of Shubenacadie River. Stewiacke River runs in a southwestern direction, paralleling the southern border of the map-area for several miles.

Shubenacadie River, the largest river in Nova Scotia, deserves special mention. The tidal change in water level of this river is approximately 25 feet; a change probably equalled by no other river of its size in the world. Lyell (29, p. 162) very aptly described it as "a current of red mud in violent motion" although actually the colour of the water is a dull chocolate-brown. The mud content of the water is commonly so high that the resulting mixture assumes the consistency of a thin paste.

The incoming tidal bore on Shubenacadie River is a phenomenon not soon forgotten. At low tide, the river consists of a narrow ribbon of calm, muddy water, winding between shining banks of chocolate-brown mud. The tidal flats likewise present a barren stretch of mud with a glass-like surface, unmarred except for the occasional foraging sea-gull or piece of refuse deposited by the outgoing tide. Motion in the river has practically ceased, and all is quiet. Then in the distance a faint hissing noise is heard that gradually increases in intensity until the sound of rushing water can be distinguished. The initial wave of the tidal bore, about 6 inches high, can then be seen approaching at a speed of approximately 10 miles an hour. The normal direction of the current is reversed, and the peaceful stream is rapidly transformed into a rushing torrent of water that twists and swirls about small bars and other obstructions. The tidal flats and muddy banks are rapidly obscured from view, and in a matter of minutes no resemblance of the former quiet, peaceful stream remains.

As the tide recedes, and the level of the river falls, channels several inches deep are cut in the muddy sloping banks of the river by small rivulets. When the tide has completely receded, many small sandbars form, displaying current ripple-marks. These disappear or change shape with the varying current of each incoming tide.

Shubenacadie River probably follows the general course of a pre-glacial antecedent river. During the first advance of the continental ice-sheet, drainage was disrupted, and the channel was choked with ice, gouged out, and deepened. To explain the sharp, elbow-like bends in the river it is suggested that, as drainage was re-established upon recession of the ice-sheet, the river in general resumed its former channel. In certain sections, however, debris deposited by the ice diverted the flow of water, which therefore cut a new channel in the bedrock. Fracture sets in the rock would control the new course and elbow-shaped curves would result. The strike of the fracture sets that probably formed the bend at Eagle's Nest Point are north 30 degrees west and north 80 degrees east and correspond to those on Mill and Pitch Brooks.

Salmon River, the second largest river in the area, has its headwaters in the Cobequid Mountains. From the upper reaches of the river the water leaves the Cobequid Mountains in a series of cascades and falls that rapidly diminish in magnitude as the lowland area is approached. Below the mouth of Steele Run, Salmon River has lost much of its energy, and the banks are gently sloping. Black River, a main tributary of the Salmon, is a relatively rapid flowing stream that has carved a deep channel in shales and sandstones. Calvary Stream enters Black River from the southeast at Riversdale and also has a gorge-like channel. The banks of Calvary Stream provide some of the best exposed sections of bedrock in the north half of the map-area.

Salmon River is evidently a consequent stream, but most of its tributaries are of the subsequent type and follow the less resistant beds of underlying bedrock. North, Chiganois, and Debert Rivers are likewise all consequent streams.

Within the mountains the rivers have gorge-like valleys. Down-cutting has obviously been rapid, with the more resistant rocks producing falls and rapids. The chloritized flow rocks in particular are very resistant to erosion, and invariably form falls. As the streams emerge from the mountains onto the lowlands a considerable decrease in gradient occurs, and with the slowing down of the water much of its load is deposited.

Most of the lesser streams in the map-area are short and carry a relatively small volume of water. During the months of July and August many of the smaller creek beds are completely dry, and the major streams become mere rivulets. The upper reaches of the minor streams have very shallow banks, whereas in the lower reaches small cascades and waterfalls are encountered wherever resistant beds of sandstone are interlayered with softer shales.

In general, the drainage pattern of the area is dendritic, little control over the stream pattern being exercised by fractures in the bedrock. A possible exception is found in the southwest quarter of the map-area, where a poorly developed rectangular type of drainage is encountered. The latter is described in the section under faulting.

Soil Development

Most of the surficial deposits of the area are glacial till the constitution of which, as well as the relative size of the fragments, is determined mainly by the nature of the underlying bedrock. The resistant crystalline rocks of the Cobequid complex break into fragments that range in size from gravel to boulders. The conglomerates, sandstones, and shales of the Carboniferous uplands and Triassic lowlands weather down to a mixture of gravel, sand, silt, and clay. Conglomerates produce a gravelly soil, and the amount of clay and silt present depends on the amount cementing the pebbles in the conglomerate. The sandstones weather down to sands that contain much silt and clay. Shales ultimately produce clay as the end product of their erosion.

The soils that result from the weathering of the above materials tend to remain unmixed, and bedrock boundaries correspond very closely with soil boundaries. Apparently glaciation has not prevented the recognition of formational boundaries, and where outcrops are lacking contacts may be determined approximately by a careful examination of the soil types. Fletcher used this method extensively and drilling in recent years has proved the accuracy of his deductions.

Bedrock in the map-area consists of three types; igneous, metamorphic, and sedimentary, each of which produces a characteristic soil. The small area of igneous and metamorphic rocks in the northwest corner of the map-area produces a gravelly type of soil, which spreads thinly over much of the bedrock. It contains many large boulders and is unsuitable for agriculture. This area is covered by a heavy second growth of mixed hardwood and coniferous trees.

By far the greater part of the region is underlain by sedimentary rocks of Triassic and Carboniferous age. The soft, red rocks of Triassic age contain a calcareous cement that reacts readily with atmospheric agencies and ground waters to form a porous, crumbly rock. The soil that ultimately forms from these rocks is high in lime and these red Triassic soils make rich farming lands. Triassic rocks range in texture from a fine shale to a coarse conglomerate and the texture of the glacial till varies accordingly.

The Carboniferous rocks consist of sandstones, shales, and conglomerates. The sandstones and shales are mainly grey and brown, the conglomerates may be grey, green, brown, or purplish red. Gypsum and most of the limestone are confined to the Mississippian rocks.

The till offers a striking diversity in colour, which is directly related to the variation in colour of the underlying bedrock. Till derived from Carboniferous rock is predominantly brown and red, and can be distinguished from the red Triassic till which is a peculiar salmon-red hue. Yellow and grey tills are produced from sandstones and shales of Carboniferous age.

The brown and red rocks weather more readily and completely than the grey types, and soil developed on till from the former is more friable and better suited for agriculture. An examination of the more heavily populated farming areas of the region indicates that all the better farms occur in regions underlain by Triassic sandstone or brown and red Carboniferous rocks.

Marshlands

The marshland soils, which lie chiefly along the north shore of Cobequid Bay between Truro and Debert, form one of the richest farming sections of the entire area. These soils cover an estimated area of approximately 4,000 acres, of which about 3,000 acres have been dyked. The remainder is salt marsh. At present, 1,400 acres of the dyked marsh is imperfectly drained; the remaining 1,600 acres is adequately drained for most crops.

The texture of these marshland soils ranges from a light silt loam to a silty clay loam and they are, for the most part, somewhat lighter in colour than other marshland soils of the province.

Early in the eighteenth century the French settlers realized the value of these marshlands, and initiated the practice of dyking. One cannot help but admire the ingenuity and skill of these people, for many of these dykes, built entirely by hand, are still standing. Marshland soil is today reclaimed with bulldozers and draglines. A running dyke is thrown up with a fairly thick base narrowing to about 8 feet at the top. The dyke is then packed and smoothed out by the bulldozer, and finally treated with lime or gypsum, or both, fertilizer, and a mixture of grass seeds. A rapid growth of grasses on the running dyke is essential to the success of the operation because erosion would otherwise be rapid on the exposed slopes of the structure.

Drainage from the dyked areas and of streams through the dykes is controlled by aboideaux. These are sluices placed in the running dykes at about half-tide level, thereby preventing the salt water from entering. At low tide, fresh water from the dyked area is allowed to pass into the drainage channel or river. A carefully balanced clapper opens with the pressure of fresh water at low tide and closes when the salt water covers it from the outside as the tide rises.

CHAPTER III

GENERAL GEOLOGY

Summary Statement

The oldest rocks in the area consist of a series of pre-Carboniferous strata intruded and metamorphosed by rocks of general acidic composition and possibly Devonian age. This complex forms the Cobequid Highlands, a small part of which crosses the northwest corner of the area.

In fault contact with the rocks of the complex is a thick succession of sedimentary rocks of Mississippian and Pennsylvanian age, apparently interrupted by several small unconformities.

TABLE OF FORMATIONS

Era	Period or epoch	Group or formation (approximate thickness, feet)	Lithology
Cenozoic	Recent		Stream gravels, tidal alluvium lake deposits
	Pleistocene		Glacial drift, stratified gravel
	Unconformity		
Mesozoic	Triassic	Annapolis formation 1,000	Brick-red, calcareous sandstone, conglomerate, shale
	Unconformity and basic intrusions (?)		
Palæozoic	Pennsylvanian	Pictou and Cumberland groups 5,000	Brown, green, and grey conglomerate, sandstone, shale
		Riversdale group 3,000	Grey shale, sandstone
	Unconformity (?)		
	Mississippian	Canso group	Red and grey sandstone, shale
		Disconformity (?)	
		Windsor group (upper) 1,300	Grey limestone, red and green shale, gypsum (?)
		Windsor group (lower) 1,300	Black and red limestone, red and green shale, gypsum
		Pembroke formation 100	Red limestone conglomerate, red calcareous shale
		Macumber formation 30	Grey, arenaceous, laminated limestone
		Minor disconformity	
		Horton group 4,000	Red and grey, sandstone, grit, shale, conglomerate
	Devonian ?		Granite, syenite felsite, diorite, acidic porphyritic rocks, aplite dykes, diabase
	Pre-Carboniferous		Argillite, shale, sandstone, chloritic schists, graphitic schists

The Carboniferous rocks were folded, truncated and unconformably overlain by a series of red, predominantly sandy beds of Triassic age occupying an open syncline centred along Cobequid Bay.

A few small diabase dykes cut the Carboniferous rocks and are presumably of pre-Triassic age.

Pre-Carboniferous Rocks

The Cobequid hills consist of a complex of sedimentary and volcanic rocks that have been cut by intrusive rocks of various compositions. The hills form part of a long, narrow remnant of the Atlantic upland, and stretch from the head of the Bay of Fundy almost to Northumberland Strait, a distance of 75 miles. This Cobequid massif, which has been worn down to low, hilly uplands, contains the roots of an ancient narrow mountain range that was in existence during Carboniferous times. During the Pennsylvanian period, the mountains were subjected to periodic orogenic uplift, and the resulting products of erosion were deposited in the bordering basins. The presence of three separate basal conglomerates of different ages has led to the conclusion that three distinct periods of uplift occurred within the Pennsylvanian alone (6, p. 474).

The core of the Cobequid hills is composed mainly of syenite, granite, diabase, and felsite. The resistant nature of these crystalline rocks has undoubtedly been the decisive factor in the preservation of the complex. Intruded by the igneous rocks are volcanic and sedimentary strata of possible Silurian and Devonian ages (35, pp. 9-11). The latter sediments have been cut by minor intrusive rocks of possible Carboniferous age.

Dawson (15, Suppl., p. 79) early recognized the complex arrangement of the Cobequid hills. He stated that "There is a central mass of red intrusive syenite or syenitic granite, usually having a large predominance of red orthoclase, with a moderate quantity of hornblende and quartz. This sends veins into the overlying beds, and is itself penetrated by dykes of diabase. On this central mass rests a great thickness of felsites, porphyries, felsitic agglomerates and diorites, evidently of volcanic origin. Upon these are grey, black, and reddish slates and quartzites, with a bed of limestone and penetrated by metallic veins." As a result of his studies, Dawson (15, pp. 580, 581) concluded that the rocks of the Cobequid complex had been altered and elevated prior to the Carboniferous period. He found no evidence that proved them to be older than Upper Silurian.

Too little of the Cobequid complex occurs in the Truro map-area for the age relationships of its different components to be properly understood, nor has sufficient detailed work been done elsewhere to elucidate the problems. Any hypotheses presented here must therefore be regarded as tentative.

The Cobequid Complex

Rocks of the Cobequid complex are exposed along the north boundary of the map-area from its western limit to a point less than a mile east of Chiganois River.

The rocks may be divided into two distinct lithological groups. The older group consists of a series of mixed sedimentary and volcanic rocks whose age relationships are uncertain. Cutting these rocks is a series of younger intrusive rocks that range in composition from diabase to granite.

SEDIMENTARY AND VOLCANIC GROUP

Rocks of the sedimentary and volcanic group comprise about three-quarters of all pre-Carboniferous rocks exposed in the area. Incomplete sections occur along Pine, Totten and Staples Brooks, and on Debert and Chiganois Rivers and their other tributaries. No outcrops were found east of the Delaney Settlement road and very little outcrop is found in the interstream areas. The sedimentary and volcanic rocks extend as far north as the main granitic masses that form the core of the Cobequids.

The rock types in this group consist of fine-grained, purplish argillites, red and grey sandy shales, green, grey and brown sandstones, highly altered chloritic schist, and black, graphitic schist.

The extreme angularity of the grains in many of the clastic rocks is indicative of a possible volcanic origin. It is probable that at least some of these rocks originated as volcanic tuffs and breccias that were deposited in a slowly subsiding geosyncline.

Many of the sedimentary rocks have been subjected to severe shearing movements, and have undergone extensive chloritization. Also, they have been intruded by dykes of diabase and felsite that cut haphazardly across the bedding planes. Along the northern boundary of the map-area, the sedimentary rocks have undergone severe alteration by the main intrusive mass of the Cobequid massif.

Argillites

The argillites are only slightly metamorphosed by compaction, and very closely resemble hardened shales to the naked eye. In general, except where jointing has developed, they appear massive and structureless, but some of the outcrops, particularly along Pine Brook, show a tendency towards fine banding.

Microscopically, the argillites are seen to consist of angular to rounded grains of quartz and feldspar, with grains of epidote, rutile, and zircon scattered throughout. Iron oxide is abundant in irregular granular masses. Secondary pyrite is also a common constituent. The cementing material is a mixture of chlorite, sericite, kaolin, and ferruginous matter. The only indication of metamorphism is a slight tendency towards parallelism of the mica crystals. The argillites are very fine and even grained. They vary in colour from light grey to dark brown.

Shales

Megascopically, the shales are similar in appearance to the argillites, with the exception of banding which is occasionally present in the former. Under the microscope, a definite parallelism of the chlorite and sericite flakes becomes apparent. Recrystallized feldspar fragments and quartz granules are present in approximately equal amounts. Scattered grains of rutile, zircon, epidote, and pyrite are the accessory minerals. The shales are commonly cut by tiny veins of ankerite, quartz, and calcite.

Sandstones

The sandstones vary in colour from greenish grey to brown. They are uniform in appearance, and are poorly bedded to massive. Usually they exhibit gentle dips, but locally are highly contorted and cut by numerous fractures. Minute fragments of unidentifiable carbonized plant remains are commonly found along the bedding planes.

Microscopically, the sandstones are found to consist of a mixture of fine to coarse quartz, orthoclase, and plagioclase fragments, with quartz predominant. Crystals of zircon, pyrite, and rutile are scattered haphazardly throughout the sandstones, along with numerous minute fragments of hornblende, biotite, and augite.

The loosely packed feldspar and quartz grains are cemented by an extremely fine-grained mixture of sericite and chlorite. The sandstones are occasionally cut by veins and stringers of quartz and calcite which contain a few crystals of pyrite and magnetite.

The sandstones are fine to coarse grained, even textured, clastic rocks with individual grains rounded to subangular.

Chloritic Schists

The highly chloritized rocks do not display, either megascopically or microscopically, features diagnostic of an extrusive or pyroclastic origin. Bands of these chloritic "greenstones" are found on all streams west of, and including, Chiganois River. The contacts between the schists and sandstones and shales are rarely exposed, but where they can be studied, they are faults. The schists have been cut by numerous veins of ankerite, calcite, and quartz, and in addition usually contain pyrite.

In hand specimen, the chloritic schists are dark green, and are difficult to differentiate from many of the younger basic igneous rocks. The general appearance of these rocks suggests a volcanic origin, but as previously stated, a study of thin sections reveals no evidence diagnostic of either an extrusive or pyroclastic origin. However, vague relict structures which could have been phenocrysts or fragments of breccia occur in the chloritic mass.

In the field, chloritic schists are generally difficult to distinguish from some of the basic igneous rock types.

Graphitic Schists

Black graphitic schists that might easily be mistaken for coaly shales are well exposed on Pine and Totten Brooks. The schist band, where exposed, does not exceed 25 feet in width, and forms the contact between the pre-Carboniferous rocks and Pennsylvanian rocks to the south. It is cut by numerous veinlets of quartz, calcite, and ankerite and locally is heavily pyritized.

In thin section, the rock is seen to be extensively fractured and schisted. The black colour is derived from films of graphite that coat the schistosity planes. A few highly altered and sheared feldspar and quartz crystals can be discerned.

The schist lies in a shear zone of major proportion which parallels the south face of the Cobequid mountains and separates their rocks from the younger unaltered Pennsylvanian sediments to the south.

Origin and Age

The origin and age of the volcanic and sedimentary group of rocks are in doubt. The general abundance of feldspar fragments in the sandstones is indicative of a high-rank greywacke, but a good number of the specimens examined were low in feldspar. Due to the extreme angularity of their constituent grains, it is thought that at least part of the sedimentary rocks have a pyroclastic origin.

The schists were formed by shearing with accompanying recrystallization under pressure.

The only fossils collected from the sedimentary and volcanic group were poorly preserved carbonized plant debris from the relatively undisturbed sandstones immediately north of the old iron mine on Totten Brook.

The rocks of the volcanic and sedimentary group are older than the main mass of igneous rocks of the complex and the writer considers them to be of Silurian, and possibly, in part, of Devonian age.

INTRUSIVE ROCKS

Distribution

Intrusive rocks, varying in composition from granite to diorite, are found associated with the volcanic and sedimentary rocks of the Cobequid complex. The main granitic body is exposed only on the upper reaches of the streams west of Chiganois River, along the extreme northern boundary of the map-area. These rocks have suffered intensely from fault movements that occurred along the southern face of the Cobequid Mountains.

The more basic intrusive rocks extend farther south into the pre-Carboniferous sedimentary rocks, and are well exposed on the streams west of Chiganois River.

Granitic Rocks

Very few exposures of true granite are found within the limits of the map-area, but where they do occur, as on Debert River, the granites are pink to grey. Feldspar and quartz are present in approximately equal amounts. As the percentage of quartz decreases, the rocks locally grade into syenite. The mafic constituents, which consist almost entirely of hornblende and biotite, are in all instances subordinate. Grain size ranges from medium to fine, i.e., from 1·5 mm. to 0·5 mm.

Several thin sections of granite from outcrops along Debert River were examined microscopically. Quartz and feldspar together make up about 85 per cent of the rock. The feldspars are mainly microperthite and oligoclase, with a lesser amount of microcline and orthoclase. The quartz and feldspar are occasionally in graphic intergrowth. The outlines of both the feldspars and quartz are generally irregular and jagged.

Hornblende is usually present, but never forms more than 10 per cent of the rock. Biotite, partly altered to chlorite, is also a common constituent. Accessory minerals, consisting of scattered crystals of magnetite, epidote, zircon, apatite, tourmaline and ilmenite, were noted in several of the thin sections examined.

The zones surrounding the granite masses have been extensively altered by the intruding granite magmas. Dykes and sills, usually less than 50 feet in width, have been intruded into the surrounding rocks from the main granite body. As a result, many of the pre-Carboniferous sedimentary rocks have been extensively metamorphosed and granitized. The dykes are usually pegmatitic in nature.

At several localities, basic volcanic material has evidently been assimilated by the granitic magma, and a rock similar in appearance and composition to diorite or gabbro has formed. Such a rock is found at the first falls on Debert River, about a mile north of the Cottam Settlement bridge. There a diorite gradually merges upstream into a granitic, less mafic rock of the main Cobequid intrusive mass. In thin section, the diorite is found to consist mainly of fine intergrowths of untwinned oligoclase and plagioclase, poikilitically enclosed in coarse crystals of actinolite. The amphiboles are of secondary origin and the entire rock has been recrystallized.

These rocks have been intensely faulted along the southern face of the Cobequid Mountains. Individual quartz and feldspar crystals, when examined microscopically, are seen to be fractured and sheared. Locally, the rock assumes a cataclastic texture, wherein individual feldspar crystals have been bent and broken and the lamellæ displaced. This deformation probably occurred during the formation of the Cobequid fault which parallels the south face of the mountains.

Acidic Porphyritic Rocks

Both porphyritic (quartz) rhyolite and porphyritic (quartz-feldspar) rhyolite are found on several of the streams just within the northern boundary of the area. These rocks are probably intrusive in origin, but in no place were they observed in contact with other rocks.

The porphyries exhibit a remarkably well developed cataclastic structure which is best seen under crossed nicols. Thin sections reveal large shattered crystals of quartz, microperthite, and albite with an interstitial quartz-feldspar mosaic. Strain shadows are common in both feldspar and quartz.

Aplite Dykes

On Debert River and along most of the streams west of Chiganois River aplite occurs as dykes and stringers cutting the members of the sedimentary and volcanic groups. The dykes seldom exceed a few feet in width, and are usually less than a foot wide.

The dykes are composed of fine-grained, sugary textured aplitic material, which ranges in grain size from aphanitic to 0·5 mm. Under the microscope, the rocks are seen to consist of feldspar and quartz, with mafic minerals practically non-existent. The rocks have undergone two well defined stages of crystallization, as evidenced by the fact that interstices between the original feldspar and quartz crystals have been filled by micrographic intergrowths of quartz and feldspar.

The aplitic rocks are probably related to the main granitic intrusions, but the exact relationship could not be determined due to lack of exposures.

Diabase Dykes

Diabase dykes are found cutting rocks of both pre-Carboniferous and Carboniferous ages in the Truro area. Members of the sedimentary and volcanic group, as well as the granitic type rocks of the Cobequid complex, have been cut indiscriminately. On Salmon River, ¾ mile upstream from the mouth of Black River, a dyke of diabasic rock several feet wide cuts sandstones and shales of Carboniferous age.

Fletcher (17, p. 152) mentioned a hill of coarse black diorite on the Truro-Pictou highway, east of Penny Mountain. The hill can be seen, but only one small outcrop of diabase, similar in appearance to that on Salmon River, can be found.

Megascopically the diabases are characteristically fresh, dark grey to black, massive, and fine to medium grained. The intruded rocks are commonly highly altered near the contact with the diabase.

Microscopically the rock invariably presents a well defined ophitic texture. The dykes are composed essentially of plagioclase feldspar and augite with small quantities of magnetite and apatite. The plagioclase forms lath-shaped crystals lying in all directions in the dark irregular augite grains, giving rise to the ophitic texture that is a distinctive feature in the coarser grained occurrences.

In the extreme northeast corner of the map-area, a small west-flowing stream crosses the Pictou highway and empties into Steele Run. The rocks along this stream have been extensively ankeritized and are cut by quartz veins. Two dykes, each about 400 feet wide, composed of dark green dioritic rock with much assimilated material cut the sedimentary rocks, and waterfalls occur at these points. The sedimentary rocks in the vicinity of the contacts have been highly altered by the intrusive rocks. Although no outcrops could be found except in the stream channel, the nature of the terrain lying between Steele Run and the highway suggests a large intrusive body in that area.

Approximately half-way between the highway and Steele Run, the stream makes a sharp turn to the south. Just below the bend, the west bank of the creek forms a cliff, about 20 feet high, composed of rock that has the appearance of a volcanic breccia. The material has been extensively weathered, and varies in colour from white to black in a distance of a few inches. Individual fragments commonly exceed 3 inches in diameter, and the entire rock has been extensively pyritized. A few crystals of chalcopyrite are also present.

With the possible exception of a few exposures of grey-green, quartzitic sandstone, the entire sequence of rocks along the stream has been altered by intrusive material, and subjected to extensive fracturing and faulting movements. The sandstones in particular display abundant slickensides.

Age of the Intrusive Rocks

The small area of the Cobequid complex exposed in the map-area does not provide sufficient information for accurate determination of age relationships. Contacts among the different rock types are seldom well exposed. In several instances, the sheared nature of the contact rocks is thought to be due to the Cobequid fault which parallels the southern face of the mountains.

On the basis of field relationships, coupled with evidence derived from microscopic examination of thin sections, it can be assumed that rocks of the sedimentary and volcanic group are the oldest in the area. Cutting these strata are the younger granitic rock masses and their associated dykes, which are older than the Pennsylvanian sediments to the south. A group of diabasic dykes in turn cuts both the pre-Carboniferous rocks of the mountain complex and also the Carboniferous sedimentary rocks to the south.

Weeks (35, pp. 14, 15) tentatively ascribed a Devonian age to the main batholithic intrusions of the Cobequid complex, because they resemble closely many of the granites of the Saint John area of New Brunswick, that have been assigned a Devonian age by Alcock (1, pp. 35, 36). If the sedimentary and volcanic group in the Truro area is of Silurian age, a late Silurian or Devonian age is postulated for the granitic rocks that intrude it.

The diabasic dykes on Salmon River are post-Mississippian, and probably pre-Triassic in age, as nowhere in the area were Triassic sedimentary rocks cut by intrusive rocks.

Carboniferous Rocks

MISSISSIPPIAN

HORTON GROUP

Distribution

Horton strata outcrop throughout much of the south half of the map-area. This part of the district is an eastward extension of the so-called Walton anticline (35, p. 15), which has been extensively folded into a series of small anticlines and synclines. The best exposed sections of Horton sedimentary rocks are to be found along the west bank of Shubenacadie River for a distance of a mile north of the railway bridge, and in Rutherford, Lepper, and Soley Brooks.

The Horton strata consist of a sequence of conglomerates, grits, sandstones, siltstones, and shales. The contact with older rocks is not exposed.

The boundary between the Horton rocks and the overlying younger Triassic sedimentary rocks is exposed intermittently from Shubenacadie River eastward to a point about a mile west of Christie Brook. There the Horton is brought into probable faulted contact with sediments of the Canso group. An assumed fault, striking northeast from Little River, separates Horton strata from those of Canso age.

The exact position of the southern boundary of the Horton group is difficult to determine in many districts due to lack of outcrop. Vegetation, abrupt changes of soil type, and examination of sludge from several drill-holes, were made use of in outlining the contact. Where exposed, the contact between the Horton group and the younger Windsor sedimentary rocks is conformable.

Lithology

Bell (8, pp. 30-45) divided the Horton group into the Horton Bluff and Cheverie formations. The lower, or Horton Bluff formation, consists of grey, feldspathic conglomerate, grit and sandstones, interbedded with dark grey argillaceous shales. The upper, or Cheverie formation, consists chiefly of red shale and grey arkosic grits. Bell estimated the two formations to have a maximum combined thickness of 4,000 feet. This figure is thought to be nearer the minimum than the maximum thickness in the Truro map-area. There are no continuously exposed sections in the area with definite beds delimiting the top and bottom of any series, nor are there complete sections whereby accurate thicknesses of the series can be measured, because extensive faulting has caused continual repetition of sequences. Many sections have also been largely obscured by drift.

For these reasons, no attempt was made by the writer to subdivide the Horton group into separate formations. Bell (8, p. 39) indicated that the Cheverie formation cannot everywhere be separated lithologically from the Horton Bluff formation and this statement holds true throughout the greater part of the Truro map-area.

Lithologically the deposits change very rapidly, and it is impossible to trace the lenticular beds over any great distance. However, the abundance of *Lepidodendron* cf. *corrugatum* fragments within the Horton rocks is sufficient evidence to correlate these rocks with the Horton Bluff and Cheverie formations which Bell (8, pp. 30-45) described at Windsor, some 50 miles west of the Truro area. The composition of the rocks appears to be similar, both microscopically and megascopically.

The oldest part of the Horton in the Truro area consists of a series of feldspathic grits, sandy shales, and siltstones which originated as stream-laid deposits. Small lenses of feldspathic quartz-conglomerate, with pebbles of well rounded vein quartz, quartzite and grey slate in a matrix of angular quartz grains, are commonly found interlayered with the feldspathic grits. Kaolin is present in the conglomerate in variable amounts and the friability of the conglomerate depends on this factor. Lenses of crossbedded feldspathic sandstone are generally interlayered with the grits and conglomerates. The fine-grained sediments, siltstones and shales, usually develop sericite along their bedding planes. They also usually display crossbedding and current ripple-marks. The colour varies from light grey to reddish brown. This part of the Horton group is exposed on Field Brook and the lower reaches of Rutherford Brook.

These rocks gradually give way to fine-grained arenaceous shales, dominantly light grey. Locally, the colour may vary from a very dark grey to a greenish grey, with occasional tinges of red. Ripple-marks and rain-prints are well preserved. Flakes of muscovite occur along, and parallel to, the bedding planes. Broken-up plant remains are commonly present. Calcareous concretions are numerous (*see* Plate III B). Thin lenticular lenses of grey, calcareous limestone, less than 1 foot thick, are interbedded with the shales. The material in the lenses consists of angular quartz grains in a calcareous matrix. Due to greater hardness, the lenses project from the more easily eroded shales.

The arenaceous shales are overlain by progressively finer argillaceous shales and laminated silts. These sediments vary in colour from light grey to dark grey. Thin bands of pure quartz sandstone may be present locally. Scattered plant remains are present in these rocks, and fish scales are numerous. The beds of this part of the Horton group are well displayed along the west bank of Shubenacadie River, immediately north of the railway bridge for a distance of about one-quarter mile.

The upper part of the group consists predominantly of chocolate-brown and green argillaceous shales, arkosic grit and grey to maroon sandstone and orthoquartzite. The passage upward into the argillo-arenaceous chocolate-brown shales is gradual. The first indications are small inclusions of calcareous red shale. The lowest chocolate-brown beds are calcareous sandy shales changing gradually to red and grey sandstones with abundant muscovite along the bedding planes. Plant fragments and red clay balls commonly occur in lenses of red, slightly calcareous conglomerate. The grey arkosic grits are made up dominantly of particles of orthoclase and clear quartz. Biotite and muscovite are generally present. The matrix consists mainly of kaolin.

The excellent exposures of chocolate-brown shales and sandstones in Victoria Park, Truro are of late Horton age.

Structure

Horton sedimentary rocks have a gentle regional dip to the southwest throughout the greater part of the map-area. A series of southwest-trending folds cut across this regional dip. The folds are for the most part of an open, parallel type. Drag-folding between beds in the Horton was seldom observed, but movement could have taken place along the more incompetent shale horizons. Such movement is suggested by the crushed appearance of the shales in Victoria Park. Slickensides commonly occur along the axial regions of the major folds in the resistant sandstone beds. Surface expression of folding has largely been removed by erosion.

Horton rocks throughout the region are cut by numerous faults with small stratigraphic displacement. Erosion has destroyed the topographic expression of many of these faults. In numerous instances, however, they form the loci of local drainage gullies, and control in part the channels of some of the larger streams.

The complex system of faults along Shubenacadie River indicates the severe deformation that particular section of the Horton has undergone. By inference, the remaining part of the Horton in the map-area may have undergone similar deformation. It is usually impossible to determine whether the faults are normal or thrust in displacement, because of similarity in strata on either side. The stream pattern in the area bordering Shubenacadie River is not normal trellis drainage, because the main streams do not, as a rule, follow outcrops of weaker rock but flow at random across the strike of the formations. The rectilinear arrangement of the drainage pattern in the western part of the sheet leads to the conclusion that the area bordering Shubenacadie River has been cut by two sets of faults, one striking northwest and the other west. No evidence of such a pattern is indicated by the drainage pattern in the eastern part of the area.

Crossbedding is characteristic of the coarser sediments in the Horton group. Current ripple-marking is a prominent feature, particularly in the sandy shales. Strata are lenticular, and horizon markers absent. The upper part of the group is commonly channelled.

Origin and Age

Horton sedimentary rocks owe their origin to an older upland that lay to the south in Horton time. A statistical study of the current ripple-marks which are well displayed throughout the area indicates the dominance of northeasterly flowing currents. The mineralogical composition of the Horton sedimentary rocks offers conclusive proof that they were formed from the Devonian granite batholith and associated Precambrian rocks that lie to the south. The Horton rocks are composed largely of slate particles, clear quartz grains, fragmentary feldspar crystals, quartzite pebbles, and kaolinite. The coarse feldspathic nature of the lower part of the Horton group is indicative of an intermontaine environment of deposition.

As the sediments are of considerable thickness, deposition probably occurred on a gradually subsiding flood plain. In early Horton time, erosion was more active due to a steeper stream gradient, and hence the sediments deposited on the flood plain would be relatively coarse. But in middle and late Horton time, as base-level was approached by the eroding rivers, the material carried down and deposited would be progressively finer. Irregularities in this sequence can be explained by local upwarpings of rapid increase in rainfall. Bell (8, pp. 37-38) stated that the lower parts of the group were formed as fluviatile deposits in a climate of abundant rainfall.

All evidence concerning the Horton sedimentary rocks is indicative of continental conditions during deposition. A marine origin is excluded by the presence of erect plant stems and the prevailing red colour of the sediments. Interference ripples, sorted gravels containing well rounded pebbles, crossbedding, laminations, sun-cracks, channelling, and angular quartz grits are further indications of a nonmarine origin. The absence of marine fossils, limestone, and salt deposits further substantiates this statement.

Strong water currents played an active part in deposition of the Horton. Many of the beds show well formed interference ripples, and in several instances calcareous sandstone lenses are found. A large part of the sediments are well sorted, with prominent crossbedding. The lower members of the Horton group do not contain extensive channel markings, but the upper members, as previously mentioned, are well channelled.

There is no evidence of desert conditions during deposition of the Horton and no glacial till is found. Therefore, the origin of the sediments was either fluviatile or lacustrine.

The dominantly grey sedimentary rocks exposed along the west bank of Shubenacadie River, immediately north of the railway bridge, are probably of the lacustrine type. These rocks are extensively scoured and strongly ripple-marked. The lime content is relatively high in comparison with many other sections of the Horton, and numerous calcareous concretions are present. A few poorly preserved fish scales and ostracods are found in some of the laminated shale beds. Such a thickness of rocks must have formed in a body of water which persisted for a considerable length of time. The bulk of the rocks in the Horton, however, contain numerous land plant remains, such as *Lepidodendron* cf. *corrugatum*. Furthermore, the rock types in general are inconsistent with a lacustrine origin, as attested by the association of angular quartz grains with mica and kaolin.

The above facts indicate that the greater part of the Horton group was deposited in a fluviatile environment.

During the early part of Horton time the climate was probably temperate as much plant debris is present. The iron content of the rock is largely unoxidized and many soil beds occur, with plentiful rootlets in place. This is evidence of a moderate rainfall during the early part of Horton time, with an accompanying temperate climate, with few if any temperature extremes.

During middle and upper Horton time, the temperature gradually began to increase, oxidation became more widespread, and much less carbon is present in the rocks. A plentiful rainfall still existed, however, for numerous plant remains were preserved during this period. Furthermore, no alkaline salt deposits occur. Bell (8, p. 42) postulated an acceleration in uplift of the positive areas bordering the negative basin of deposition in which the Horton sediments were accumulating at the close of middle Horton time. This uplift would cause moisture-laden winds to rise on the windward slopes, and increased precipitation would result, in much the same manner as on the western slopes of our coast ranges.

Rocks of the Horton group are of Mississippian age (8, pp. 40-44), and are the oldest Carboniferous strata in Nova Scotia.

WINDSOR GROUP (LOWER)

Strata of lower Windsor age consist of a series of marine sedimentary rocks that conformably overlie continental deposits of Horton age with slight local evidence of an erosional break.

The basal beds of the Windsor group consist of limestone and limestone conglomerate, which have been separated into the Macumber and Pembroke formations, respectively.

The remaining part of the lower Windsor group could not be subdivided for field mapping. It consists of a series of gypsum, anhydrite, and red shale beds, of variable thicknesses, interbedded with a sequence of marine limestones.

Macumber Formation

The name Macumber was first proposed by Weeks (35, p. 20) for the lowest member of the Windsor group. The Macumber formation, in the Truro map-area, overlies conformably the uppermost sandstones and shales of the Horton group. Bell (8, p. 45) stated that the upper part of the Horton group is conformable with the overlying Windsor group in the Windsor district. The Macumber formation consists of grey to black, fine, thinly bedded limestone. It is in turn overlain disconformably by red limestone conglomerate of the Pembroke formation.

Distribution and Thickness

Dawson (15, p. 266) aptly described the Macumber formation, which outcrops at the south of Shubenacadie River, as "a black laminated crystalline limestone without fossils". This outcrop, named Black Rock from its distinctive colour, is the only well exposed area where the formation can readily be examined. Small exposures of unfossiliferous limestone, of probable Macumber age, occur near Smithfield and on Little River.

The thickness of the Macumber limestone in the Truro area is doubtful. Weeks (35, p. 21) has pointed out that in some areas it may be lacking entirely.

The only section which can be measured is found at Black Rock, where a thickness of 27 feet is recorded. This figure is approximate, as the rocks have been extensively drag-folded.

Lithology

The Macumber formation at Black Rock is a light grey to buff, arenaceous, well bedded limestone that reacts readily with hydrochloric acid. The rock is medium to fine grained in texture, and contains about 20 per cent of angular quartz grains. The exposure is cut by numerous quartz and calcite veins and stringers. A vein of pyrolusite (*see* page 110) cuts irregularly across the strata.

Structure

At Black Rock the uppermost Horton beds are medium-grained, micaceous, dark grey sandstones. The contact is marked by an inch-thick bed of friable shaly black sandstone containing tiny cubes of pyrite less than 2 mm. on the edge. The basal Macumber beds consist of grey, laminated, irregularly bedded, unfossiliferous limestone.

The contact between the Horton and Macumber rocks is also well exposed on Little River. There the uppermost Horton is grey, massive, medium-grained sandstone, whereas the Macumber is grey, laminated, unfossiliferous limestone. A 20-inch-thick zone of unconsolidated fault breccia and gouge separates the two rock types. This zone is probably associated with the major fault zone which parallels Little River.

Bell (8, p. 45) proved the contact to be conformable in the Windsor district, and it is assumed to be so in the Truro map-area, except where a fault contact exists.

The Macumber formation is overlain disconformably by the Pembroke conglomerate. Excellent contacts are exposed at Black Rock and on Five Mile River, (*see* Plate II A). Fragments of Macumber limestone, sometimes several feet in diameter, are generally found incorporated in the Pembroke conglomerate.

The Macumber formation has been extensively drag-folded in the Black Rock district. The rocks show little evidence of major faulting, but small normal faults of slight displacement are present.

Origin and Age

The Horton rocks that conformably underlie the Macumber formation have been shown to be of terrestrial origin, whereas the overlying Windsor sedimentary rocks are of marine origin. Thus the Macumber formation appears to have been laid down as an initial limestone deposit from a gently transgressing Windsor sea. Bell (8, p. 45) suggested that the break between the Horton and the Windsor is of slight importance and therefore difficult to recognize. Weeks (35, p. 21) pointed out the lack of limestone in rocks of Horton age, and suggested this criterion as a basis for the separation of the Horton and Macumber sediments.

In several instances rocks of Macumber age appear to be lacking entirely from the sequence. They were either not deposited there, or have been completely removed by erosion. The overlying Pembroke conglomerate, however, characteristically contains angular fragments of Macumber limestone. It is postulated that at the beginning of Pembroke time, the floor of the Pembroke sea was subjected to faulting movements, which caused slipping and brecciation of the upper beds of Macumber limestone. The resulting fragments were then rapidly consolidated, with little, if any, transportation.

Bell (8, p. 45) ascribed a lowermost Windsor age to the Macumber formation, and placed it in subzone A of the Windsor goup. No fossils are present in the Macumber rocks exposed in the Truro area but as the formation is overlain and underlain by strata of proven Mississippian age, the Macumber is of Mississippian age.

Pembroke Formation

The name Pembroke was first proposed by Weeks (35, p. 21) for a formation of red to grey-brown limestone conglomerate, with lesser amounts of calcareous sandstone and mudstone, that he described as occurring in the map-area immediately west of the Truro map-area. The Pembroke formation overlies the Macumber limestone with a well defined disconformity. The Pembroke rocks are in turn overlain by red shale, gypsum, and anhydrite beds of the lower Windsor.

Distribution and Thickness

The Pembroke formation is well exposed at several different localities in the map-area. Large outcrops occur at Five Mile River (*see* Plate II A), Black Rock, Beaver Brook, Manganese Mines, Farnham Brook, and in the vicinity of South Maitland.

Information is not available for determination of the exact thickness of the Pembroke formation in the Truro map-area. Near Beaver Brook, 60 feet of the conglomerate is exposed in the south river bank. At East Mountain, diamond drilling has proved the limestone to be 100 feet thick. Weeks (35, p. 22) gave a thickness of 115 feet for the conglomerate; Crosby (10, p. 94) estimated the formation to be 100 feet thick. The writer accepts 100 feet as its approximate thickness in the Truro area.

Lithology

The basal part of the Pembroke conglomerate is well exposed near Black Rock, where the Pembroke and Macumber formations are in disconformable contact (*see* Plate II B). There the Pembroke is a buff to red conglomerate containing angular fragments of Macumber limestone ranging in diameter from ¼ inch to 12 inches. The conglomerate also contains rounded pebbles of vein quartz, red shale, and sandstone. Near Beaver Brook, the exposures consist of grey and red massive, porous limestone which weathers to a brick-red hue. In a vertical cliff 60 feet high, boulders of this limestone, some of which measure 3 feet in diameter, are cemented together by a matrix of red shale and ferruginous, calcareous cement. The boulders are angular, and no stratification is present in the conglomerate.

The upper part of the Pembroke limestone grades into soft, red, calcareous shales and mudstones. At Black Rock the Pembroke conglomerate is overlain by red mudstone, but the contact is obscured by glacial drift. Much of this red phase of the Pembroke has been destroyed by erosion, because it readily disintegrates unless protected by a more resistant bed.

Structure

As previously stated, the disconformity between the Macumber and Pembroke formations may be observed at Black Rock and on Five Mile River in the extreme southwest corner of the map-area.

The Pembroke formation is normally overlain by a bed of gypsum and anhydrite of lower Windsor age. In places, however, these evaporites are absent, and the Pembroke is overlain by lower Windsor red shales and mudstones.

Origin and Age

The basal beds of the Pembroke conglomerate consist primarily of angular fragments of Macumber limestone cemented by a coarsely crystalline limestone matrix. Rounded pebbles and fragments of older rocks of possible pre-Carboniferous age are commonly present. The abundance of pure vein quartz pebbles in several outcrops, particularly in the vicinity of Penny Mountain, suggests that part of the material in the Pembroke conglomerate was derived from the Meguma Gold-bearing series to the south of the map-area. The conglomerate also contains fragments of grey quartzite and sandstone which are strikingly similar in appearance and composition to rocks of Horton age.

The method by which the upper beds of the Macumber limestone were brecciated is puzzling. The phenomenal coarseness of the breccia may perhaps offer a clue. At Cheverie, about 50 miles to the west on the south shore of Minas Basin, the Macumber limestone has been broken into angular blocks which are, according to Weeks*, sometimes 30 feet across.

Northeast of Levis, Quebec, bands of limestone conglomerate, from a foot to more than 100 feet thick, occur at various horizons in both the Levis and Sillery formations. The pebbles and boulders of grey limestone in the conglomerate range from a fraction of an inch to several feet in diameter. According to Alcock (2, p. 113), the origin of the limestone conglomerate may be attributed to faulting of the sea floor, with attendant earthquakes, accompanied by local slipping and brecciation of the limestone beds.

The nature of the basal beds of Pembroke conglomerate favours an origin similar to that which is thought to have formed the conglomerates

* Personal communication.

in the Levis and Sillery formations. The extreme angularity of the greater part of the fragments of Macumber limestone is indicative of severe tectonic movements accompanied by rapid burial with little or no transportation of the rock fragments. The smaller fragments which are occasionally sub-rounded, may have undergone some wave transportation, mainly by rolling along the sea bottom.

The excellent exposures of Macumber limestone at Black Rock are extensively drag-folded, but the overlying Pembroke conglomerate is relatively undisturbed. Therefore, the orogenic movements which affected the Macumber formation appear to have occurred near the end of, or immediately following, deposition of the limestone beds. Also, at Black Rock, the Macumber formation has been cut by numerous normal faults with small stratigraphic displacements.

The general angularity of the fragments of the Macumber limestone indicates that the forces that brecciated the Macumber were violent and short-lived. It is suggested that normal faulting, with attendant slipping and brecciation of the limestone beds, formed submarine precipices and cliffs on the floor of the Pembroke sea. The resulting talus and breccia were then rapidly consolidated before the individual fragments could be subjected to appreciable erosion.

No fossils have been found in the Pembroke conglomerate. Bell (8, p. 46) placed the Pembroke formation in subzone A of the Windsor group. As it is overlain and underlain by strata of Mississippian age, the Pembroke formation is of Mississippian age also.

Late Lower Windsor Rocks

Red and Green Shales

Red and green shales make up about two-thirds of the total of lower Windsor rocks. The beds are lenticular in character, and may or may not be present in any particular section of the sequence. A rhythmitic repetition of red shale and gypsum or anhydrite with fossiliferous limestone appears to have taken place. The relatively thick shale beds are unfossiliferous, so far as is known.

Distribution and Thickness

Red shales and sandy shales of the lower Windsor group are found mainly in the southwest quarter of the map-area. Excellent exposures are found along the east bank of Shubenacadie River south of Black Rock, and along Pitch Brook.

The best exposed section of lower Windsor shales is found on Shubenacadie River near the mouth of Pitch Brook. Unfortunately, the strata have been contorted by underlying gypsum beds, and local brecciation has resulted. Furthermore, the area has been cut by numerous faults, so that sections of unknown thickness have undoubtedly been faulted out. As a result, accurate determination of thickness of the red beds is impossible, but an estimate of 1,200 feet is considered to be approximately correct for the depth of the shales in this district.

Lithology

Red shales of lower Windsor age are characteristically uniform in grain size, texture, composition, and appearance. Oversized grains are never found in the red beds. Crossbedding is commonly present, and many beds show well developed ripple-marks. The bedding is usually apparent, but not due to variation in grain size. Jointing, when present, occurs in the form of open fractures that may or may not cross the bedding planes at an angle.

The peculiar colour of the red beds is due to the presence of ferric oxide. A grey or green colour signifies a low portion of ferric oxide, and usually a preponderance of ferrous over ferric compounds. In the lower Windsor red beds, green shales occur in streaks and blotches in the red strata, occasionally in narrow bands following joint planes. In some districts, the outcrops are of a mottled appearance, and include both shales and sandstones. The green spots are usually roughly oval in shape, and indefinite in outline. Occasionally they are flattened parallel to the bedding planes. The green spots vary from a few inches up to several feet in diameter.

It would appear that the ferruginous material that gave the red beds their distinctive colour was introduced contemporaneously with deposition of the sediments. As the igneous rocks underwent weathering, the ferrous minerals present were decomposed and the resulting iron-rich products in a very fine state were segregated from the coarser particles, mixed with the fine mud and clay, and transported and deposited along with these finer sediments.

A study of thin sections by the writer indicates most of the fine quartz and feldspar grains to be surrounded by a thin layer of hematite. This hematitic material exists also as an interstitial filling between the grains. The surface of many of the individual grains is not completely covered by the hematite coating. Evidently the grains were coated by hematite before final deposition in their present position, and during transport, the hematitic covering suffered from erosion.

Therefore, the iron was presumably introduced prior to sedimentation. Further evidence lies in the fact that the red shales are higher in iron content than their interbedded sandy counterparts. If the iron cement had been introduced following sedimentation, the more pervious sandy layers should have had the higher iron content. Such is not the case. Furthermore, underlying and overlying gypsum beds show no evidence of the introduction of iron solutions during the post-sedimentation period.

Structure

The red beds of the lower Windsor have been extensively folded and faulted. At the mouth of Pitch Brook, the strata have been overturned, and nearly all other exposures have high angles of dip. The beds are lenticular in nature, and may or may not be present between the gypsum and limestone members of the group.

Origin and Age

Due to the extreme muddiness and salinity of the waters during the deposition of the red beds and of the gypsum there would be no life and, therefore, no fossils have been found.

Shallow water conditions are postulated for the deposition of lower Windsor red beds. Deposition of limestone may have occurred contemporaneously with deposition of the red shales, but in a deeper part of the basin. Below the main bed of limestone near Pleasant Valley, an interfingering of beds of red and grey shales occurs, indicating fluctuation of facies. Therefore, near the shore of the basin, red clastic beds could have been deposited without any limestone beds.

It is more probable, however, that the beds of fossiliferous limestones that are found underlain and overlain by red shales in the lower Windsor, were deposited during periods when the Windsor basin was refreshed by waters from the outside sea, with an accompanying increase of animal life.

The fact that layers of gypsum and anhydrite are interbedded with the red beds is indicative of a warm, semi-arid climate during their deposition.

Because red beds are found both underlying and overlying fossiliferous limestones of lower Windsor age, they belong to the same age group.

Marine Limestone

On the basis of stratigraphic position coupled with palæontological evidence, the lower Windsor limestone is correlated with Bell's zonation (8, p. 46), and is placed in subzone B of the lower Windsor.

Lower Windsor limestone can be divided into two distinctly separate types as described below.

Type A. This type of limestone is aptly described by Goudge (22, p. 44). He depicts the limestone as being "of a peculiar type, the main part being composed almost entirely of shells replaced by black, crystalline dolomite and firmly held together by a cement of the same material. The cavities in and between the fossils are coated with tiny red crystals of calcite in some cases, and of dolomite in others . . . the deposit is slightly less pure than are most shell limestone deposits, it being characterized by a higher content of iron oxide and by a slightly greater content of silica than is usual."

In general, this type of lower Windsor limestone is black and red, partly dolomitic, massive, and extremely fossiliferous. The delicate internal structures of the fossils, such as the spiralia of spiriferid brachiopods, are characteristically well preserved.

Type B. The second type of lower Windsor limestone is grey to black, well bedded, and fossiliferous. It commonly weathers buff to a depth of one-quarter inch. The fossils are mostly broken and poorly preserved.

The lower part of this limestone consists of red siltstones and grey calcareous shales, grading upward into well bedded, buff weathering, shaly limestone that is sparsely fossiliferous. This shaly limestone in turn grades upward into a massive, grey, more fossiliferous limestone, in which the fossils are poorly preserved. The latter limestone band is overlain conformably by a light buff sandstone, followed by red shales and siltstones.

Distribution and Thickness

Examples of Type A limestone are found on the east bank of Shubenacadie River immediately south of the mouth of Pitch Brook; a mile southeast of Irwin Lake; and in the bed of Little River north of the small lake east of Brookfield. Representative examples of Type B limestone are found on Maynard Brook, one-half mile upstream from the mouth; along the stream immediately north of Upper Pleasant Valley; and below the gypsum outcrop opposite Eagle's Nest Point.

The thickness of the lower Windsor limestone undoubtedly varies in different localities. A maximum thickness of 40 feet is indicated from exposed outcrops.

Structure

Lower Windsor limestones of both types may or may not be overlain and underlain by red shales or gypsum. The gypsum opposite Eagle's Nest Point is underlain by Type B limestone of lower Windsor age, which Dawson (15, p. 267) mentioned as containing large numbers of flattened shells of *Conularia*, as well as terebratulae. He also stated that "faults, denudation, and disturbance render it quite impossible to discover in the river section the relation of this mass of gypsum to the neighbouring beds".

The deposits have been folded, faulted, and tilted subsequent to consolidation. Where bedding is present, dips are generally steep. Deposits of shell limestone appear to form mounds and ridges of irregular size; the quarry at Hilden provides a typical example. Such deposits are thought to have formed as reef cores that extended above the general level of sedimentation (31, p. 297).

Origin and Age

The origin of limestones will be discussed later under the chapter dealing with economic geology. Goudge (22, p. 2) stated that "virtually all limestones have been formed under water by the action of organic or chemical agencies, or a combination of the two, on dissolved calcareous matter, and have been deposited in layers or beds usually separated by a layer of shaly material. Each bed represents a period of uninterrupted deposition and each interbed of shale indicates a break in the process, or a change of conditions."

The excellent preservation of fine internal structures in the shell limestone is indicative of fossilization under quiet conditions. Current action must have been gentle in such localities, because the limestone contains such a small amount of clastic material. On the contrary, the bedded limestone contains much clastic material and fossils are poorly preserved. This type of limestone was probably deposited in shallow water, where wave and current action was more pronounced.

Winder (37, p. 38) correlated the lower Windsor limestone with subzone B of Bell's (8, p. 46) classification, on the basis of fossil content of the limestones. Stratigraphical evidence has also proved the limestone to occupy a position within the sequence compatible with such a correlation.

Gypsum and Anhydrite

A bed of gypsum and anhydrite customarily overlies the younger Pembroke formation. In many instances, outcrops are lacking, and the gypsum can be traced only by the surface expression of karst topography. Due to the usual complexity of structure wherever gypsum beds occur, strata are invariably warped and brecciated in contact with the gypsum. In several districts where Pembroke conglomerate occurs, no evidence of gypsum can be found. Hence, the gypsum beds are inferred to be lenticular in character.

Distribution and Thickness

Excellent exposures of gypsum are found intermittently throughout the south half of the map-area. The greater number of outcrops occur in proximity to the Horton-Windsor contact. By inference, the basal bed of gypsum is thought to be of considerable thickness and continuity. In several instances, as along the south side of Little River, the Horton rocks are in direct contact with gypsum beds.

At least three separate beds of gypsum and anhydrite are known to be present in the southwest quarter of the map-area. They are of variable thickness and, as previously stated, of a lenticular nature. Due to contortion of the beds, thicknesses can be measured only approximately, but they vary from a few inches to a maximum of 275 feet.

With the exception of the East Mountain district, no gypsum is found in the north half of the map-area.

Lithology

Most of the exposures of gypsum are grey-white. Impurities, if present, may change the colour to black or orange. The texture is ordinarily granular, and grain size may vary from fine to coarse. The gypsum is generally highly contorted, but individual beds are outlined by thin stringers of dark limestone. Near the mouth of Shubenacadie River, the red shale beds are cut by a network of orange satin spar veins up to 4 inches in width, which form a network of veins with no relation to the bedding, folding, or general fault pattern of the surrounding rocks (*see* Plate IV B).

In the stratigraphical sequence, gypsum is shown at several horizons. At different localities, however, red beds may separate it from the limestone, or it may be entirely absent from the sequence.

Structure

Limestone and gypsum are usually, but not invariably, found in direct contact with each other. In places, however, the gypsum may be well below and separated from the limestone by red shale beds. On the west bank of Shubenacadie River, a 10-foot band of massive gypsum has red beds above and below. Near Upper Pleasant Valley, a limestone band is separated from gypsum by intervening red beds, but a short distance to the west the limestone and gypsum are in contact. Therefore, if the two outcrops of gypsum are of the same bed, then limestone and red shale deposition must have been contemporaneous, and the extent of the limestone facies was controlled by the encroachment of the red shale facies.

It is noted that sedimentary rocks lying close to beds of gypsum are commonly deformed. This is due to the volumetric expansion consequent upon a change from anhydrite to gypsum. Deformation caused by such folding may be of considerable magnitude. Areas of folding up to one-quarter mile in width have been attributed to this cause. Such folds may be examined on the west bank of Shubenacadie River, opposite Eagle's Nest Point.

Karst topography is commonly found over many of the gypsum beds in the area. Round funnel-shaped depressions and saucer-shaped hollows, some of them occupied by pools of water with no visible outlet, show that the gypsum has been dissolved by ground water. Decay extends down to the ground-water level, which may be 75 feet or more below the surface. Caverns form beneath the surface, and the roof, if sufficiently weakened, may collapse. The surface relief over such areas becomes, on a small scale, extremely rugged, and vertical cliffs with a height of more than 30 feet are not uncommon in karst areas.

These karst areas are easily located by stereoscopic examination of air photographs.

Origin and Age

A detailed discussion regarding the origin of gypsum is presented in the chapter dealing with economic geology. The generally accepted theory is evaporation of sea-water from a lagoon or restricted basin in an arid or semi-arid climate.

In the lower Windsor series, the association of limestone and gypsum indicates conditions for the deposition of these two rocks to be closely related. A delicate balance in environmental conditions must have existed in order that alternate deposition of limestone and gypsum could take place. In order to bring about deposition of evaporites, the climate must have been either arid or semi-arid.

Bell has postulated (8, p. 55) that sulphate-depositing seas covered, at various places and times, an area of approximately 40,000 square miles of the Maritimes during Windsor time. Because a normal marine sequence of strata does not occur in the Truro map-area, it is probable that lower Windsor strata, which includes the gypsum beds, formed in one large basin that was cut off periodically from the sea. Fossils in the limestone beds of lower Windsor age are of the shallow water type; therefore the depth of the basin was not excessive. The presence of several beds of gypsum and limestone indicates repetition of conditions of deposition. Periodically as the supply of sea-water was cut off from the basin, evaporation proceeded until the concentration of salts was such that gypsum was deposited. Then the sea re-entered the basin, bringing in animal life and lowering the salinity of the water so that life could exist. This cycle was repeated time after time.

Bell (8, p. 83) stated that "gypsum quarries are floored in most instances by 'hard plaster'. This occurrence strongly suggests that the gypsum, in large part, is an hydrated product of anhydrite and there is little reason to believe that this anhydrite may not have been originally deposited as such." In referring to the large outcrop of white gypsum opposite Eagle's Nest Point, Dawson (15, p. 267) mentioned the anhydrite that is found in the lower part of the quarry. Wherever exposed, gypsum has been extensively folded and contorted, presumably by the volumetric expansion of the original anhydrite upon the addition of water. Furthermore, the ratio of anhydrite to gypsum increases with depth in gypsum quarries. In some instances, anhydrite may be found partly altered to gypsum. Therefore, it is assumed that the gypsum beds were originally deposited in the form of anhydrite.

Inasmuch as gypsum beds that were deposited by the lower Windsor seas are overlain and underlain by sediments of proven Mississippian age, they too are, of Mississippian age.

FAUNAL DISTRIBUTION OF THE UPPER WINDSOR LIMESTONE
(Locations of fossil assemblages shown in Figure 1)

Locality No. 1 — Zone E
Composita windsorensis
Loxonema cf. *nerviense*
Orthoceras sp.
Phillipsia eichwaldi

Locality No. 2 — Zone D(?)
Worm trails

Locality No. 3 — Zone C
? *Anemitina* sp.
Chonetes cf. *harderensis*
Composita windsorensis
Harttella gibbosa
? *Loxonema* sp.
Martinia cf. *galataea*
Orthoceras sp.
Parallelidon dawsoni
Productus subfasciculatus
Spirifer adonis

Locality No. 4 — Zone E
Composita sp.
Dielasma davidsoni
Martinia cf. *thetis*
Nuculana sp.
Productus lyelli
Productus cf. *semicubiculus*
Protoniella beedii
Rhipidomella cf. *michelina*
Sanguinolites sp.
Spiriferina cf. *octoplicata*

Locality No. 5 — Zone E
Ambocoelia acadica
Martinia cf. *thetis*
Productus lyelli
Productus semicubiculus
Protoniella beedii
Bucanopsis beedii

Locality No. 6 — Zone E
Leptodesma cf. *acadica*
Productus lyelli
Productus semicubiculus
Protoniella beedii

Locality No. 7 — Zone D (?)
Worm trails

Locality No. 8 — Zone C
Carbonized plant remains
Worm trails

Locality No. 9 — Zone E
Allorhynchus hartti
Ambocoelia acadica
Dielasma sp.
Martinia cf. *thetis*
Modiola cf. *hartti*
Phillipsia eichwaldi
Productus cf. *avonensis*
Productus lyelli
Productus semicubiculus
Protoniella beedii
Spiriferina cf. *octoplicata*
Spiriferina verneuili

Locality No. 10 — Zone E
Modiola cf. *hartti*

Locality No. 11 — Zone E
Ambocoelia acadica
Hartella gibbosa
Martinia cf. *thetis*
Productus lyelli
Sanguinolites sp.

Locality No. 12 — Zone E
Phillipsia eichwaldi

Locality No. 13 — Zone D (?)
? *Dielasma* sp.
Worm trails

Locality No. 14 — Zone C
Carbonized plant remains
Worm trails

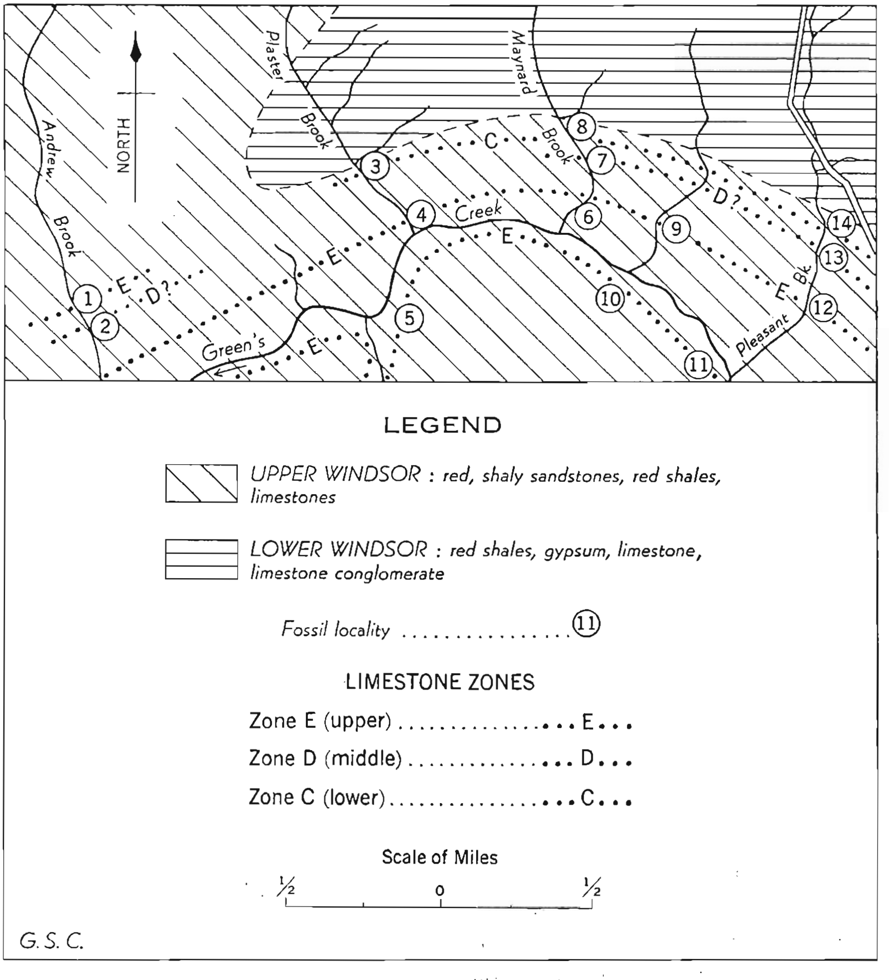

Figure 1. Map showing locations of upper Windsor limestone zones, Colchester county, N.S. Numbers show approximate locations of fossil assemblages. (Modified after Winder, 1951.)

WINDSOR GROUP (UPPER)

Sedimentary rocks of upper Windsor age are almost entirely in the southwest quarter of the map-area. They consist of red and green sandy shales interlayered with three distinctly different limestone zones. One band of gypsum may underlie the limestone beds, but this gypsum bed is probably of lower Windsor age.

During the field season of 1950, representative fossils from the upper Windsor limestones were collected and later identified by Dr. C. G. Winder (37). The traces of the three limestone zones are shown in Figure 1, with the localities from which fossil assemblages were collected, and the fossils from the different localities are listed on page 36.

Marine sediments of upper Windsor age in the mapped area are considered to fit Bell's zonation (8, p. 46), based on the section exposed along the Avon River at Windsor, N.S. In the Windsor fauna Bell (8, p. 71) considered the presence of *Martinia* indicative of upper Windsor time. Specimens of *Martinia* were found at localities Nos. 3, 4, 5, 9 and 11 on the upper Windsor limestones of the Truro area (*see* Figure 1).

In order to correspond to Bell's zonation, the three limestone bands have been placed, in order of increasing age, in the following zones:

Zone E — upper zone
Zone D — intermediate zone
Zone C — lower zone

The upper zone is correlated with Zone E because of the presence of *Ambocoelia acadica*, *Bucanopsis beedii*, and *Phillipsia eichwaldi*. The intermediate zone is placed in Zone D on stratigraphical evidence alone. This zone is sparsely fossiliferous, and no index fossils have been found. The lower zone is correlated with Zone C because of the presence of *Spirifer adonis*, coupled with stratigraphic position.

Bell's zonation of the upper Windsor was based almost entirely on corals. In the Truro area not a single coral was found. Hence, the zonal correlation of the upper Windsor limestones may be subject to revision upon acquisition of additional palæontological evidence.

Two small exposures of rocks of probable upper Windsor age are found in the north half of the mapped area. About 500 feet southeast of the Truro-Pictou highway, near the head of Clifford Brook, a quarry has been dug in an outcrop of massive grey limestone. Although the rock is fossiliferous, individual specimens are poorly preserved. The following specimens have been identified by P. Harker, of the Geological Survey of Canada:

Productus sp. cf. *P. avonensis* Bell
Dielasma sp.
Bryozoa

On the basis of this rather meagre evidence, the limestone is assumed to be of upper Windsor age.

On Farnham Brook, approximately one-half mile north of the Truro-Pictou highway, black, shaly, highly contorted, fossiliferous limestone is exposed in the stream bed. The following fossils were identified:

Pelecypods
Orthoceras sp.
Bellerophontid gastropods
Productus sp.

This is probably a high Windsor fauna, possibly of Zone E.

Distribution and Thickness

The northern boundary of the arc of upper Windsor sedimentary rocks between Green Oaks and Pleasant Valley lies north of and roughly parallel to the curve of Green's Creek. The contact between the lower Windsor and upper Windsor sedimentary rocks has been arbitrarily placed on the map, due to lack of critical outcrop.

From poorly exposed sections along the creeks that drain south into Green's Creek, a minimum thickness of 1,300 feet of upper Windsor sedimentary rocks is thought to be present.

The previously mentioned outcrop of upper Windsor limestone in the quarry near Clifford Brook is 125 feet long and 50 feet wide, and rises 25 feet above the level of a small brook nearby. No other rocks of upper Windsor age occur in this vicinity.

On Farnham Brook, the black limestone is faulted and contorted, making an accurate determination of thickness impossible. The limestone band is probably between 50 and 100 feet thick.

Lithology

In the arc of upper Windsor sedimentary rocks in the southwest quarter of the map-area, each limestone zone has distinctive lithological characteristics. The different zones will be briefly described in order of decreasing age.

Zone C This lowest zone is well exposed on Plaster Brook in the form of a 70-foot bed of fossiliferous, grey, well bedded, clastic limestone lying above green and red muddy shales. The limestone contains narrow bands of sandy shales which seldom exceed 4 inches in width. The top 15 feet of limestone is highly dolomitic, and unfossiliferous.

The limestone is in turn overlain by a 20-foot-thick band of red and green muddy shales, followed by a 25-foot bed of black, massive, shaly limestone. Fossils in the limestone are poorly preserved.

The limestone beds are gradational into the red beds, which are similar in appearance to those of lower Windsor age. The green content of the shales is slightly higher, however; a fact which may possibly be attributed to weathering.

On Maynard and Pleasant Brooks, shaly, grey, laminated limestones appear in the same stratigraphic position. With the exception of worm trails and carbonized plant remains, this limestone is unfossiliferous.

The total thickness of Zone C strata is probably 400$\pm$ feet.

Zone D Outcrops of Zone D limestone are similar in appearance to the Zone C limestone exposed on Maynard and Pleasant Brooks. Worm trails and carbonized plant remains are abundant. The limestone is of a clastic nature, as evidenced by the presence of sand grains along the bedding planes. Thicknesses of the band, as exposed on Andrew and Pleasant Brooks, are estimated at 15 and 30 feet, respectively.

The limestone is overlain by a bed of soft, brick-red, sandy shales with green alteration. The thickness of the shales is estimated at 700 $\pm$ feet.

Zone E The upper, or Zone E limestone, is exposed in the form of a well defined arc that cuts all the south-flowing brooks which empty into Green's Creek. Outcrops of this limestone also occur along the south bank of Green's Creek. The strata consist of layers of massive, grey, fossiliferous limestone, seldom more than 6 inches thick, separated by layers of calcareous, grey shales. Fossil assemblages from different localities show considerable variation, with the maximum number of individuals being concentrated in the crest of the arc.

The thickness of the limestone and shale band varies from 30 to 75 feet.

The top beds of Zone E consist of green and maroon shales with interbedded sandstone lenses. The shales are similar in appearance to indurated varved clays, which have been subjected to deformation.

The thickness of the Zone E strata is estimated to be in excess of 225 feet.

The upper Windsor limestone in the quarry near the head of Clifford Brook is dense to fine grained in texture, blue and grey, and is much veined with thin seams of white calcite. Iron oxide in places imparts a rusty colour to the rock. No bedding is visible. Contacts with neighbouring rocks are not exposed, but are probably faults.

As previously mentioned, the upper Windsor limestone on Farnham Brook is highly contorted and fractured. The limestone lies in probable faulted contact with Horton sandstones to the south, while the northern limit of the bed is not exposed. The limestone is black and shaly, and is cut by numerous calcite stringers. Bedding is well developed, and pyrite is commonly found along the bedding planes.

Structure

Upper Windsor sedimentary rocks are underlain conformably by strata of lower Windsor age. In the Green Oaks-Pleasant Valley area, the upper Windsor sediments have been deposited in a synclinal basin whose shape is distinctly outlined by the upper Windsor limestone beds. The semi-circular course of Green's Creek is controlled by the asymmetrical shape of the syncline.

Upper Windsor strata have been affected by the same regional forces that deformed the underlying lower Windsor sedimentary rocks. Due to the greater flexibility of many of the upper Windsor beds, minor folds are more pronounced than in the more competent older beds. Locally, beds of red shales and limestone have been completely overturned and intensely contorted, probably largely by the expansion of underlying anhydrite beds.

Although little evidence exists today, the upper Windsor rocks have undoubtedly suffered from faulting. At various localities, the presence of slickensides and gouge in the red shales is evidence of shearing movements. The small north-flowing stream that enters Green's Creek about one-half mile southwest of the mouth of Plaster Brook evidently follows a north-trending fault zone along which the limestone horizons have been considerably offset. It is also possible that the sharp deflection of Green's Creek to the south at the mouth of Plaster Brook may be due in large part to this fault.

Origin and Age

Conditions for deposition of upper Windsor sediments were similar to those that existed in lower Windsor times, and no break in sedimentation occurred. The presumed absence of gypsum, however, indicates that a restricted basin for the formation of this evaporite did not exist, and the sea had free access to the area. The presence of shaly grey limestone is indicative of normal marine conditions at least during periods of limestone deposition.

The sediments appear to have been deposited in an embayment on an open coast-line where conditions were favourable for the development of a populous fauna. Limestone deposition was bounded by the clastics, and in the unstable basin limestone was deposited in three distinct zones. Shelled animals apparently inhabited the deeper parts of the basin, but their habitat was controlled by rapid lateral change so that, at any one locality, with its own peculiar ecology, only certain genera could survive.

Bell (7, p. 92) stated that accelerated uplift of the Cobequid positive area to the north occurred at the beginning of upper Windsor time. The position of the limestone bands in the Green's Creek area may mark the approximate northern limit of the upper Windsor sea. The general instability of the basin during upper Windsor time is indicated by the rapid lateral change of the fauna in the limestone zones, as well as by the alteration of limestone and red clastic phases.

The origin of the upper Windsor limestones in the vicinity of East Mountain is in doubt. It is possible that an arm of the upper Windsor sea extended into that region, and the sediments deposited there have been exposed by erosion of the overlying strata.

Correlation of upper Windsor limestones in the area, with Bell's zones would place the upper Windsor sediments in the Truro area in the upper Visean of England and Belgium.

CANSO GROUP

Sedimentary rocks of Canso age, composed predominantly of thick beds of sandstones interlayered with bands of fissile, chocolate-red shales, are present in a down-faulted block of triangular shape which covers approximately 50 square miles of the east half of the map-area. The highly disturbed and metamorphosed sedimentary rocks on Steele Run are also, at least in part, of Canso age.

Canso strata are notably deficient in fossil content. This fact, coupled with the similarity in lithological characteristics to the Horton sedimentary rocks which they overlie, makes accurate separation of the two groups extremely difficult. Canso strata are overlain by the distinctive grey shales and sandstones of Riversdale age, and the Riversdale-Canso contact can be more readily determined.

In the Truro map-area, Canso sedimentary rocks are commonly characterized by veins of ankerite. This criterion is particularly applicable along Steele Run, where the ankerite is present in veins several feet wide. It is also of note that strata of probable Canso age, exposed upstream along Salmon River from the junction with Black River, are lithologically similar to the sedimentary rocks in the vicinity of the Londonderry iron deposits. Perhaps future geological work will prove the presence of Canso rocks in strata heretofore classed as pre-Carboniferous in the latter area.

Scarcity of fossil evidence renders accurate determination of the Canso boundary impossible. The contact with the younger Riversdale sedimentary rocks is exposed on Salmon River, but westward from this point, the contact is obscured by drift. Eastward from the mouth of Black River, the fault contact follows the latter river for a short distance, and re-appears on Calvary Stream, which it parallels to the edge of the map-area. The west and southeast boundaries between the Canso and Horton groups are also believed to be faults.

Lithology

Because ripple-marked, crossbedded, laminated, and mud-cracked beds are prevalent in the Canso, the strata are clearly water-laid. Bell (9, p. 10) was of the opinion that conglomerates are rare or lacking in the Canso group. Such is not always the case in the Truro area, as narrow bands of conglomerate were commonly encountered. It would appear that the tectonic movements which occurred at the close of Windsor time were of a gentle regional nature.

Rocks forming the upper part of the Canso group are well exposed in the lower part of Christie Brook. There dull red quartzites, interlayered with massive maroon argillites and shales, outcrop in a series of waterfalls. The sharp contact between the quartzites and the shales occurs at the base of the falls. There are several veins of pure white milky quartz up to 5 inches wide in the vicinity of the falls. Small crystals of pyrolusite are intermingled with quartz pebbles in the stream-bed, but no mineralized rock was found in place. Farther upstream, the sedimentary rocks consist of red weathering, medium-grained, massive, grey sandstones, interbedded with maroon shales and argillaceous sandstones. The rocks in the upper reaches of the brook are well bedded, and the finer members are generally laminated.

Structure

In the Truro area, as elsewhere in Nova Scotia, Canso sedimentary rocks appear to lie normally on marine sedimentary rocks of Windsor age or nonmarine rocks of equivalent age. In several instances, however, the Windsor strata have been either removed by erosion or obscured by faults which brought the Canso group and older Horton group into contact.

A fault contact between the Canso group and overlying Riversdale group is exposed on Salmon River. The true nature of the original contact is obscured, but at several localities elsewhere in Nova Scotia it is disconformable. At Parrsboro, 60 miles to the west, a marked angular unconformity exists between the two groups. A similar situation probably exists in the Truro area. The contact between Canso sedimentary rocks and Pennsylvanian rocks on Steele Run also appears to be a fault.

The beds on Rutherford Brook as far north as a series of cascades on Murray Brook tributary are typically Horton in appearance. The cascades, composed of reddish, medium-grained quartzite, are separated from brown micaceous sandstone and siltstone of probable Canso age by a fault with downthrow on the north. Possible extensions of this fault may be seen on Little River, and on Johnny Brook, a tributary of Calvary Stream. Although interstream extensions of this fault are largely hypothetical, the northeast alignment is too conspicuous to be disregarded.

The boundary between the inferred Canso beds and undoubted Horton beds of Victoria Park-Hilden area is also in doubt. The pronounced change of attitude between the rocks exposed along Christie Brook and those in the streams west of Wilson Mountain is indicative of a north-striking fault in this area.

In the vicinity of Penny and East Mountains, the presence of upper Windsor limestones favours a Canso age for at least part of the surrounding sedimentary rocks. South of East Mountain, however, manganese-bearing limestone of lower Windsor age is found resting directly upon sandstones of Horton age, thereby indicating the presence of a Horton block of strata in this region.

The entire section underlain by Canso sedimentary rocks has been extensively folded and faulted, particularly in the vicinity of Penny and

East Mountains. Many sections have been completely overturned, and repetition of strata undoubtedly occurs. The rocks along Salmon River westward from the mouth of Black River, have a general north strike and lie in a syncline whose axis passes near Union station.

Origin and Age.

Canso sediments were evidently deposited in a slowly subsiding geosyncline that was initiated at the close of Windsor time. The absence of appreciable thicknesses of conglomerate is indicative of gentle, progressive downwarping of an area that was being slowly aggraded.

The sediments, which were probably derived from an older upland that lay to the south in Canso time, are of fluvio-lacustrine origin. The Cobequid Highlands to the north may possibly have provided a source for at least part of the sediments.

As previously mentioned, fossil flora and fauna in the Canso group are extremely meagre. Dr. Jesse Hyde in his notes[1] recorded a collection of "small lamellibranchs and Leaia" from beds immediately beneath Union station, about 3 feet above water level. Drs. W. A. Bell and M. Copeland, of the Geological Survey of Canada, identified the following fossils during an examination of the area in 1954 and 1955[2]:

Salmon River, north side, about ½ mile below Union station
Asterocalamites sp.
? *Calamites* (*Mesocalamites*) *cistriformis*

Salmon River, about 1,000 feet below mouth of Black River
cf. *Lyginopteris* (*Calymmotheca*) *stangeri* (Stur)

Salmon River about ¼ mile above mouth of Greenfield Brook at *Estherioid* and *Leaia* horizon
Spathulopteris ? sp.

Locality 4565. Greenfield Brook, about 1 mile upstream from mouth
Spathulopteris ? sp.
Diplotmema dissectum ? Brongniart

Locality 4566. About 500 feet east of Christie Brook bridge on road to Greenfield
Asterocalamites sp.

Greenfield Brook, below mouth of Braynion Brook
Asterocalamites sp.

Steele Run, about 2,000 feet below north edge of map-sheet
Asterocalamites sp.

On the whole, the evidence of the plants, while not conclusive, favours a Canso age for the rocks at the localities specified. A Canso age for the

[1] On file with Geological Survey of Canada—48-1, Sept. 2, 1912.
[2] Personal communications

sedimentary rocks on Steele Run and on Salmon River east of the mouth of Greenfield Brook is supported by the rare occurrence of a lamellibranch in the former and of *Estheroids* and *Leaia* in the latter.

PENNSYLVANIAN

Rocks of Pennsylvanian age underlie most of the north half of the mapped area. They are entirely of nonmarine deposition, and betray an intermontane origin. Rock types consist of red and grey shales, sandstones and quartzites, with interlensed beds of fan-conglomerates which are dominantly brown or green or both. Due to complex sedimentary conditions, subdivision of the strata on a lithological basis is extremely difficult. Furthermore, many of the coarser sedimentary rocks are unfossiliferous, so that palæontological evidence for age determination is lacking.

Dawson (15, p. 129) was the first to attempt a subdivision of the Upper Carboniferous in Nova Scotia. He divided the Upper Carboniferous into three groups:

(1) The Upper Coal formation—containing plants, but no coal.

(2) The Middle Coal formation—containing the productive coal measures.

(3) The Millstone-grit series—containing red and grey sandstone, shale, and conglomerate. No productive coal measures present.

Due possibly to the popular trend of thought at that time, Dawson failed to realize that the accumulation of a considerable thickness of sediments is not necessarily indicative of marine conditions. In more recent years, geologists have arrived at the concept that great thicknesses of sedimentary rocks may be derived wholly by land-basin deposition. No marine sediments are to be found in that part of the Truro area underlain by Pennsylvanian strata. Hence, a land-basin origin is postulated for these rocks.

On the basis of palæontological evidence, Bell (9, p. 3) divided the Upper Carboniferous rocks of Nova Scotia into the following groups, in order of increasing age:

Pictou group
Cumberland group
Riversdale group
Canso group

In the Truro map-area, the Riversdale group is identifiable by a preponderance of grey to black, fissile, sandy shales that contain species of *Leaia* and *Anthracomya*.

The Cumberland and Pictou groups are probably both present in the area. Bell (personal communication) identified a number of fossil specimens from the coal dump at Kemptown, and has tentatively assigned a Cumberland age to them. Unfortunately, many of the coarser sedimentary rocks in the Pictou and Cumberland groups are unfossiliferous, and therefore it is impossible to determine the contact from palæontological evidence. The writer has found it impractical to attempt a subdivision of the two groups on a lithological basis, and hence they are mapped as one unit on the accompanying map.

Rocks of Pennsylvanian age lie in faulted contact upon the south face of the Cobequid complex in the mapped area. In places, the trace of the fault is well exposed. The older Cobequid sedimentary and extrusive rocks have been lifted an unknown amount relative to the Pennsylvanian sedimentary rocks to the south. Along much of the contact, however, the fault is not exposed, and its exact position cannot be located.

RIVERSDALE GROUP

The strata that outcrop in the vicinity of Riversdale, about 12 miles northeast of Truro, were originally assigned a Carboniferous age by Dawson (15, p. 270). Fletcher, however, on the basis of his field evidence, mapped them as Devonian (17, p. 23). Considerable controversy existed over the correct age of these sedimentary rocks until Ami (4) compiled the results of palæontological investigations and proved the rocks to be of Carboniferous age.

Bell (9, p. 12) rejected the term Riversdale as a formational name, and applied it to the group of rocks that lie stratigraphically between the Canso and Cumberland groups of his classification. In the Truro map-area, Riversdale strata lie in faulted contact with rocks of Cumberland age, and are thought to rest either disconformably upon or in faulted contact with older rocks. North of Cobequid Bay, Riversdale sedimentary rocks appear to be in faulted contact with red conglomerates and sandstones of Triassic age.

According to Bell (9, p. 12) the Riversdale group is characterized by the presence of *Neuropteris smithsii*, *Whittleseya desiderata*, naiaditiform *Anthracomya*, and *Naiadites* of the *N. modiolaris* group. Species of *Leaia*, *Estheria*, ostracoda and *Spirorbis* are common as well.

Strata of Riversdale age are exposed in a belt that stretches from Chiganois River to beyond the eastern border of the map-area. Type sections are poorly exposed along North River, from a point immediately south of the mouth of Canoe Brook to the village of North River; along Black River, from a point one-half mile southwest of Riversdale station for 2½ miles northeasterly; and along Salmon River for 2 miles upstream from a point three-quarters of a mile north of the mouth of Black River. The best exposed section of Riversdale sedimentary rocks is along North River, where they outcrop intermittently over a width of about 3 miles.

Due to the extensive drift mantle, outcrop is very seldom encountered in the interstream areas.

The exact thickness of the Riversdale group is difficult to estimate in the Truro area. The group is limited on both the north and south sides by fault contacts. Furthermore, exposed sections show evidence of extensive faulting with unknown displacements. The entire sequence has been extensively folded, and locally beds are completely overturned. An approximate thickness of 3,000 feet is assigned to the Riversdale sedimentary rocks in the area on the basis of measurements made on the section exposed along Salmon River.

The most striking feature of the Riversdale group is the large percentage of grey, fissile, sandy shales. Both red and grey beds occur, with the latter much in excess. The strata are evenly bedded and clearly water-laid. Layers of grey, grey-green, and grey-red sandstones may be interlensed in the shales, but evidence of strong current action is rare. Mud-cracked, ripple-marked beds are plentiful (*see* Plate III A). Black, coaly shales are abundant, but no workable coal seams of Riversdale age are known in the Truro area.

Typical Riversdale strata are intermittently exposed in the river banks along South North River, for a distance of over 3 miles upstream from the mouth. Grey shale beds alternate with layers of grey sandstone which are seldom more than 30 feet thick. The sandstones, commonly massive and crossbedded, contain numerous plant remains and petrified tree roots which are often several feet long. The grey shales contain abundant shells of a naiaditiform *Anthracomya*.

The Riversdale group is separated from the younger Pennsylvanian rocks by a fault which is exposed on North and Salmon Rivers. The fault crosses Salmon River about a mile south of Kemptown, and strikes west to cross North River one-half mile south of the mouth of Canoe Brook. Bell (7, p. 98) has traced the eastward extension of the fault to Landsdowne station, about 10 miles east of Riversdale.

A fault contact is exposed on Salmon River between the Riversdale group and older rocks. A similar situation exists on Calvary Stream a short distance east of Riversdale. Much of the remaining contact between the Riversdale and underlying rocks is obscured by drift, but it is presumed to be a fault.

The contact between Riversdale and Triassic sedimentary rocks is not exposed. On several streams, the rocks were examined to within 20 feet of the contact, which in all instances was concealed by drift and stream gravels. The contact is, however, probably a fault. The criteria upon which this conclusion is based are the paucity of pebbles of adjoining older rocks in the Triassic conglomerates nearby, the steeper dips of the

Triassic which indicate drag in several cases, and the presence of the actual fault in the adjoining area to the west of the map-area (35, p. 34).

Riversdale strata have been severely folded. Dips are commonly steep, and many of the beds have been completely overturned. The axial planes of the folds trend west, in accordance with the general strike of the strata. The sediments were evidently deposited in a syncline which was later subjected to compressive stresses that probably came from the south during late or post-Riversdale time.

Strata of Riversdale age are extensively faulted, with the general strike of the major faults paralleling the axes of the folds so that in the Truro map-area, they are contained in a down-faulted block several miles in width.

It is probable that the bulk of Riversdale sediments originated in the Meguma massif to the south, and were carried to the basin of deposition by northward-flowing rivers from the Meguma watershed. However, the large amount of clastic chloritic material in Riversdale sedimentary rocks indicates that some of it must have been derived from the Cobequid massif to the north.

A striking similarity exists between many of the Riversdale sedimentary rocks and those of the Horton group. Red shales are present in both, but in lesser amount in the Riversdale group. This fact, coupled with the abundance of plant remains in the Riversdale sediments, is indicative of a warm, humid climate during Riversdale time.

Bell (9, p. 30) has assigned a Westphalian A age to the Riversdale group. The following fossils were identified by him (personal communication) from collections made along North and Salmon Rivers by the writer:

Small naiaditiform *Anthracomya*
Minute *Neuropteris smithsii*
Naiadites of *N. modiolaris* group

On the basis of this evidence, a Riversdale age has been assigned to the strata that underlie the younger Pennsylvanian sediments in the Truro map-area.

CUMBERLAND AND PICTOU GROUPS

The band of sedimentary rocks that immediately overlies the Riversdale group in the north half of the mapped area is made up of a mixed assemblage of rocks that range in grain size from coarse conglomerates to fine shales. On the basis of meagre fossil evidence, representatives of both the Cumberland and Pictou groups are believed to be present.

The rocks are predominantly grey, grey-green or brown. The coarse sedimentary rocks are, for the most part, brown; the finer sandstones and shales are generally grey, although many exposures of chocolate-coloured, arenaceous shales are found. Locally, thin beds of grey-green conglomerate, seldom exceeding a few feet in thickness, are present.

The most important coal showings in the Truro area occur in rocks of probable Cumberland age. None of these coal seams are being exploited at present, and records of their past development are given in the section on economic geology.

Strata of late Pennsylvanian age are exposed in a belt that extends across the entire width of the map-area. Sections are displayed along Debert, Chiganois, North, and Salmon Rivers. Unfortunately, these sections are extensively faulted, and entire sections are missing. One of the best exposed sections is found on Pine Brook, where over a width of about a mile of gently dipping conglomerates, sandstones and shales outcrop intermittently in a shallow syncline. The sedimentary rocks there consist mainly of grey, quartzitic sandstone, which contains abundant carbonized plant remains. Many of the sandstones have a reddish tinge. Shales are in minority in the sequence, but narrow lenses of conglomerate are present.

A band of green conglomerate, averaging less than a mile in width, parallels the south face of the Cobequid Mountains. The conglomerate is composed of stream-worn pebbles derived from the Cobequids, set in a chloritic matrix. Weeks (35, p. 27) placed this belt of rocks in the basal Pennsylvanian. The writer found no basis for doing so in the Truro area, and believes it to be of Cumberland or Pictou age.

From Debert River westward, Cumberland or Pictou rocks, or both, are in faulted contact with the younger Triassic sedimentary rocks.

The exact thickness of the Cumberland and/or Pictou groups could not be determined, because no locality could be found where the Riversdale group is in normal contact with the younger Pennsylvanian rocks. A minimum thickness of 5,000 feet of late Pennsylvanian sedimentary rocks is exposed in the section along Debert River.

Differentiation between the Pictou and Cumberland groups in the Truro area on lithological evidence alone is impractical; many of the conglomerates and coarse sandstones of both groups are unfossiliferous.

Bell (7, p. 105) noted the dominance of red beds and the arkosic character of many of the Pictou sedimentary rocks, whereas the Cumberland group is made up mainly of grey sandstones and shales.

The Pictou series, as defined in the Truro area, consists of an alternation of reddish brown conglomerates, dark red shales and mud-stones, arkosic grits, and dark red sandstones. Dark red colours predominate. The conglomerates carry well rounded pebbles of pink feldspar, vein quartz, sandstone, quartzite, and acidic intrusive and volcanic rocks. Locally, the conglomerates are grey-green, due to the high content of chloritic material in the matrix.

Cumberland strata in the mapped area consist mainly of grey, well bedded, fine-grained sandstones, grading locally into arenaceous grey shales. The sandstones vary in colour from grey to reddish grey, depending on the degree of oxidation which has taken place, and may assume a greenish hue where a high content of chlorite is present.

Locally, thin beds of grey-green conglomerate are present as lenses in the sandstones and shales. The sandstones are crossbedded, and the narrow bands of shale are ripple-marked. Occasional thin bands of black, coaly shales, seldom exceeding a few inches in width, contain abundant plant remains. The grey sandstones likewise commonly contain a high percentage of broken up plant remains.

The contact between the Cumberland and/or Pictou groups and the older Riversdale group is believed to be a fault, which is exposed on Salmon and North Rivers.

West of Chiganois River, the contact between the Triassic sedimentary rocks and the Cumberland and/or Pictou sedimentary rocks is not clearly exposed. Weeks (35, p. 34) recognized the faulted nature of the contact in the adjoining map-area to the west. The distorted attitudes of the rocks on Debert River, just south of the mouth of Totten Brook, indicate that the fault extends eastward into the Truro area, at least as far as Chiganois River.

The true nature of the Cumberland-Pictou contact in the Truro area is unknown. Bell (9, p. 22) was of the opinion that sedimentary rocks of Pictou age rest unconformably upon Cumberland strata in the Springhill area. In the vicinity of New Glasgow the contact between the two groups is a disconformity. It is likely, therefore, that Pictou sedimentary rocks rest, if not unconformably, at least disconformably, upon Cumberland strata in the Truro area. No evidence of a faulted contact between the two groups could be found.

Upper Pennsylvanian sedimentary rocks have been extensively folded and faulted. The faults have a general west trend, parallel to the regional strike of the strata. Cross-faults, readily recognizable, are of a minor nature. The axes of the major folds strike approximately west, parallel to the base of the Cobequid mountains.

Cumberland sedimentary rocks originated in a subsiding basin of deposition that extends from the head of Chignecto Bay to the eastern edge of Pictou county.

By comparison of thin sections, the origin of the bulk of the Cumberland sediments found in the Truro area can be traced directly to the Cobequid massif, which lies immediately to the north of the map-sheet. During Cumberland time, the Cobequid complex was evidently a positive area subject to erosion. Southward flowing streams carried the resulting detrital material to its present position. Considerable material was also undoubtedly brought into the area by streams which originated on the highlands of central New Brunswick.

The following fossil plants, collected by the writer and identified by Dr. W. A. Bell[1], were obtained from waste dumps of coal splint in the vicinity of Kemptown, on the Truro-Pictou highway:

Matiopteris comata Bell
Neuropteris flexuosa Sternberg
Pecopteris pilosa (Dawson)
Lepidodendron lanceolatum Lesquereux
Asterophyllites charaeformis (Sternberg)
Annularia aculeata Bell
Sphenophyllum cunneifolium (Sternberg)

Although the florule contains too few species for a wholly satisfactory decision on its age, a Westphalian B age in terms of European chronology is considered to be the most probable reference. Thus the strata in that region would be correlated with the Cumberland group.

Most of the boulders and pebbles in the brown conglomerate of supposed Pictou age are traceable to the Cobequid massif to the north. Included in the conglomerate, however, are pebbles of grey sandstone and quartzite that are undoubtedly of earlier Pennsylvanian age. A type section of Pictou sedimentary rocks is exposed in the vicinity of the coal prospect on Chiganois River, about 2½ miles north of the Belmont.

The presence of a coarse conglomerate is indicative of relatively rapid uplift of the Cobequid massif to the north, at the close of Cumberland time. Alternating beds of conglomerate sandstone and shale are additional proof of periods of gentle subsidence followed by rapid uplift.

The relatively red colour of the Pictou sedimentary rocks as compared with these of Cumberland age, suggests that a slightly more arid climate prevailed during Pictou times. The presence of an abundant flora in rocks of Pictou age in other sections of Nova Scotia precludes the possibility of a semi-arid climate, which might be indicated by the high degree of oxidation of the beds.

Bell (9, p. 29) assigned a Westphalian C and D age to the Pictou group in terms of European chronology.

Permian

The base of the Triassic, where observed in the map-area, rests with marked angular unconformity on the contorted beds of the Carboniferous formations. The Permian system, both in the mapped area and elsewhere in Nova Scotia, is completely lacking.

[1] Bell, W. A.: personal communication.

Triassic

ANNAPOLIS FORMATION

Rocks of Triassic age occupy about one-quarter of the map-area. They lie in the eastern end of a synclinal basin that terminates about 6 miles east of Truro and extends westward to the western tip of Nova Scotia on Brier Island.

Powers (32, p. 6) assigned the beds in the Truro area to the Annapolis formation, and gave an adequate report of these continental beds. Bell (8, p. 59) gave more definite evidence of the equivalence of the Acadian Triassic to the Newark series of Connecticut and Virginia.

Conglomerates and sandstones of the Annapolis formation border the north side of Cobequid Bay in a belt that varies in width from 7 to 3 miles, and the south side in a much narrower belt. The eastern limit of Triassic rocks is a point on Salmon River 6 miles east of Truro.

The exact thickness of the Triassic is not known, but a considerable thickness must be present along the north shore of Cobequid Bay. A minimum thickness of 1,000 feet is exposed along Debert River.

Lithology

The Annapolis formation is noted for the heterogeneous distribution of its constituents. Conglomerates, sandstones, and shales are interbedded at random. The conglomerates and sandstones are strongly crossbedded. The strata are all red, but vary locally from brick-red to brownish red. Most exposures of the sedimentary rocks are even grained. Pebbles consist of vein quartz, quartzite, sandstone, shale, felsite and granite. The individual grains are cemented by a mixture of calcite and iron oxide. The pebbles are usually subangular, with rounded corners.

In thin section, the sandstones are found to be approximately similar in composition to the conglomerates. Angular to rounded quartz grains predominate, intermingled with fragments of slate, quartzite, and igneous rock. The cement is a mixture of iron oxide and calcium carbonate. Small fragments of chlorite, presumably from the chloritic flows to the north, are present in the matrix.

Structure

Within the map-area, Cobequid Bay is bordered by low land underlain by practically horizontal Triassic strata.

The northern contact between the Pennsylvanian and Triassic rocks is a fault as far east as Chiganois River. There the continuous nature of the contact is broken, presumably by a north-trending fault. Eastward from the Chiganois, the contact is thought to be a fault, that strikes in a straight line to a point about 1½ miles east of North River. From there the contact swings south and west to encircle Penny Mountain.

The eastern limit of the Triassic is well exposed in Salmon River, 6 miles northeast of Truro. There the red Triassic conglomerates lie in marked angular unconformity upon red shales of probable Canso age.

In Clifford Brook, east of Valley station, the lowest Triassic rock is a medium-grained conglomerate lying almost horizontally upon the red Horton shales. In Half Moon Brook, crumbly coarse sandstone conglomerates containing pebbles up to 2 inches in diameter rest upon Canso shales with marked angular unconformity.

The contact between the Triassic and Horton rocks on the south side of Cobequid Bay is not so well exposed. In Lepper Brook, which runs through Victoria Park, the contact is unconformable. In the brooks between Truro and the mouth of Shubenacadie River, Triassic rocks rest nearly horizontally upon the dominantly red Horton sandstones. Contacts are seldom well exposed, but the marked variance in dips between the strata of the two series is indicative of a major unconformity.

As previously stated, Cobequid Bay lies in the eastern terminus of a syncline which has undergone relatively little folding. With the exception of those regions adjoining faulted rocks the beds of Triassic sedimentary rocks dip towards the bay with dips seldom exceeding 5 or 6 degrees. This gentle dip must simulate that of the strata when they were first deposited in a slowly subsiding geosyncline.

The disturbance that took place at the close of the Triassic probably produced the west-trending faults that limit the northern margin of the Triassic rocks. The fault that lies north of the Triassic strata west of Chiganois River can be traced from Cape Sharp near Parrsboro to Chiganois River. This fault possibly continues eastward for an unknown distance.

The Triassic rocks in the area have been cut by numerous north-trending faults with slight displacement. An exception exists on Chiganois River, where the Triassic-Pennsylvanian contact has been offset an appreciable distance.

There is no evidence of igneous activity having occurred during Triassic time in the mapped area. In the adjoining map-area to the west, however, Weeks (35, pp. 31, 32) described a series of volcanic flows, consisting of brownish grey to black basalt of Triassic age.

Origin and Age

The Triassic rocks that lie south of Cobequid Bay contain many constituents that are directly traceable to the underlying Horton rocks. Fragments of slate from the Gold-bearing Meguma series to the south are also present. On the north side of the Bay, much of the Triassic contains a large percentage of pebbles derived from rocks of the Cobequid massif to the north.

Poor sorting, crossbedding, channelling phenomena in the sandstones, and subangularity in shape of the pebbles in the conglomerate, are indicative of transportation and deposition by torrential streams. The sediments were probably deposited in the form of flood plains, and perhaps in part, as broad, alluvial fans.

The red colour of the Annapolis formation is evidence of oxidation of the iron content during transportation and deposition. The absence of arkose and scarcity of carbonized plant remains point to intense subaerial oxidation with accompanying semi-arid conditions. The absence of gypsum and salt is evidence against extreme aridity during Triassic time.

As has been previously noted, the Triassic sedimentary rocks owe their origin in large part to the rocks of the Cobequid massif, as well as to the older underlying formations. Some of the constituents were derived from the slates and quartzites of the Meguma series to the south. It is thought that the New Brunswick highlands to the northwest may have provided an appreciable amount of the material of which the Triassic sedimentary rocks are formed.

Dawson (15, pp. 86-113) was the first person to outline adequately the distribution of Triassic rocks in the Bay of Fundy region, and to correlate them correctly with the Newark series of Virginia. Miss Ruth Holden (24, pp. 243-255) made a study of lignitized material from Triassic sedimentary rocks of Martin Head, N.B., and correlated these rocks with the Lettenkohle of Germany. Fish remains from sandstone overlying the North Mountain basalt at Scott Bay, about 50 miles southwest of the Truro map-area, were assigned a Newark age by Powers (32, p. 121)

The Annapolis formation in the Truro map-area is of Triassic age and because of its distinctive lithological characteristics, can readily be correlated with the above mentioned sedimentary rocks.

Pleistocene and Recent

GLACIAL GEOLOGY

As Truro map-area is a small part of a much larger physiographic unit, the glacial history of the region will be better known when the neighbouring areas are examined and the information correlated.

Glacial striæ can be found on the summits of hills in the Cobequid Mountains immediately north of the map-area; therefore the ice-sheet that covered the area must have been over 900 feet thick and more probably was several thousands of feet thick.

Only by inferences from recurrence of the ice-sheet on neighbouring areas can it be postulated that the ice advanced and retreated over the area two or three times, because the relatively soft Carboniferous rocks retain little evidence of former glaciation.

The area is covered with a thin mantle of drift, rarely exceeding 50 feet in depth. In the regions underlain by soft rock, ice rounded off the hills and ridges, thereby leaving a gently undulating surface. Many of the hill tops are practically bare, whereas the small valleys have been filled with glacial debris. Many of the hills possess a "drumlin-like" form, but upon closer examination these hills are found to be false drumlins or "roc-drumlins". Several examples of this phenomenon are to be found along the south shore of Cobequid Bay, between Truro and Clifton. There some of these drumlin-shaped hills have been partly eroded away by the tides, thus exposing their deeply weathered rock core.

A southern movement of the ice-sheet is indicated by abundant erratics of intrusive rocks that are found throughout the map-area. Syenites, granites, felsites, diorites, and highly chloritized flow rocks from the Cobequid complex to the north are found scattered at random. A count of stones from a sample of drift near Riversdale indicates that crystalline rocks from the Cobequids form up to 35 per cent of the glacial debris in that region. The remaining 65 per cent consists of rock types peculiar to the bedrock on which the drift rests.

In the glacial debris around Truro, several small rounded pieces of amygdaloidal trap rock were noticed. These stones may have come from the trap rocks of North Mountain to the west of the map-area, and if so an eastern movement of the ice at some period during the ice age is indicated.

The nature of the bedrock, where it is not exposed, is in large part reflected in the composition of the overlying boulder clay and till. This fact was frequently employed in defining the contacts where the nature of the basement rocks could not be determined from outcrop exposure.

Throughout the south half of the mapped area, the till is brick-red to brown due to the brown colour of many of the underlying Mississippian rocks. In the north half of the region, the till is dominantly grey due to the corresponding grey colour of many of the Pennsylvanian sedimentary rocks. The brown conglomerates of supposed Pictou age produce a correspondingly brown till.

A preponderance of boulder till prevails along the base of the Cobequids. Glacial boulders up to 6 feet in diameter are often found embedded in this till, the constituents of which were derived from rocks of the Cobequid complex to the north.

Deposits of stratified gravels and sands which originated as glacial stream deposits are normally crossbedded.

GLACIAL STRIÆ

Only two exposures of bedrock that exhibited definite glacial striæ were found within the map-area. One of these is near the head of a small brook that lies about 500 feet east of the road that joins the Brookfield barites deposit to the Brookfield-Middle Stewiacke highway. The outcrop displays three sets of glacial striæ, possibly short stages of the same epoch of glaciation, with a divergence of approximately 15 degrees. The oldest set strikes south 8 degrees east, the middle set south 23 degrees east, and the most recent set south 5 degrees west.

The second exposure is in a road-cut approximately $1\frac{1}{4}$ miles south of Riversdale. Well developed striæ, $\frac{1}{4}$ inch in depth, strike south 25 degrees east.

ESKERS

Two poorly formed eskers are in the southeast quarter of the map-area. The larger of the two eskers is 2.5 miles east of Camden. It forms a narrow, slightly sinuous ridge about 1 mile in length trending approximately south 70 degrees west. Murray Brook, which flows in a direction slightly east of south, has carved a channel about 50 feet deep and 400 feet wide through its western extremity. The base of the ridge varies in width from a few tens of feet at the western tip to slightly over 500 feet at the eastern extremity, where it merges into the surrounding surface features. It rises gradually from a height of 450 feet at the western extremity to 550 feet above sea-level at the eastern end. The sides are steep, with an average slope of 27 degrees. The crest is smooth and broadly rounded, with an approximate width of 20 feet. Sand, gravel and boulders are the main components of the esker but stratification, if present, is poorly developed. All sedimentary rocks from sand size up are water-worn. No evidence of cross-bedding could be found. The crest and sides of the esker are covered by very thick second-growth timber, which makes detailed examination extremely difficult.

The second esker is on the upper reaches of Christie Brook, 1.3 miles southeast of Archibald. It is about the same shape and size as the one already described. The slope of the sides averages 38 degrees. The trend, which is south 45 degrees east, is approximately at right angles to that of the esker on Murray Brook. A large gravel pit with a vertical face of 15 feet has been opened on the east side of the esker. Well water-worn, coarse gravels are exposed. Striated boulders, up to 18 inches in diameter, occur indiscriminately throughout the gravel. No crossbedding is evident. The esker, which is readily accessible, provides an excellent gravel supply for the region.

The water-worn pebbles in the eskers consist mainly of a mixture of sandstones, quartzites, diorites and felsites. The igneous pebbles are highly rounded, a fact which is indicative of long transit. These pebbles undoubtedly originated from the igneous rocks found in the Cobequid complex to the north. Therefore the rivers that formed the eskers flowed in a general southerly direction showing that the ice-sheet was retreating northward. The trend of the esker near Archibald agrees closely with the strike of glacial striæ previously described. The divergence in trend of the remaining esker cannot be as easily explained. It is possible that it is but a remnant of a formerly much larger ridge most of which has been removed by erosion. The part remaining may have been originally deposited in a local meander of a glacial river, as it has a slightly curved form.

Imbrication of pebbles in the two eskers at several different horizons further indicates that the glacial rivers that formed them flowed from the north.

OUTWASH PLAINS

Debert, Chiganois, North, and Salmon Rivers have deposited outwash plains of considerable area in their lower reaches. This deposition must have occurred at a time when they were overfed with gravel from the melting ice. Goldthwait (21, p. 100) postulated that, during the ice age, Cobequid Bay was 60 feet higher than at present and this fact would account for the presence of several larger outwash deposits some distance upriver from the present mouths of the rivers.

The largest of these deposits is in the district surrounding Debert village. This deposit covers several hundreds of acres and is of considerable economic importance, as it forms one of the largest sources of readily available gravel in Nova Scotia. Crushed and washed gravels of many grades are shipped from it throughout the Maritimes.

The deposits of glacial outwash found along Chiganois and North Rivers are of lesser importance. Much of it consists of water-worked gravels derived from the Cobequid highlands to the north. In time of flood the rivers become loaded with debris which is deposited as the gradient of the rivers decreases on reaching the more subdued relief of the Carboniferous uplands.

Truro stands on a broad, gravel plain about 60 feet above sea-level, which was probably formed as a delta by outwash from Salmon River during periods of flood. At present most of the plain is hidden by buildings, but debris from several gravel pits and excavations for buildings prove the underlying material to be outwash. This plain corresponds closely in height with the large delta at Parrsboro on the north shore of Minas Basin, 50 miles west of Truro. By inference this part of Nova Scotia has risen at least 60 feet since the end of glaciation.

Small deposits of glacial gravels are found throughout the map-area. For the most part the gravels are poorly sorted and show little evidence of stratification. Most pebbles are well rounded, and glacial striæ are present on many of the large boulders.

RIVER TERRACES

Well developed rock and drift terraces are found along several of the larger streams in the east-central part of the mapped area. Excellent examples are found along Salmon and Black Rivers, between Valley and Riversdale. The streams flow in a steep-walled gorge which has been cut to a depth of over 100 feet in solid bedrock. The gorge is bordered on either side by terraces of stream-laid gravels well over 30 feet deep.

It would appear that the gravels were deposited sometime during the latter part of the Pleistocene, for several well defined abandoned stream channels are found in the gravel floor. A particularly well exposed example of such a channel can be seen about 800 feet south of Riversdale station; evidently Calvary Stream once occupied this channel before abandoning it to pursue its present course.

RECENT

Recent deposits include tidal alluvium, stream alluvium, and lake deposits.

Tidal alluvium has built up the extensive salt marshes that border Cobequid Bay on all sides. They have already been described under the section dealing with marshlands. Much geological interest is attached to the marine alluvium along Shubenacadie River for the facilities that it affords at low tide for the study of ripple-marks, sun-cracks, impressions of rain drops, footprints of birds and animals, and related phenomena. The mode of preservation of similar phenomena in older rocks can be aptly illustrated and proved.

Stream alluvium is best exposed in the large gravel deposits of Debert River, which have been described. Numerous terraces composed of stratified stream gravels may be examined along several of the streams that flow into Black River from the south.

Lake deposits consist of muds and clays that are at present being brought into the lakes by inflowing streams. Many of the lakes have boggy bottoms that may be several tens of feet deep. This sediment consists largely of vegetable matter that has grown on the spot.

Bogs form a class of recent deposits which are closely associated with lake deposits. Boggy areas are numerous throughout much of the south half of the mapped area. They occur in areas of limited relief that are poorly drained.

A typical example of a bog is found about 2 miles west of Hilden, just south of the road that joins Hilden to Irwin Lake. The vegetation in the bog must have grown in its present position, as no streams enter that could have transported the decaying vegetation to the bog. In the water soaked soil the decay of dead vegetable matter has proceeded more slowly than the acquisition of fresh material. The vegetable matter has assumed the composition of a low-grade peat near the surface of the bog, and it is presumed that this peat increases in quality with depth.

Several kernels of bog iron ore were picked up from the drift along the southeast edge of the bog. This ore probably owes its origin to organic acids that were produced by the vegetable matter after it had been saturated with water for a considerable length of time. Acids in circulating ground water may remove the oxide of iron from the soil that underlies the bog, and eventually deposit it near the outlet.

CHAPTER IV

STRUCTURAL GEOLOGY

It is impractical to attempt to represent on the accompanying map all, or even most, of the folds and faults that have affected the strata in the Truro area. Only the major folds and faults have been indicated.

Folds

Within the limits of the map-area, rocks of Carboniferous age have been extensively folded, but the younger Triassic sedimentary rocks are relatively flat lying and undisturbed. Major folding movements evidently took place in pre-Triassic time.

Rocks of Mississippian age have a regional strike to the southwest. Pennsylvanian strata have a general west strike, and have been deposited in a basin that parallels the easterly trend of the Cobequid massif. Appreciable folding movements are assumed to have taken place during the interval between Mississippian and Pennsylvanian times by the variance in trend between the folds in rocks of Mississippian and Pennsylvanian ages. There are two distinct sets of folds, an early southwest-trending set which affects the south half of the map-area, and a later east-trending set, which affects the north half of the area.

SOUTHWEST FOLDS

Southwesterly trending folds affect most of the rocks of Mississippian age in the south half of the map-area. The positions of the fold axes as designated on the accompanying map are only approximate, due to lack of outcrop over much of the area. For descriptive purposes, the major southwesterly trending folds have been named as follows, from west to east: Beaver Brook syncline and Truro anticline; Greenfield syncline and Rutherford Brook anticline.

The Beaver Brook syncline is thought to be an eastward extension of the syncline that was mapped by Weeks near the southern border of the adjoining Londonderry map-sheet. A band of Windsor sedimentary rocks is preserved in the syncline, which evidently controls the course of Beaver Brook. The laminated limestone at Black Rock near the mouth of Shubenacadie River has been extensively drag-folded. These drag-folds strike and plunge 20 degrees southwest. The general southwest strike of the fold axis is confirmed by the attitudes of the rocks on Selma Brook and in the east bank of Shubenacadie River north of the railway bridge.

The limbs of the Truro anticline are fairly well exposed along several of the streams. The axis of the fold forms a gentle arc extending from Truro to Andrew Brook.

The presence of the Greenfield syncline is ascertained from the attitudes of the rocks along Christie and Greenfield Brooks and Salmon River. The southern extension of the fold is difficult to locate, due to the distorted nature of the rocks in the vicinity of the Horton-Windsor contact.

The limbs of the Rutherford Brook anticline are well exposed on Rutherford and Murray Brooks. The nose of this fold is found at a point about a mile south of the junction of the two brooks. The attitude of the outcropping rocks indicates that the Rutherford Brook anticline plunges steeply to the southwest. The northern terminus of the fold is difficult to trace due to scarcity of outcrop.

The structure of the bedrock in the southeast corner of the area is complicated by a combination of faults and folds. It is thought that the relatively soft Windsor sedimentary rocks in the vicinity of Smithfield and Otter Brook have been preserved in shallow synclines, whose axes have a general northeast trend.

Major southwesterly trending folds have been affected by secondary warpings, caused by orogenic movements that were much smaller in magnitude than those which caused the original folding. These major folds have also been cut by numerous faults of considerable displacement.

The general character of the folds in the Mississippian rocks indicate they are of the open, parallel type. The massive sandstones of Horton age, which make up the basement rocks of the Mississippian, consist of relatively strong beds which were firmly consolidated prior to deformation. If such rocks were to be subjected to horizontal compression, a series of parallel, open folds would result, particularly if the strata were under light overburden. Small drag-folds are characteristic of the less competent shaly layers. Locally, on the limbs of the major folds, the rocks have been severely crumpled. The excellent exposures of chocolate-coloured shales and sandstones in Victoria Park at Truro, illustrate the intensity of the deformation. It is apparent that faulting has been the direct cause of much of the fracturing and crushing found in these rocks and similar exposures to the east.

The Windsor sedimentary rocks in the southwestern section of the area are more closely folded than are the older Horton sedimentary rocks. It is probable that both ages of rocks were subjected to the same regional forces but the Windsor strata have been more extensively deformed due to the greater flexibility of the less competent Windsor shale, limestone, and gypsum. This deformation was probably aided by the expansion of the gypsum beds.

The shape of the arc of upper Windsor sedimentary rocks in the southwest section of the area is controlled by the curved form of the semi-resistant limestone beds that are present in the sequence. The rocks form an asymmetrical syncline on the south limb of the Truro anticline. This syncline was probably formed by folding of the original marine basin in which the Windsor sediments were deposited.

Evidence of extremely severe local folding is found in several well exposed sections of Mississippian sedimentary rocks along Shubenacadie River. Entire sections, such as the one at the mouth of Pitch Brook, have been completely overturned. Beds on either side of the Shubenacadie have been warped into a series of tight folds striking approximately parallel to the river. These folds bear little, if any, relation to the major fold axes, and are presumed to be the result of faulting. Beds of gypsum in this area have also undoubtedly aided deformation of the affected strata.

EAST-TRENDING FOLDS

Sediments of Pennsylvanian age were deposited in a gently subsiding basin which lay, for the most part, in the north half of the map-area. The eastward trending axis of this basin paralleled the general strike of the Cobequid massif. The sedimentary rocks have been thrust into a series of gentle folds by compressional forces from the south which reduced the original width of the basin considerably.

It is probable that the eastward trending folds in Carboniferous strata in the north half of the map-area were superimposed upon the major south-westerly trending folds that occur in the south half of the mapped area. The secondary folding evidently took place during post-Canso pre-Triassic time.

The post-Canso disturbance, although relatively severe, was restricted to limited areas. North of the Cobequid axis, strata of Riversdale age are found resting with accordance upon Canso and Windsor sedimentary rocks (9, p. 18). In the Parrsboro area, a marked angular unconformity exists between Canso and Riversdale strata (9, p. 12). In the Truro map-area, Canso rocks have been severely deformed, in a manner appreciably greater than those of later Pennsylvanian age. The contact between the Canso and Riversdale groups is probably a fault and the true nature of the original contact cannot be observed. Variance of dips between the two groups indicates an unconformity.

During late Pennsylvanian time the area was subjected to the same epeirogenic uplift that affected all the Maritime provinces. This uplift was evidently accompanied by gentle folding. In the Truro area, folds in the Pennsylvanian rocks are generally broad and open. Where steep dips are present they can usually be attributed to faulting.

Two major folds can be readily recognized in the north half of the map-area. For descriptive purposes, they have been named the Debert River syncline and the North River anticline.

The axis of the Debert River syncline cuts Pine and Totten Brooks at a point about $2\frac{1}{2}$ miles north of the Canadian National Railways. From there the axis strikes about 15 degrees north of east to cut North River near the northern limit of the map-area. Dips on the limbs of the fold average about 35 degrees, although locally faults have thrown the strata into almost vertical position. In some instances, beds have been overturned. The north limb of the syncline is cut by a major fault, which approximately parallels the strike of the fold.

The position of the axis of the North River anticline is in doubt. The axis of the fold crosses North River at a point one-half mile south of the mouth of Canoe Brook. From there it strikes east to cross the Salmon River a mile south of Kemptown, and thence eastward off the map-area. From North River westward, the position of the fold axis cannot be determined due to lack of outcrop.

The attitude of strata along Salmon River for 1 mile north of the Riversdale road indicates the presence of a syncline. There the strata have locally assumed a vertical dip. The regional dip appears to be southward, but a study of ripple-marks and crossbeds indicates that the beds have been overturned, and that the true dip is to the north. The east-west extension of the fold cannot be determined from the limited outcrops which are exposed.

The entire area of Pennsylvanian sedimentary rocks south of the North River anticline has been extensively deformed as a result of faulting. Because attitudes of exposed rocks give an erroneous picture of the general structure, no attempt has been made by the writer to map the trend of folds in this region.

Little evidence of folding is found in strata of Triassic age. Locally, minor flexures in the red sandstones may occur, but they are evidently the result of faulting movements, rather than major warping disturbances.

Faults

Faults in the Truro map-area form two distinct systems, an earlier west, and a later north-trending system. Of the two systems, the former is of the greater importance. In addition to these two major systems, the strata have been cut at random by numerous faults with irregular attitudes and minor displacements. These faults assume no distinct pattern.

Surface expression of the two fault systems is best exposed in the southwest quarter of the mapped area. The area bordering Shubenacadie River is faulted into a series of rectangular sections, and the drainage assumes a roughly rectangular pattern as the result of these faults. Several of the streams, including Pitch Brook, have pronounced right-angled changes of direction, which are presumably a reflection of the fracture pattern of the bedrock. The fault systems strike approximately north 30 degrees west and north 80 degrees east. Although the fault pattern as shown on the accompanying map is based on evidence considered fairly reliable, other interpretations are not impossible.

The straight nature of the fault traces on the surface is well displayed by Selma Brook, which apparently flows in a fracture in the Horton rocks. Dips of fault planes exposed along Shubenacadie River are either vertical or very steep.

The nature of the drainage pattern is not haphazard, and obviously does not coincide with the fold pattern. Along Shubenacadie River, continental beds of Horton age are found adjacent to, and frequently several tens of feet above, the later marine sediments of Windsor age. The present fault pattern has apparently been superimposed upon the fold pattern. If the drainage pattern is indicative of the fracture pattern, it is noted that a rectangular type of drainage does not exist east of the Truro-Halifax highway.

Along Little River rocks of Horton age lie in faulted contact against gypsum and shales of lower Windsor age. The fault is exposed along the face of a cliff that rises abruptly from the river, opposite the Brookfield Barite mine. The Windsor sedimentary rocks have been down-faulted relative to the Horton rocks. Karst topography along the contact obscures the fracture zone. Two miles east of the mouth of Brandy Brook, the contact between the Horton sandstones and basal Windsor limestone is exposed on the south bank of Little River. There the contact is a fault, and a brecciated zone of unconsolidated gouge, about 18 inches thick, occurs between the two rocks types. The fault strikes about south 55 degrees west, dips 50 degrees northwest and lies parallel to the bedding. Possible extensions of this fault may be found on the Murray Brook and Calvary Stream. Although this fault is of considerable magnitude, its relation to the major east-trending fault along Little River is unknown.

The presence of a major fault in the Smithfield lead-zinc property was proved by diamond drilling. Surface expression of the fault is absent, but it strikes south 80 degrees east and dips 65 degrees north. The east and west limits of the fault are unknown.

Practically all rock sections exposed along streams in the south half of the map-area display evidence of extensive faulting. Displacement seldom exceeds a few tens of feet. The excellent exposures of Horton shales and sandstones in Victoria Park at Truro exhibit the general sheared nature of much of the Mississippian strata.

The north half of the map-area exhibits four major east-trending faults, each of which will be described in turn.

COBEQUID FAULT

The fault of greatest displacement in the north half of the map-area is the Cobequid fault, which can be traced from West Advocate, north of Cap d'Or, on the west, to the Pictou coalfields on the east. This fault, was clearly recognized by Weeks (35, p. 27) in the adjoining map-area west of the Truro sheet. It lies parallel with the southern face of the Cobequid mountains, and separates them from rocks of Cumberland or Pictou age.

Surface expression of the Cobequid fault may be found on Pine Brook, Old Sam's Brook, Totten Brook, the east branch of Staples Brook, and Chiganois River. The Carboniferous rocks have been down-faulted an unknown amount relative to the older mountain complex. On Pine, Totten and Old Sam's Brooks, the fault is marked by a zone of broken and mylonitized rocks several tens of feet wide. In thin section rocks of the Cobequid complex display a high degree of mylonitization in the vicinity of the fault. The brecciated zone is cut by numerous veins of ankerite and calcite.

PORTAPIQUE MOUNTAIN FAULT

In the adjoining map-area to the west, Weeks (35, p. 34) found evidence of a major fault between the Pennsylvanian rocks on the north and the Triassic rocks on the south. This fault had earlier been traced from Cape Sharp to Chiganois River, a distance of 50 miles, by Powers (32, pt. 3, p. 256). For descriptive purposes, the name Portapique Mountain fault, as adopted by Weeks, will be used in the present discussion.

On Pine Brook, this fault separates rocks of Cumberland or Pictou age from the younger Triassic sedimentary rocks. The exact position of the fault on this brook cannot be found because the contact is obscured by drift. The position of the fault can be more accurately determined on Debert River, where the contact between the Triassic and Pennsylvanian sedimentary rocks can be located within a few feet. There grey, fissile, Pennsylvanian rocks are extensively fractured and schisted in the vicinity of the contact. The Triassic sandstones stand almost on edge, while the Pennsylvanian rocks a few feet away may have a relatively gentle dip. Furthermore, the absence of a basal conglomerate in the Triassic would indicate the presence of a faulted contact.

On Chiganois River, the Portapique Mountain fault is exposed about 2 miles north of Belmont. The fault consists of a zone of sheared rock about 100 yards wide, in grey, sandy mudstone and shales. The brecciated rocks have been cut by numerous veinlets of calcite. The rocks on either side of the sheared zone have been fractured and contorted.

The eastward extension of the fault cannot be traced because of lack of outcrop. The downthrown side of the fault is on the south. Displacement, according to Powers (32, p. 256), is 2,000 to 3,000 feet.

NORTH RIVER FAULT

Rocks of Riversdale age have been separated from the younger Cumberland or Pictou sedimentary rocks by a fault which, for descriptive purposes, has been named the North River fault.

Exposures of the fault may be found on North and Salmon Rivers. On North River, it is exposed at a point one-half mile south of the mouth of Canoe Brook. There grey and chocolate-coloured, well bedded, fossiliferous sandstones of probable Cumberland age are conformably underlain downstream by a 40-foot-wide band of massive, dark grey, unfossiliferous limestone of probable freshwater origin. The limestone is cut by numerous small calcite stringers, and is separated from underlying grey, fissile Riversdale shales by a well defined fault zone 18 inches wide. South of the fault, the rocks are obscured by drift, but the general sheared nature of the Riversdale shales in this vicinity indicates the presence of a major fault zone below the limestone.

The fault crosses Salmon River a mile below Kemptown and continues eastward off the map-area to the vicinity of Landsdowne station, where it has been recognized by Bell (7, p. 98). On Salmon River, rocks in the vicinity of the fault have been highly contorted and fractured. Slickensides occur in the less competent beds. The quartzites have been cut by small veins of ankerite.

The age relationship and folding of the beds on each side of the fault are suggestive of a high angle reverse fault with downthrow on the north

RIVERSDALE FAULT

The Riversdale fault is believed to extend westward across the area from the eastern limit of the map-area to the vicinity of Penny Mountain, and possibly beyond. About 2,000 feet below the bridge on the Riversdale road the southward-dipping Riversdale shales are in faulted contact with a diabase dyke cutting Canso rocks which also dip to the south. On Calvary Stream, east of Riversdale, many of the rocks are schisted, and numerous sheared zones are found, particularly in the lower reaches of the stream. One-half mile upstream from the mouth a main sheared zone, striking south 80 degrees west, indicates the locus of a major fault. The contorted attitudes and general sheared nature of the rocks along the lower reaches of Calvary Stream indicate the presence of a fault that roughly parallels the course of the stream, and separates rocks of probable Canso and Riversdale ages. This fault is possibly an eastward extension of the fault previously mentioned on Salmon River.

The westward extension of the Riversdale fault from Salmon River is, for the most part, hypothetical. However, wherever the contact between the Riversdale group and older rocks is exposed, the contiguous rocks are sheared and fractured. Dips in the vicinity of the contact are invariably irregular and the beds dragged. Basal conglomerate in the Riversdale group is lacking.

The downthrown side of the Riversdale fault is on the north.

The north-striking faults in the north half of the map-area are much less important than the others. Faults trending north occur at various points along Debert, Chiganois, North, Black, and Salmon Rivers. Displacement seldom amounts to more than a few tens of feet, and shear zones seldom exceed 3 feet in width. An exception is found on South North River, where a fault zone 30 feet wide is well exposed at a sharp bend in the river, about 2½ miles upstream from the mouth. The amount of displacement along the fault is unknown, but it must be of considerable magnitude, because grey, fissile shales have been brought into contact with chocolate-coloured sandstones.

The faulted nature of the strata from Penny Mountain eastward to Manganese Mines and beyond can be clearly recognized by the discordant attitudes of the bedrock. The rocks, wherever exposed, bear evidence of extensive faulting. Diamond drilling in the vicinity of East Mountain has proved the presence of numerous faults in that district.

Within the limits of the map-area, Triassic rocks appear to have suffered very little from faulting since deposition except along the north contact. The north contact is almost entirely a fault contact and the Triassic rocks have steep dips there.

CHAPTER V

HISTORICAL GEOLOGY

During late Precambrian time the thick sediments of the Meguma series were deposited in the region immediately to the south of the map-area, probably from a source somewhere to the east. At the close of Precambrian time the Meguma series was severely folded, faulted and uplifted and the Cobequid geosyncline was initiated several tens of miles north of the Meguma geosyncline. The age of the rocks deposited in the geosyncline is not known but they were affected by the Shickshockian Disturbance which lasted from Middle Silurian to Middle Devonian time. During this time the Cobequid rocks were extensively faulted and folded and intruded by granitic rocks. A long period of erosion followed and large areas of the Cobequid complex were exposed.

Bell (7, p. 79) stated that early in Mississippian time a trough existed between the Meguma batholith on the south and the massif of central New Brunswick on the north. Into this trough sediments of lower Mississippian or Horton age were deposited by streams that drained from the positive bordering areas. By inference, the bordering areas were uplifted. The resulting sedimentary rocks are of fluvial or fluvio-lacustrine origin. The fossil evidence indicates a warm, temperate climate accompanied by a heavy rainfall. Numerous remains of ferns and trees are found in the sandstones. Beds of conglomerate and stream gravels indicate variations in the depositing power of the streams which were probably accentuated by minor uplifts of the region. The presence of several thousands of feet of Horton clastic sedimentary rocks in the mapped area is indicative of progressive subsidence within the Cobequid trough.

At the close of Horton time a prolonged period of crustal stability ensued with accompanying erosion. Deposition consisted entirely of river wash that was deposited in valleys. Ridges were worn down, and valleys filled with debris. Streams and rivers eventually reached old age, and the sedimentary rocks that formed were dominantly shales and fine-grained sandstones.

This period of quiet erosion and deposition was followed by a gentle tilting of the area, and an arm of the early Windsor sea entered. At this time beds of limestone, shale and gypsum were deposited, most of which have been hidden from view by later sedimentary rocks and a mantle of glacial drift.

Towards the close of Mississippian time the sea had free access to the region as the limestones possess normal marine facies. Ripple-marks in the limestones attest to the prevalence of shallow water in the Windsor sea.

The red colour of many of the continental sediments, coupled with a lack of organic matter, is indicative of exceedingly high temperatures and semi-aridity during much of early Windsor time.

It is not known whether the Cobequid ridge was submerged during the early advance of the Windsor sea. If such a submergence did occur, all evidence has since been removed by erosion. It is possible that repeated shallow submergences did occur.

At the close of Mississippian time the region experienced a broad general uplift accompanied by gentle folding, and the sea withdrew from the area completely. A period of erosion ensued with accompanying deposition of the Canso sediments.

Early in Pennsylvanian time uplift was renewed. The uplift must have been rapid, because many large areas are underlain by Pennsylvanian conglomerate. Pennsylvanian sedimentary rocks lie unconformably upon, as well as in faulted contact with, the rocks of the Cobequid complex to the north. No rocks of Pennsylvanian age are found in the south half of the map-area. Clastic rock types of Pennsylvanian and Mississippian ages are similar in composition, therefore climatic conditions during the two periods were probably similar. No evidence of marine sedimentation is apparent during the Pennsylvanian.

At the close of Pennsylvanian time the area was again uplifted, and sedimentation ceased The entire region underwent faulting coupled with slight folding. Subaerial erosion by normal agencies commenced.

Erosion prevailed until the middle Triassic. Much of the rugged relief must have become gently rolling by this time. Then a slight downwarp of the Cobequid trough occurred, and erosion of the igneous rocks to the north increased. At the same time, the climate became much more arid. As a result, the sediments that were deposited in the syncline underlying Cobequid Bay were rendered highly susceptible to oxidation.

There is no further record of Mesozoic history in this area after deposition of the Triassic sandstones.

The history of the area throughout the Tertiary and Quaternary eras is obscure. During the Pleistocene the region underwent extensive continental glaciation. Much of the relief was subdued, and a relatively heavy mantle of drift was deposited.

CHAPTER VI

ECONOMIC GEOLOGY

There has been a relatively small mineral production in the Truro area in the past and no mines are being worked at present. In past years, gypsum, barite, iron, coal, lead and manganese were mined and production figures for the different deposits are given in the detailed descriptions that follow. The recent increased interest in metals should lead to renewed prospecting activity.

Barite Deposits

BROOKFIELD BARITE DEPOSIT

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Spence, H. S.
1922: Barium and Strontium in Canada; Mines Branch, Dept. of Mines, Canada, Bull. No. 570.
Stevenson, I. M.
1951: The Barite Deposit at Brookfield, Colchester County, Nova Scotia; M. Sc. Thesis, McGill University.
Weeks, L. J.
1948: Londonderry and Bass River Map-Areas; Geol. Surv., Canada, Mem. 245.

The property is situated $2\frac{1}{2}$ miles northeast of Brookfield, Colchester county, and approximately 12 miles south of the town of Truro. Access to the deposit is by way of an improved dirt road that branches off from the Middle Stewiacke to Brookfield highway a mile east of Brookfield.

The deposit was first mentioned by How (1869, p. 160). Later, in 1891, Fletcher (p. 192) briefly described the property, and indicated that it had been worked intermittently prior to 1891. In 1944 Canadian Industrial Minerals Limited of Walton, N.S., took an option on the property, and put down three diamond drill-holes with a total depth of 426 feet. This company then ceased exploratory work and withdrew their option. In 1945 Maritime Exploration Limited renewed exploratory work on the deposit and sank five diamond drill-holes. The property then remained inactive until 1948, when Maritime Barytes Limited realized the economic possibilities of the deposit, and instigated a diamond-drilling program that was carried out intermittently until 1951. The company drilled 28 holes, with a depth totalling 6,155 feet. Preliminary surface work included erection of a 50-ton concentrating plant (*see* Frontispiece). The property came into production during the summer of 1951, but was closed down the following year due to financial and milling difficulties.

The rock formations in the vicinity of the deposit consist entirely of Carboniferous sediments deposited in Mississippian time. The main rock types are arkoses, quartzites, and shales of the Horton group, overlain with slight structural disconformity by the less resistant limestone, gypsum, and red shale beds of the marine Windsor groups.

The area is covered by a shallow mantle of glacial drift, seldom exceeding 25 feet in depth.

The barite property lies on the contact between Horton rocks and those of Windsor age. The Windsor sedimentary rocks occur in the form of a narrow syncline which extends to a point $2\frac{1}{2}$ miles east of the deposit. Along the northern edge of the fold, Horton and Windsor rocks are in disconformable contact with each other. The southern contact is a fault, with beds of gypsum lying in juxtaposition with red Horton shales and grey sandstones.

The Carboniferous formations in the vicinity of the deposit have been affected by broad, folding movements, which probably extend downward into the underlying Precambrian rocks. Marine sedimentary rocks of Windsor age have been deformed by a secondary post-Windsor folding of minor order. Commonly, these folds are recorded in the topography by small anticlinal hills of limestone. This secondary folding is thought to be partly due to expansion of the underlying beds of Windsor anhydrite and gypsum upon the addition of ground water.

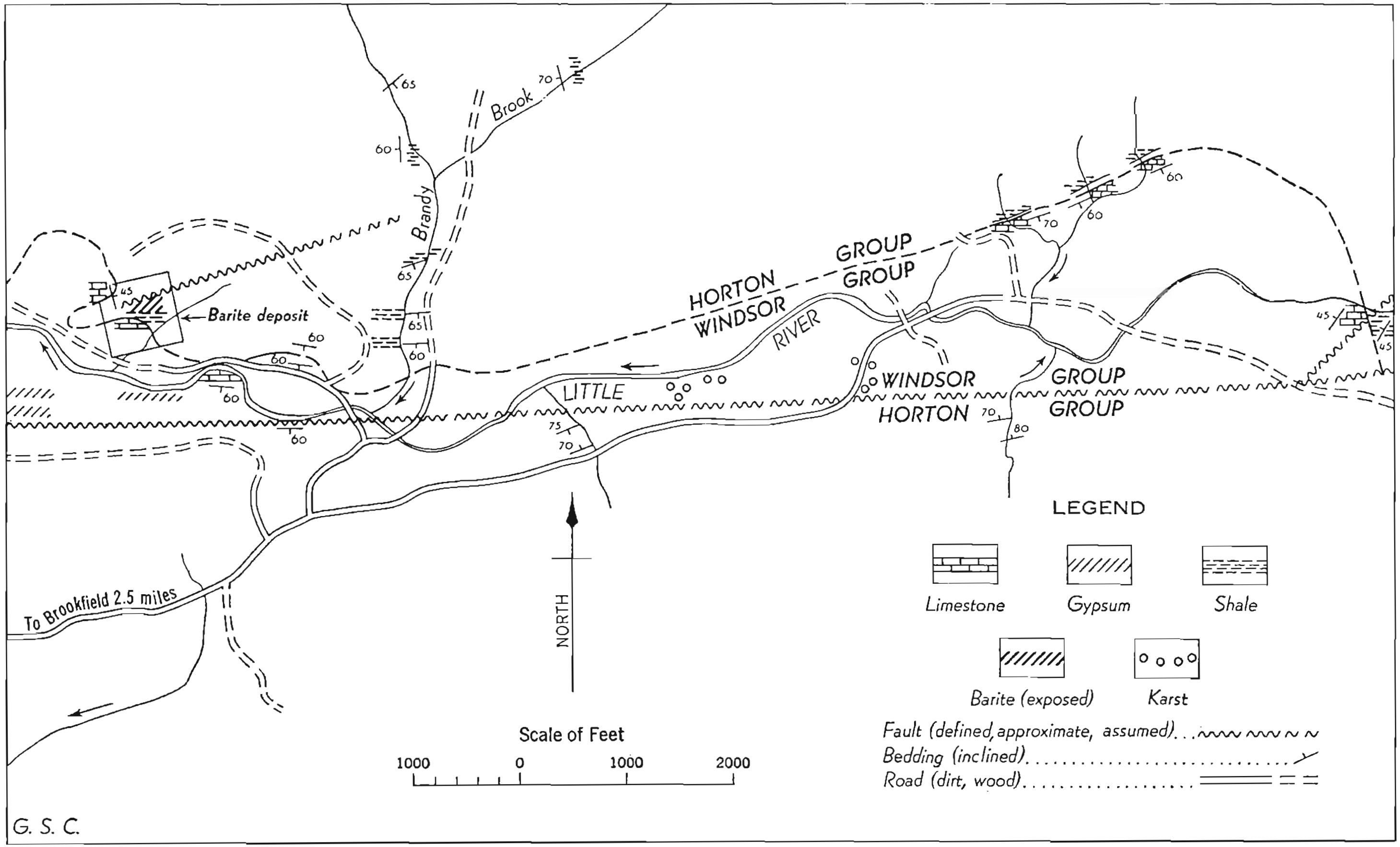

Figure 2. Plan of Brookfield barite deposit, Colchester county, N.S., showing regional structure.

Carboniferous strata in the vicinity of the property are cut by numerous faults with small stratigraphic displacements. Surface expression of many of the faults has been destroyed by erosion, but locally they form the loci of drainage gullies.

Diamond drilling has disclosed the presence of several northeast-trending normal faults characterized by high angles of dip. Many of the fault zones are brecciated.

The most prominent fault in relation to the orebody is readily distinguishable by surface expression. This fault strikes north 70 degrees east, and the resulting fault line is extremely straight. The orebody lies at or near the western terminus of the fault. A small deposit of limonite, formerly mined, occurs about 200 yards east-northeast of the barite, within the fault zone

Because both Horton and Windsor strata have been equally affected, the faulting is of post-Windsor age. It is probable that faulting and folding movements occurred contemporaneously during post-Mississippian pre-Triassic time.

The orebody outcrops on the summit of a hill 200 feet high, which has its steeper slope facing south, overlooking Little River. A detailed study of the structure is rendered extremely difficult by a mantle of glacial drift that covers the slopes of the hill to a depth of several feet. Structural data are of necessity derived almost entirely from drill-core records.

The barite is found entirely within sedimentary rocks of the Horton group, which in the vicinity of the property have a regional west strike and an average dip of 60 degrees north. The orebody dips northwest at about 60 degrees and plunges east at approximately 45 degrees. The steep dip to the northwest could be due to the influence of the fault that strikes north 70 degrees east at the deposit. The ore appears to occupy part of the crest of a sharp fold that plunges to the east. It is evident that both pre-ore and post-ore faults exist, but accurate time determination of this faulting is impossible, because of insufficient drill-core data, and the complex manner in which the bedrock is fractured.

To date, approximately 100,000 tons of ore averaging 80 per cent barites have been proved by drilling above natural drainage. The ore has been stripped on the summit of the hill, and an area 200 feet long by 50 feet wide exposed for open-pit mining. No estimate of the ore reserves below ground-water level has been made.

In hand specimen the barite is pure white with excellent orthorhombic cleavage; siderite, when present, is brown, with well developed rhombohedral cleavage. The texture of both minerals is coarsely crystalline, the average grain size being 10 mm. in diameter. The siderite is disseminated

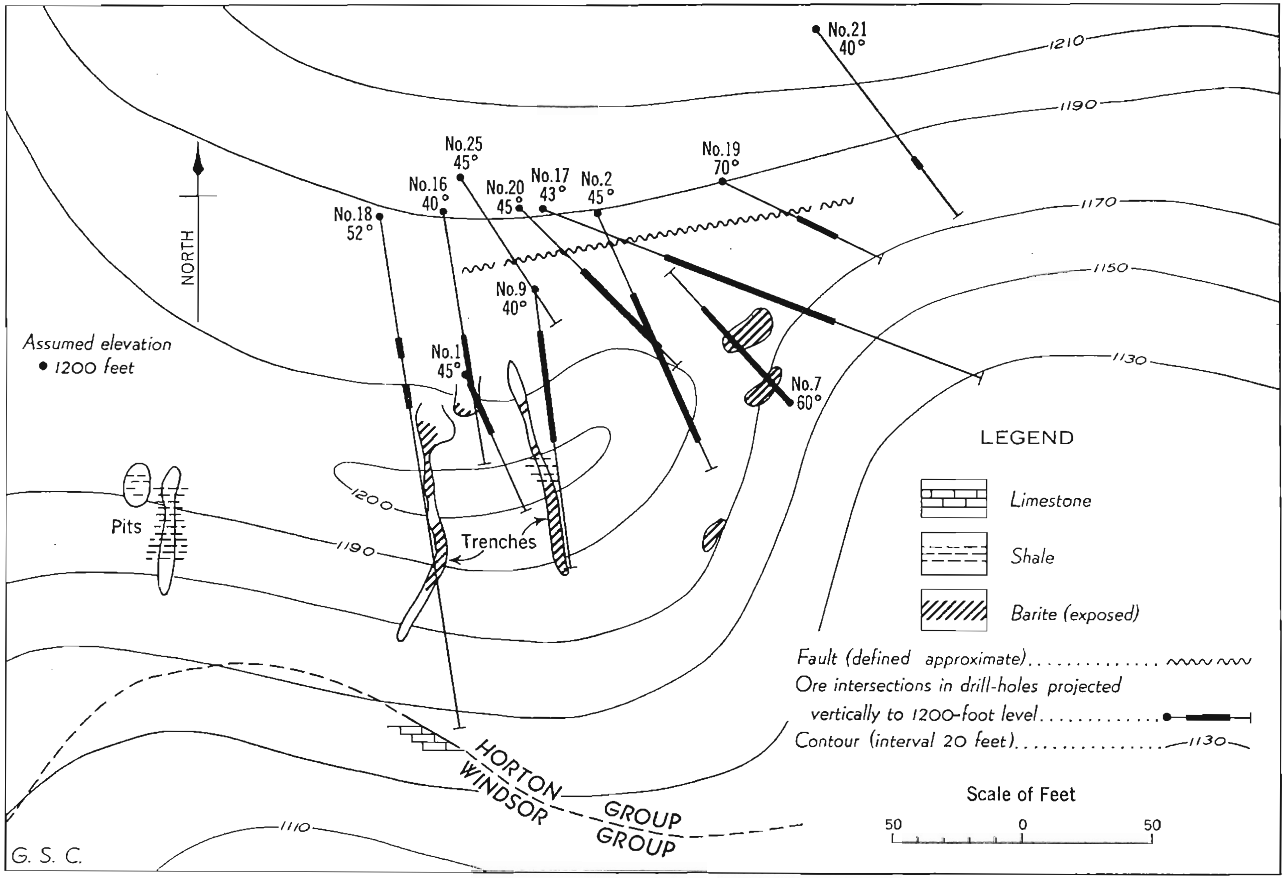

Figure 3. *Plan of Brookfield barite deposit, Colchester county, N.S., showing ore intersections in diamond drill-holes. (Compiled from data provided by courtesy C. O. Campbell.)*

throughout the barite in narrow, approximately parallel bands (*see* Plate VI A).

Under the microscope, the ore is seen to be of fairly uniform grain size and holocrystalline texture. The barite is colourless in thin section, with prominent orthorhombic cleavage. The crystals are basal tablets, elongated parallel to the "a" and "b" crystallographic axes, and flattened at right angles to the "c" crystallographic axis. Sections parallel to 100 give a positive biaxial figure. Birefringence is weak. The siderite is grey-brown with subhedral crystals displaying good rhombohedral cleavage.

Secondary quartz occurs as euhedral crystals disseminated through most of the thin sections examined.

The barite and siderite are mutually intergrown, thereby indicating contemporaneous deposition from solution. The origin of the quartz crystals is obscure, but they evidently formed subsequent to the deposition of the barite and siderite.

The ore is found principally in fine-grained, grey and red Horton shales, many of which have been extensively brecciated. The interstices between the brecciated particles have been filled with coarsely crystalline barite and siderite (*see* Plate VI B). The shales have been slightly altered along the contact between shale and ore.

The origin of the barium radical in the deposit is rather obscure. Analyses carried out on shales and sandstones show these rocks to contain 0.05 per cent of barium oxide (Clarke, 1924, p. 30). Spring waters also generally carry barium. Therefore it is possible for the sandstones and shales of the Horton series to have provided the barium found in the deposit. Even though very small traces of barium were present in solution, deposition could have occurred, due to a low solubility ratio.

Crosby (p. 175) considered the barite at Pembroke, N.S. to be of hydrothermal origin. However, no igneous rocks outcrop within several miles of the Brookfield deposit. Furthermore, there is no evidence of associated sulphides in the Brookfield deposit such as occur at Pembroke.

The barium in the Brookfield deposit is probably of hypogene origin, having come up as barium chloride, which is soluble in water. The barium would then be deposited by reaction of the calcium sulphate of the gypsum beds.

Microscopic examination of the ore indicates contemporaneous deposition of barite and siderite, wherever the latter is present. It is probable that iron carbonate and barium carbonate were intermingled in the rising ore-bearing solution, and were deposited together. Lack of oxygen has prevented oxidation of the siderite to limonite.

Other impurities, such as secondary quartz and aluminium silicates, make up less than 2 per cent of the ore. These impurities crystallized slightly later than the barite and siderite, as numerous barite crystals contain fractures filled with quartz.

Barite was deposited in fractures in the Horton sandstones and shales. Thus, pre-ore faults must have been present. The ore has replaced some of the shales. The solutions were low temperature, because the host rock shows little evidence of alteration. For some unknown reason, barite seems to favour the grey Horton shales, rather than the red variety.

OTHER BARITE OCCURRENCES

The barite deposit at Brookfield constitutes the only known occurrence of barite of economic interest in the Truro map-area. Minor amounts of the mineral are found intermingled with the manganese ore at East Mountain and at Black Rock. A few crystals of barite were found in an exposure of limestone at the head of the small creek that drains out of the bog 2 miles west of Hilden. The lead-zinc ore at Smithfield also contains traces of barite.

Coal Deposits

References:

Dawson, W. J.
1891: Acadian Geology, (Fourth Edition).
Fletcher, H.
1891: Report on Geological Surveys and Explorations in the Counties of Pictou and Colchester, Nova Scotia; Geol. Surv., Canada, Ann. Rept., vol. V, pt. P.
Gesner, A.
1836: The Geology and Mineralogy of Nova Scotia.
Gilpin, E.
1880: The Mines and Mineral Lands of Nova Scotia.
Macdonald, C. O.
1909: The Coal and Iron Industries of Nova Scotia.

The presence of several seams of coal has long been recorded within the area. As early as the first quarter of the nineteenth century several small seams were in production. Gesner (1836, p. 130) mentioned small seams of coal on "De Burt, Chiganois, and Salmon Rivers".

Gilpin (1880, p. 28) stated: "At many other localities discoveries of coal have been made; but the seams hitherto have not been considered of economic value. Among these may be mentioned the North River of Truro . . . , where the opposing crops of a 20 inch seam have been tested."

Dawson (1891, p. 276) noted that coal "in small seams occurs at Salmon River, North River, Chiganois River, DeBert River, and in the Coal Measure belt extending along the base of the Cobequids".

Fletcher (1891, pp. 170, 171) adequately described the different properties that were being worked at the time, as well as several inactive occurrences. Macdonald (1909, pp. 180-184) briefly described the properties that were being operated at the turn of the century. The details of production from the various properties since 1909 are contained in Annual Reports of the Nova Scotia Department of Mines.

The coals within the area are found in the highly faulted and crumpled Pennsylvanian basin that parallels the south face of the Cobequid mountains. Relatively well exposed sections on Debert, Chiganois, and North Rivers display the extremely complicated nature of the bedrock structure. Much of the bedrock is obscured by glacial drift, and structure of the coal seams can be examined only where they transgress the streams.

Development work on several of the properties has indicated the extensiveness of the shifting and faulting to which the seams have been subjected. In several instances local sections of the coal beds strike at right angles to the general east strike of the major trough.

The coal-bearing beds of the region, in particular the Kemptown and Debert deposits, have been affected by north-striking folds and faults with considerable vertical movement. Perhaps these are the result of transverse folding across north-striking spurs of the Cobequid Mountains.

The writer visited all localities where coal was known to outcrop in the area, but due to flooding and caving was unable to examine any underground workings. As a result, the following descriptions of deposits are compiled from published reports coupled with information gathered from surface examination. Much personal information was received as well from persons who are now living near and had access to the properties while they were operating.

KEMPTOWN COAL MINE

References:

Fletcher, H.
1891: Report on Geological Surveys and Explorations in the Counties of Pictou and Colchester, Nova Scotia; Geol. Surv., Canada, Ann. Rept., vol. V, pt. P, p. 170.

Macdonald, C. O.
1909: The Coal and Iron Industries of Nova Scotia, p. 184.

Nicolls, J. H. H.
1952: Analyses of Canadian Coals and Peat Fuels; Mines Branch, Dept. Mines and Tech. Surv., No. 831, p. 67.

N.S. Dept. Mines, Ann. Repts.: 1919, p. 36; 1920, p. 41; 1922, p. 45; 1944, pp. 79-82; 1947, p. 31.

The Kemptown coal mine is located 12 miles northeast of Truro on the main highway to Pictou.

The earliest attempt to mine coal from the deposit took place shortly prior to 1840, but no production figures prior to 1920 are available. By the year 1892, several shafts and a boring had been sunk on a small seam of low volatile, bituminous coal lying immediately west of the Pictou road. The seam ranged from 2 to 4 feet in thickness, and consisted of mixed coal and shale. In 1904, a slope was driven upon the seam, and a few tons of shaly coal were obtained.

No further record of the mine is available until the year 1919, when development work was resumed. A new slope was driven 800 feet east of the old slope, and by the end of the year the slope was down 180 feet on a 30-inch seam.

In 1920 the slope was down 235 feet, and crosscuts and airways were driven. The average thickness of the seam was 3 feet. At the close of 1922 the slope was down 500 feet, on a bearing of north 43 degrees west and a dip of 26 degrees. The thickness of the seam remained constant. Several additional airways and crosscuts had been driven.

The mine was operated continually until 1925, when it was taken over by the Kemptown Anthracite Coal Company, and operated by them for the next few years. Production figures show a gradual yearly decline in output.

In 1931 the mine was taken over and operated by the Elite Anthracite Coal Company. At that time the main shaft was down 850 feet on a bearing of north 56 degrees east and a dip of 30 degrees. The seam was about 3 feet wide, and numerous crosscuts and airways had been driven.

No production figures are available for the years 1932 to 1943 inclusive, and evidently the mine was inactive during that period. In 1944 the property was put under development by Colchester Coal Mines Limited, and production was resumed until late in 1947, when the mine was abandoned. The final plan of the workings is shown in Figure 4.

The following table indicates the yearly production from the mine. The figures were compiled from Annual Reports of the Nova Scotia Department of Mines:

Year	*Production (tons)*
1947	976
1946	unavailable
1945	unavailable
1944	1,316
1931	524
1926	309
1925	1,000
1924	unavailable
1923	1,270
1922	884
1921	372
1920	1,340

At present little can be seen of the workings except several caved shaft entrances and pits. The discard dumps have been partly grown over. The entrance to the main slope lies a few feet east of the road to Pictou, but

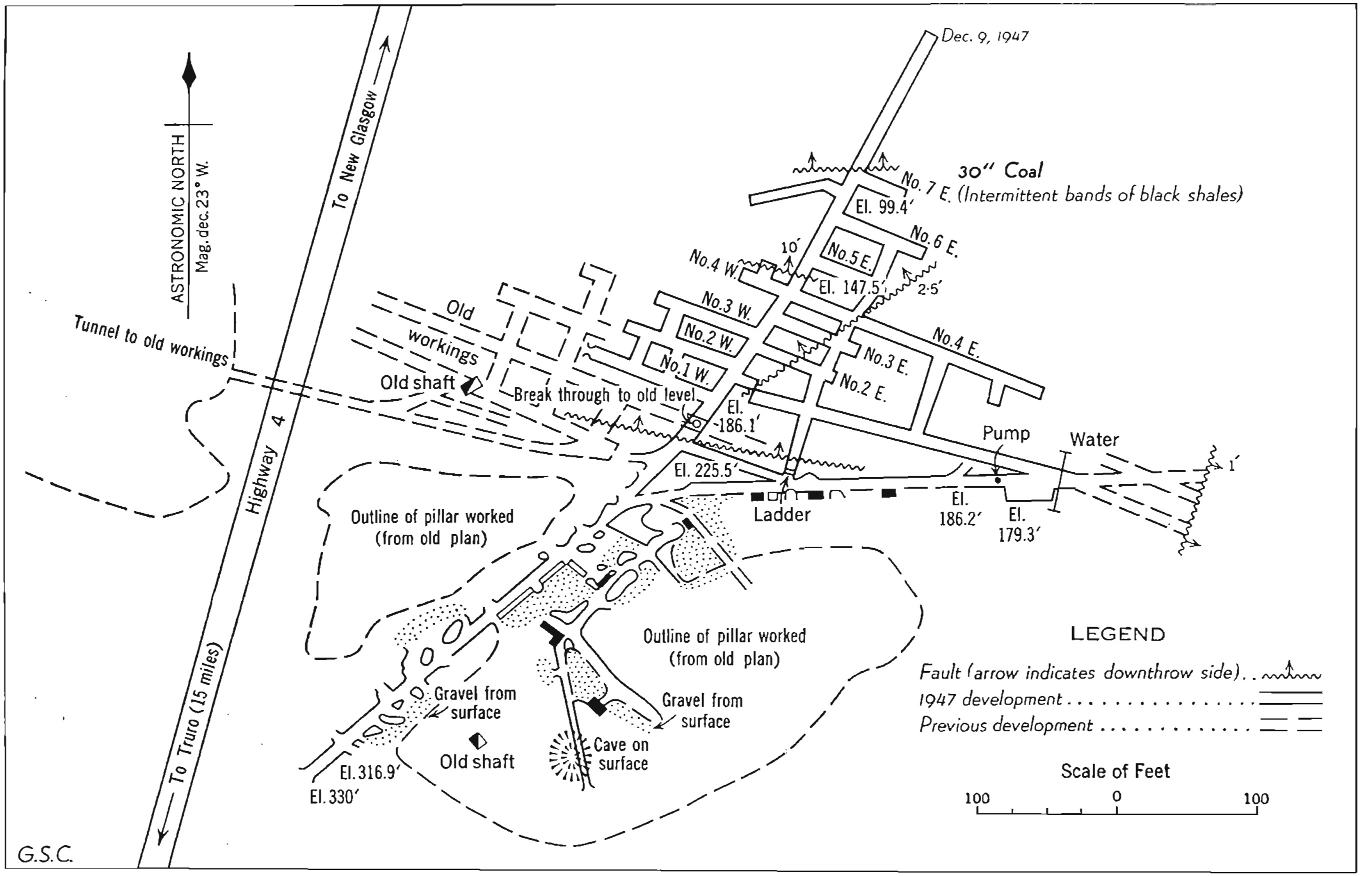

Figure 4. *Plan of workings Kemptown coal mine, Nova Scotia, 1947. (Compiled from data provided by courtesy of the Nova Scotia Department of Mines.)*

it is caved and unsafe to enter. The timbering in most of the recent underground workings is said to be in comparatively good repair, but the slopes and rooms are full of water.

The coal occurs in grey sandstone and shale of Pennsylvanian age. A collection of flora from the dump west of the Pictou road has allowed a tentative correlation of the strata with the Cumberland group. Bedrock is not exposed in the vicinity of the property, but a sample drill-hole put down in 1904 provides the following information:

	Feet	*Inches*
Surface material	11	0
Red and grey slate	21	0
Sandstone and shale	538	0
Coal	1	5
Shale and sandstone	328	7

An average analysis of the coal from the Kemptown mine, as mined in 1947, is given in the following table. The thickness of the seam was 26 inches, and 2 inches of splint on pavement was not included in the sample.

AVERAGE ANALYSIS OF KEMPTOWN COAL*

	As Received	Dry
Moisture	1·0	—
Volatile	18·8	19·0
Fixed carbon	59·7	60·3
Ash	20·5	20·7
Total	100·0	100·0
Sulphur	1·1	1·1
Calorific B.T.U./lb.	11,580	11,690

In 1941 washing tests were carried out on representative samples from the Kemptown mine by the Nova Scotia Technical College. The results indicated that the coal contains high inherent ash that cannot be removed by commercial washing. To remove the low-grade material in the raw coal in order to obtain a recovery of an acceptable grade of coal would entail discarding a large part of the run-of-mine coal.

The washing tests revealed that commercial washing would not be feasible at a lighter specific gravity than 1.75, at which point only 78 per cent recovery of a coal containing 14.5 per cent ash and a 22 per cent refuse containing 49 per cent ash would be effected.

* Goudge, M. F.: Personal information; (mining engineer, N. S. Dept. of Mines, Halifax).

DEBERT RIVER DEPOSIT

References:

Dawson, J. W.
1891: Acadian Geology, (Fourth Edition), p. 276.

Fletcher, H.
1891: Report on Geological Surveys and Explorations in the Counties of Pictou and Colchester, Nova Scotia; Geol. Surv., Canada, Ann. Rept., vol. V, pt.P, p. 171.

Gesner, A.
1836: The Geology and Mineralogy of Nova Scotia, p. 129.

Gilpin, E.
1883: Trans. Nova Scotia Inst. Sci., vol. VI, p. 93.

Macdonald, C. O.
1909: The Coal and Iron Industries of Nova Scotia, p. 49.

N.S. Dept. of Mines, Ann. Repts.: 1905, p. 12; 1906, p. 20; 1908, p. 48; 1909, p. 124; 1936, p. 89.

The Debert River coal deposit is situated on Debert River, 3 miles north of the village of Debert. The main workings lie on the east side of the river, approximately 300 yards south of the bridge that crosses Debert River at Cottam Settlement.

Mention of the deposit was first made by Gesner (1836, p. 129) but it was not until the year 1903 that development work was begun on the deposit by the Colchester Coal and Railway Company.

A 360-foot slope was driven north on the seam on a pitch of 35 degrees. At the surface the seam was 4 feet 6 inches thick, thickening to 5 feet of coal and 8 inches of fireclay at the foot of the slope.

A level was then driven west for 700 feet from the foot of the slope. In 1905 several diamond drill-holes were sunk a short distance south of the main slope. At a depth of 70 feet below the pavement a seam of clean coal 4 feet 6 inches thick was intersected. At 100 feet another seam 2 feet 6 inches thick was encountered, and at 140-foot depth a third seam, 3 feet 6 inches thick, was cut. The southward extension of the field was proved by 6 bore-holes in all, which ranged from 118 to 715 feet in depth.

The drilling proved that the slope sunk on the northern dip of the seam was on the north side of an anticlinal fold, the axis of which strikes northwest. The true dip of the coal measures is to the south.

By the close of 1905 the slope was down 550 feet, and at 460 feet levels were driven east and west. Bank heads were also driven upward to the air slopes for ventilation.

A branch line was built to join the Intercolonial Railway and the first shipment of coal was made on July 9, 1907. During 1907 a drift from the lower level of the colliery opened the second or underlying seam, which averaged 3 feet 2 inches of good coal. Early in 1908 a level was driven into this seam.

Development increased steadily during 1908. The west level of No. 1 seam was extended 700 feet, and the seam was found to remain constant in thickness and quality. The main levels on No. 2 seam were driven east and west. The thickness of the seam remained constant at 3 feet. Output varied from 10 to 30 tons per day.

For undisclosed reasons the mine closed down at the end of 1908, and remained inactive until after August of 1909. Only minor development work was carried out during that time. Production was resumed early in September and the mine remained in operation until 1910, when it was abandoned.

In 1936 the workings were pumped out to a depth of 200 feet and coal was extracted from the shaft pillars. The mine closed at the end of that year.

In 1951 the workings were again pumped out for a short distance, but because of the poor condition of the slope, due to the pillars having been extracted, further work was abandoned.

The coal seams occur in conglomerates, sandstones, and shales of Pennsylvanian age. The strata in the vicinity of the deposit are similar in appearance to those at Kemptown, and hence the Debert deposit is tentatively assumed to be in rocks of the Cumberland group. Sufficient fossil evidence for positive age determination is lacking.

A study of the structure of the rather poorly exposed river sections indicates that the coal measure is highly disturbed. The bridge over Debert River at Cottam Settlement is slightly south of the centre of the coal basin in this locality. The main seams strike approximately west, and dip north at about 30 degrees. They are on the north limb of an anticlinal fold that strikes northwest.

About 600 feet below the bridge on Debert River is a bed of grey conglomerate 150 feet wide, dipping north at 35 degrees. This conglomerate can be traced westward to a small brook about one-half mile from Debert River. There the bed is 400 feet wide, and is overlain to the south by grey sandstones and shales. The conglomerate evidently forms the crest of an anticline that plunges gently westward. The presence of a 4-foot seam of coal on the north side of the conglomerate on the brook was proved in 1883 by a bore-hole.

About 300 feet above the bridge on Debert River a coal seam about 20 inches wide is exposed. This seam strikes almost at right angles to the trend of the main coal seams. Thus it appears that the region has been subjected to extensive folding and/or faulting movements since deposition of the coal measures.

Specimens of coal from the dump were found to be fairly compact, with a conchoidal and lustrous fracture. The larger samples are laminated, with shiny, pitchy layers averaging one-quarter inch in thickness. An average analysis is as follows:

ANALYSIS OF DEBERT COAL*

	%
Moisture lost at 110 degrees C.	3·45
Volatile matter	30·40
Fixed carbon	59·25
Ash	6·90
Sulphur	1·43

The coal is high in ash and sulphur content.

Production figures, as compiled from Annual Reports of the Nova Scotia Department of Mines, are as follows:

Year	*Tons*
1908	3,951
1909	1,330
1936	191

COAL MINE BROOK DEPOSIT

References:

Fletcher, H.
1891: Report on Geological Surveys and Explorations in the Counties of Pictou and Colchester, Nova Scotia; Geol. Surv., Canada, Ann. Rept., vol. V, pt. P, p. 171.
Gesner, A.
1836: The Geology and Mineralogy of Nova Scotia, p. 129.
Canadian Min. Man. 1891, p. 63; 1892, p. 119; 1893, p. 483.

The coal deposit on Coal Mine Brook, which flows into West North River near the north boundary of the map-area, was first described by Gesner (1836, p. 130). He mentioned that two veins of coal outcropped on the banks of Coal Mine Brook, which in the vicinity of the deposit runs at right angles to the strike of the strata. The veins, which were one-quarter mile apart, were worked in 1834 for about 100 yards in each direction from the brook. The largest vein was 20 inches and the other 12 inches thick. Both veins dipped steeply south. Large fossil trees were found on the walls of the coal seam.

No further written record of the property exists until the year 1890, when about 100 feet of slope were completed and tracks were laid. Additional development work was carried out in 1891, but no coal was produced. Fletcher (1891, p. 171) described the coal as being of excellent quality but with excessive stone partings up to 1 inch in thickness.

Very little evidence of the development remains today. No production figures are available on the property.

CHIGANOIS RIVER DEPOSIT

References:

Dawson, J. W.
1891: Acadian Geology, (Fourth Edition), p. 276.
Ells, R. W.
1885: Geol. Surv., Canada, Ann. Rept., vol. I, p. 46E.
Gesner, A.
1836: The Geology and Mineralogy of Nova Scotia, p. 129.

* Macdonald, 1909, p. 182.

The Chiganois River coal deposit is located 2½ miles north of Belmont on the west bank of Chiganois River.

The existence of coal in this vicinity was first recorded by Gesner (1836, p. 129). He stated that "two small veins of coal are exposed on the sides of the Chiganois River . . . The coal strata dip north, at an angle of 45 degrees, and evidently belong to the same coal basin containing the DeBurt measures. The coal is of inferior quality . . . " Dawson (1891, p. 276) briefly mentioned the seams. Ells (1885, p. 46E) stated that a shaft was sunk here prior to 1884 in a search for coal. The coal was very shaly and of poor quality.

The most recent development on the deposit was carried out in 1925 by Mr. George Coolan. On a 5-foot coal seam a level was driven into the west bank at brook level for a distance of 222 feet; two raises were put through to the surface for ventilation. Work was then abandoned until 1927 when Mr. Chisholm of Truro carried out a small amount of work during the summer months. Since that time the workings have been abandoned and at present are badly caved.

No analyses of the coal are available, but samples from the dumps are very shaly.

OTHER COAL OCCURRENCES

Small showings of coal were noted at the following localities:

(1) On Staples Brook, due west of the Chiganois River deposit.

(2) On the Chiganois River, three-quarters of a mile south of the north limit of the map-area.

(3) On West North River, 2 miles south of the mouth of Coal Mine Brook.

(4) On a wood road 1½ miles southeast of Kemptown. This deposit was worked about 20 years ago. Two shafts, at present caved and full of water, were sunk immediately west of the road. The dump, which consists of grey-black coaly shales, is about 8 feet high. Trolley tracks and rotted trestle-timbers still remain.

Gypsum Deposits

References:

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

Cole, L. H.
1915: Gypsum in Canada, Its Occurrence, Exploitation, and Technology; Mines Branch, Dept. of Mines, Canada, No. 245.

Dana, J. D.
1895: Manual of Geology, (Fourth Edition).

Dawson, J. W.
1891: Acadian Geology, (Fourth Edition).

Grimsley, G. P.
1904: Gypsum of Michigan and the Plaster Industry; Michigan Geol. Surv., vol. 9, pt. 2, p. 186.

Hunt, T. S.
1859: On the Formation of Gypsums and Dolomites; Quart. J. Geol. Soc., vol. 16, pp. 152-154.

Jackson, C. T., and Alger, F.
1829: A description of the Mineralogy and Geology of a Part of Nova Scotia; Am. J. Sci. (Silliman's J. Sci.), vol. 15.

Jennison, W. F.
1911: Gypsum Deposits of the Maritime Provinces; Mines Branch, Dept. of Mines, Canada, No. 84.

McKinnon, A. H.
1951: N.S. Dept. of Mines, Ann. Rept., p. 181.

Messervey, J. P.
1949: Gypsum in Nova Scotia; N.S. Dept. of Mines, Pam.

Wilder, F. A.
1903: J. Geol., vol. 11, p. 116.

Numerous articles dealing with the occurrence of gypsum in Nova Scotia have been written. Jennison (1911) published a very comprehensive report on the gypsum deposits of the Maritime provinces; Cole (1915) adequately dealt with the occurrence, exploitation, and technology of gypsum in Canada.

The development of gypsum deposits in Colchester and Hants counties had begun a quarter of a century before two men from Boston published the first descriptive geological report on the area. Jackson and Alger (1829, p. 146) wrote: "Beds of gypsum, of practical worth, occur near the head of the Basin of Minas, in the vicinity of the Shubenacadie River . . . "

They were undoubtedly referring to the massive outcrops of gypsum and anhydrite that are exposed along the west bank of Shubenacadie River, particularly the one opposite Eagle's Nest Point, which Dawson (1891, p. 267) described as "an immense mass of gypsum named White's or Big Plaster Rock, and one of the principal localities of the extensive gypsum trade of this river".

No records exist that show the extent of the gypsum trade prior to the year 1833. Previously small shipments were made to the United States by chartered vessels, but the industry did not reach economic importance until the last half of the century. During the years 1861 to 1867, twenty-five ports in Nova Scotia were shipping gypsum, which was produced in twelve counties. The manufactured article became of such importance that the United States government established a severe import tariff on all gypsum products. As a result in 1908 gypsum was produced in only three counties, and was shipped from only six ports.

At present no gypsum is being produced in commercial quantities in the Truro map-area, although large deposits are available. Due to the extreme bulkiness of gypsum, a prime requisite for profitable exploitation of the product is cheap transportation, usually by water. The extremely high tides of Shubenacadie River render the loading of gypsum on large boats impractical. For this reason it is more feasible to mine the mineral in other parts of the province where large boats may be brought close to the source of supply.

Since 1872 only 247,323 tons of gypsum have been calcined in Nova Scotia. The remainder has been shipped in the crude form to be processed in other countries.

PRODUCTION OF GYPSUM IN NOVA SCOTIA*

Year	*Net Tons*
1947	2,151,270
1948	2,962,092
1949	2,558,891
1950	3,192,393
1951	3,292,713

ORIGIN OF GYPSUM

Bell (1929, p. 85) proved the source of the gypsum deposits in the Horton-Windsor district of Nova Scotia to have been from the sea water of the Windsor sea. The beds of gypsum in the Truro map-area can safely be assumed to have had a similar origin, because environmental conditions of the two areas were distinctly similar during Windsor times.

The great thickness of the gypsum beds in some of the deposits in the Truro area cannot be feasibly accounted for by direct evaporation from an inland sea. Sea water contains only 3.5 per cent of mineral salts in solution, of which 3.6 per cent consists of calcium sulphate (Grimsley, 1904, p. 186). Approximately 80 per cent of the water must evaporate before the calcium sulphate begins to precipitate; about 93 per cent, before sodium chloride is precipitated. Therefore, if a body of salt water be cut off from the sea, the calcium sulphate is precipitated before the sodium chloride. In order, therefore, that a thick bed of gypsum be formed, the sea water must be held at a certain density to allow the calcium sulphate to be precipitated without causing deposition of the sodium chloride.

The recurrent presence of ripple-marked limestones indicates shallow conditions for the Windsor sea at different stages during lower Windsor time. Therefore, in order that such great thicknesses of gypsum could form by evaporation, the sea water in the basin must have been constantly refreshed. It is probable that sea water flowed into the basin over a barrier and evaporated sufficiently to deposit its gypsum content, in a manner similar to that found in the Gulf of Karaboghaz, on the east side of the Caspian Sea. In this manner considerable thicknesses of gypsum would eventually accumulate.

Although the greater part of the gypsum that occurs in the Truro map-area is thought to have originated primarily by evaporation, it is probable that chemical precipitation of the mineral occurred as well.

* N.S. Dept. of Mines, Ann. Rept., p. 181 (1951).

It is also likely that more than one type of saline basin existed during deposition of the gypsum. Usually, but not invariably, the larger deposits are underlain by fossiliferous limestone. This fact alone points to distinctly variable environmental conditions at different localities during deposition of the gypsum.

Vein deposits of gypsum are common in the red Windsor shales of the map-area. However, the veins have apparently formed from secondary solutions derived from the main gypsum bodies, and are of minor importance. The veins cut haphazardly through the red shales, and apparently follow bedding planes and fracture channels in the rocks. Vein gypsum is composed of selenite and fibrous gypsum, which is generally orange in colour, due to iron picked up by the sulphate solutions as they percolated through the red shales (*see* Plate IV B).

In conclusion it may be stated that the beds of gypsum that occur in the Truro map-area originated as lenticular masses in a marine series of strata. The greater part of the gypsum formed as an evaporite from sea water.

One and probably two continuous beds of gypsum can be recognized in strata of lower Windsor age.

The main bed locally exceeds 50 feet in thickness, overlies the red Pembroke conglomerate, and is in turn overlain by red shales of lower Windsor age. This bed can be traced by outcrop exposures and surface expression of karst topography from near the mouth of Shubenacadie River to a point on Little River about 4 miles east of Brookfield. There the bed evidently swings southward off the map-area, to reappear just east of Putnam Brook; scattered exposures of gypsum may be found from there eastward to Otter Brook and thence off the mapped area.

It will be noted that the strike of the gypsum bed roughly parallels that of the Horton-Windsor contact.

The second, and less well-recognized gypsum bed, is exposed along the streams that flow southward into Green's Creek. This bed strikes approximately west, and outcrops about one-quarter mile north of the road that joins Brookfield and Shortt Lake.

Large deposits of gypsum are found on the west bank of Shubenacadie River. Their age relationships are in doubt, as they have evidently been preserved in the form of down-faulted blocks.

Several smaller deposits of gypsum also occur in the lower Windsor rocks bordering Penny and East Mountains.

The following group of analyses will show the different qualities of gypsum found in several of the larger deposits of the area:

Analyses of Gypsum

(Jennison, 1911, pp. 62, 66, 67)

Name of Deposit	Lime	Sulphuric Anhydride	Water, Loss on Ignition	Insoluble Mineral Water
	%	%	%	%
Stephens	32·92	46·44	20·93	0·20
Graham	32·80	46·24	20·65	1·00
Pitch Brook	32·88	44·92	20·47	1·70
Morgan	33·00	46·08	20·90	0·10
Upper Pleasant Valley	33·00	45·76	20·78	0·90
East Mountain	35·08	49·10	20·40	0·60

USES OF GYPSUM

Locally ground gypsum is used as fertilizer to a limited extent. The final operation in building a dyke consists of treating the surface of the newly constructed dyke with a mixture of lime or gypsum or both fertilizer and grass seed. Gypsum is only used where the material employed in construction of the embankment is high in salt, as might occur with material found outside the old dykes or in areas recently flooded by salt water. Gypsum improves the drainage of the soil by causing the clay particles to flocculate, a reaction probably brought about by conversion of sodium-clays to calcium-clays, thereby releasing the exchangeable sodium which is leached out as sodium sulphate. Gypsum has a beneficial effect on any soil containing an excess of sodium and on soils where the pH is too high. Such a condition seldom exists in Nova Scotia, except on newly reclaimed dyke lands. Gypsum is of value as a fertilizer only where additions of calcium are required without an accompanying rise in pH of the soil.

Gypsum is used mainly in the construction and building trades. Wallboard and sheathing that have been made from gypsum are fireproof, and do not expand or contract regardless of atmospheric changes.

When gypsum is calcined it forms plaster of Paris, which will become hard after being mixed with water. Plaster of Paris is used in wall plaster, stucco, whitewash, dentistry, casts, etc.

Ground gypsum is used in the uncalcined form as a retarder in Portland cement, a pigment base for paint, a filler for paper and cloth, a flux in glass manufacture, and as a weight in fertilizers.

Alabaster is used for statues, vases, etc.

Small amounts of satin spar and selenite are used in cheap jewellery and microscopy, respectively.

STEPHENS GYPSUM DEPOSIT

The Stephens deposit is exposed on the west bank of Shubenacadie River about 2 miles upriver from the mouth. The gypsum is of the white, fairly pure, compact variety and is associated with blue-red marls. The deposit is exposed for a distance of 650 feet, and is followed upstream by red lower Windsor shales cut by gypsum stringers.

According to Jennison (1911, p. 65) this was the largest deposit of fibrous gypsum known in the Maritimes at that time. The fibrous gypsum occurs in veins up to 18 inches thick cutting the marls in a haphazard fashion. When cleaned the fibrous veins produce exceptionally pure gypsum.

In 1869 a mill was erected at Noel, 15 miles away, at a cost of $12,000, for manufacturing the fibrous gypsum into terra alba. In 1870 the mill was burned, and operations ceased.

GRAHAM GYPSUM DEPOSIT

This deposit is located on the west side of Shubenacadie River, just above and opposite Eagle's Nest Point. The deposit was formerly known as Plaster Rock, and for many years was operated for export purposes.

It is a massive bed of slightly contorted gypsum which has been weathered into a columnar shape. The outcrop is about 500 feet wide, and appears to form the east limb of a small anticline that strikes south 40 degrees east. The interior and base of the outcrop consist of anhydrite, with the whole resting on fossiliferous limestone of lower Windsor age (*see* Plate IV A).

PITCH BROOK GYPSUM DEPOSIT

This deposit is situated about a mile east of the mouth of Pitch Brook. The gypsum, which is of the compact, light grey variety, was quarried many years ago and the product exported to the United States.

These beds extend with intermittent outcrops to Beaver Brook and thence to Irwin Lake. At Beaver Brook the gypsum is of the white variety, with some alabaster. South of Irwin Lake several small outcrops are exposed, but the gypsum shows a high content of lime carbonate in its composition and could be used only for fertilizer.

JAMES MORGAN GYPSUM DEPOSIT

One and three-quarters miles southeast of Irwin Lake a large area of gypsum is partly exposed on the farm of James Morgan. Karst topography is extremely well developed in this district. The exposed gypsum is both blue and white, and consists of the compact and granular varieties.

UPPER PLEASANT VALLEY GYPSUM DEPOSITS

Gypsum has been quarried at two localities in Upper Pleasant Valley. The larger quarry is situated $1\frac{1}{2}$ miles north of Shortt Lake, a few hundred feet east of the Irwin Lake road. The smaller quarry is found on the farm of Gerald Brine, about one-half mile north of Shortt Lake.

Both deposits are of the impure, grey type of gypsum, and have been used locally as fertilizer.

LITTLE RIVER GYPSUM DEPOSIT

Two miles northeast of Brookfield, on the west bank of Little River, a cliff of gypsum 50 feet high is exposed for a distance of over 500 feet. The gypsum is partly of the pure white variety and varies from compact to granular in texture.

Scattered exposures of contorted gypsum continue eastward along Little River.

Iron Deposits

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CHAMBERS AND PEARSON IRON MINES

These deposits are situated $2\frac{1}{2}$ miles east of Brookfield and about 200 yards northeast of the Brookfield Barite mine. The ore is found in the Horton sandstones and shales, in close proximity to their contact with the lower Windsor marine sediments.

The deposits were operated about the turn of the century, and the ore was shipped to the blast furnace at Londonderry. At present all workings are caved, and the dumps are grown over.

The Chambers deposit was first opened in 1889; total output of ore mined amounted to 44,000 tons. The ore was first noticed on the surface in the form of large boulders of several tons weight; a shaft was sunk on the main band of ore, which occurred in the form of a lenticular pocket in the red Horton shales. The iron ore consisted mainly of massive and botryoidal limonite mixed with red clay, which was washed out prior to shipment.

An average analysis of the ore processed was:

Iron — 46.5%
Insoluble — 18.6%
Moisture — 12.5%

The Pearson deposit lies immediately south of the Chambers deposit.

Two tunnels were driven northward from the small brook immediately south of the Chambers deposit on a band of limonite and siderite which varied from 18 to 30 feet in width. The ore was also worked by open-pit methods, and the badly slumped face of the quarry can still be examined. The quarry, which faced south, has a face of about 25 feet. The rocks in the quarry strike approximately west and dip south at a high angle.

Total output of the mine is not known, but the ore was of low grade. The following analysis is of ore shipped to Londonderry in 1906.

Iron — 43.87%
Insoluble — 16.39%

CLIFTON IRON DEPOSIT

The Clifton deposit is situated about one-half mile south of Clifton station, and one-quarter mile east of the Dominion Atlantic railway.

The deposit was first opened about 1873, when 497 tons of ore were shipped to Londonderry for smelting. The mine was re-opened in 1903, and 300 tons of ore were removed. Operations were then discontinued, and at present the workings, which consisted of two shafts some 70 feet deep, are caved.

The ore is said to have been limonite, red hematite, red ochre, and goethite. The orebody was about 6 feet thick, and occurred in concretionary form in Horton sandstone.

The following average analysis is from shipments made to Londonderry:

Iron — 32.24%
Silica — 45.57%
Manganese— 0.059%
Phosphorus— 0.034%

PINE BROOK–TOTTEN BROOK DEPOSIT

Shortly previous to 1890 a large open-cut and several trenches were opened in a deposit of ankerite that lies on the side of a hill north of the marsh known locally as Peter Totten's meadow. Several tons of ore were mined and shipped to Londonderry for smelting.

About 1900 ankerite was discovered on Pine Brook, at a point due west of the Totten deposit. Subsequent trenching confirmed the presence of numerous exposures of iron carbonate along the north side of the depression between Pine and Totten Brooks.

In 1943 a detailed study of the Pine Brook-Totten Brook area was undertaken by L. J. Weeks (1948, pp. 43-61) to determine the possible economic value of the ore deposit. An area 800 feet wide by 6,400 feet long was mapped by plane-table on a scale of 200 feet to the inch. In addition, a magnetometer survey was carried out with a Hotchkiss Superdip magnetometer.

The results of the examination were not conclusive, but the deposit was considered by Weeks to constitute a possible source of furnace flux from which some iron would be obtained, with the possibility that enriched bodies of iron carbonate might be encountered.

For a detailed description of the deposit, the reader is referred to Week's report.

WEATHERBE BROOK IRON DEPOSIT

The Weatherbe Brook workings are located on the upper reaches of Weatherbe Brook, just within the western limit of the map-area, and one-quarter mile north of the bridge on the base-line road. The deposit forms a part of the East Mines workings described by Weeks (1948, p. 41).

The underground workings of the Weatherbe Brook deposit are at present inaccessible. According to Lindeman (1917, p. 172) they consist of one long and several very short levels. The main adit was opened on the brook, and driven northeast for 350 feet to intersect an orebody, along which a drift was driven to the east. Ore was mined from this zone by both open-cut and underground methods.

The main level was then extended northeast for an additional 500 feet to intersect a second easterly trending orebody, along which stoping was carried out on drifts to the east and west.

Specimens from the dump indicate the ore to be a mixture of limonite, siderite, ankerite, and specularite.

The ore was hauled to Londonderry for smelting via a spur line that linked the deposit to the railway over which the ore from East Mines was carried to the smelter at Londonderry

UPPER KEMPTOWN IRON DEPOSIT

This property is located in Upper Kemptown, about 1,000 feet east of the Kemptown-New Annan road, at a point about 2 miles north of Kemptown. The workings lie on the farms of G.R. Munro and A. Archibald.

The property was worked prior to 1892, but no production figures are available. According to Mr. Munro, work was carried out during the period 1904-07, but the property has remained inactive since that time.

The workings consist of two shafts 450 feet apart, on a line striking 10 degrees south of east. The western shaft is said to be 60 feet deep, and the eastern shaft 90 feet deep. Both shafts are filled with water. The deposits apparently lie in dark grey, quartzitic sandstones, but due to lack of outcrop the ore cannot be examined in situ. The area is covered by a mantle of glacial drift, probably 2 or 3 feet thick.

An examination of the ore on the dumps indicates the primary ore to be specular hematite, which has been largely altered to earthy limonite, goethite, and specular oxide, by surface oxidation. The specular hematite apparently exists only as narrow stringers in the host rock, resulting in a product too low in iron to be of commercial value.

Lead Deposit

SMITHFIELD LEAD DEPOSIT

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The Smithfield lead mine lies 13 miles east of Brookfield station on the Truro-Halifax line of the Canadian National Railways. The deposit may be reached from Brookfield by a good gravel road for 11 miles and then 2 miles of improved secondary road that is impassable by automobile during periods of heavy rainfall. The property is 12 miles southeast of Truro.

Smithfield (occasionally known as Leadvale) was once a prosperous farming community with a school and church. The district is now entirely uninhabited, and only the remains of one or two houses are left.

Intermittent development was carried out on the property during the period 1881 to 1884. Shafts Nos. 1 and 2 (*see* Figure 5) were sunk, and a small smelter was erected for extracting the lead from the galena. In 1884 about 300 tons of ore were treated.

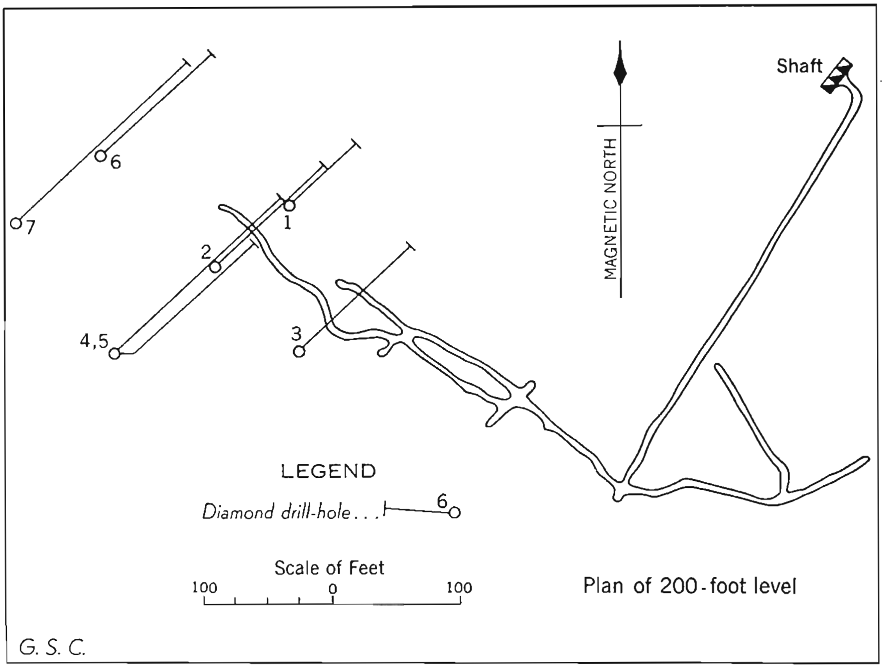

Figure 5. Plan of recent workings at Smithfield lead mine. (Courtesy Nova Scotia Department of Mines.)

The property was then closed down until the winter of 1894-95, when three diamond drill-holes were put down and shafts Nos. 3 and 4 were sunk. Metallurgical difficulties could not be overcome, and the property became inactive shortly thereafter. Total production is not known, but it amounted to only a few hundred tons.

The next work was carried out during the period 1925-27, when a company called the Leadville Mining Company was formed to explore the property's possibilities. In 1926 the task of dewatering the workings was undertaken to determine the extent and grade of the ore.

In 1927 the property was optioned to British Metals Corporation of Canada Limited, who carried out development work from January to July of that year. They deepened No. 2 shaft from 50 to 115 feet, did some drifting, crosscutting, sampling, etc., but no production is recorded.

The property remained inactive until 1945, when it was taken under option by Maritime Barytes Limited. This company did no underground work, but carried out a surface examination of the property and surrounding district.

Early in 1951, Minda-Scotia Mines Limited began a systematic surface and underground investigation of the property, which entailed an extensive diamond-drilling program accompanied by resistivity and potentiometer surveys. The examination of the deposit was carried on throughout the summer, and approximately 40 holes were drilled in the vicinity of the shafts. An orebody, 500 feet long, containing about 550,000 tons of ore with a tenor of about 6% combined lead and zinc was reportedly outlined.

Some biogeochemical work was done in the neighbourhood of the main showing, but this work was too limited in scope to be of much value.

Late in 1951 the company began sinking a three compartment shaft, which eventually reached a depth of 250 feet. At the 200-foot level a drift was driven into the ore zone for a distance of about 180 feet east and 360 feet west of the shaft. A plan view of these workings, as well as the location of several drill-holes, is shown in Figure 5.

At this time operations on the deposit were suspended, and the property was offered for sale.

The deposit is located at the east end of a long intervale formed by Smithfield River. This river flows for some distance just south of the contact where the limestone and gypsum of lower Windsor age have provided less resistance to erosion than did the sandstones and shales of Horton age that form a series of hills north of the river. The river swings south a short distance west of the property and flows southward into Stewiacke River. A long, flat-topped ridge, heavily covered by drift, lies south of and parallel with the intervale. Several boulders of fossiliferous limestone, of probable lower Windsor age, were found near the top of the ridge. Karst sink holes in the vicinity of the limestone debris are indicative of underlying beds of limestone or gypsum or both.

The Horton-Windsor contact crosses Smithfield River about 1,000 feet southeast of the workings, but the precise location of the contact could not be determined. Horton shales and sandstones are well exposed for over a mile upriver from this point.

The overburden in the vicinity of the shafts varies from 50 to over 300 feet in depth, gradually decreasing to the north. Heavy fluviatile deposits of sand and gravel are found to the south and west along the river intervale.

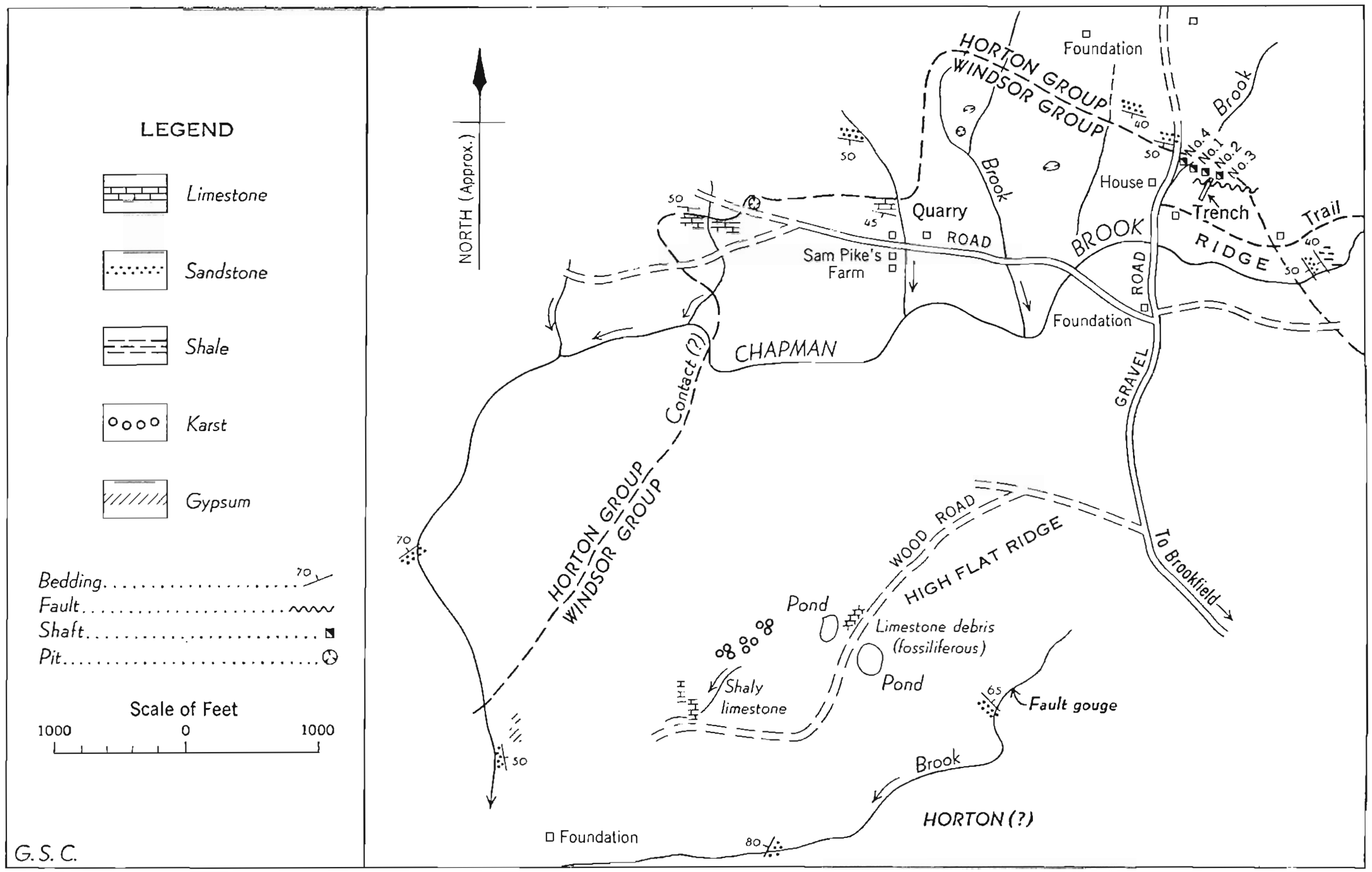

Figure 6. *Surface map of Smithfield lead property, 1951, Colchester county, N.S.*

The lead-zinc mineralization occurs in the Windsor basal limestone and limestone conglomerate, which in this region disconformably overlies the Horton shales and sandstones. There are no outcrops of the limestone in the immediate vicinity of the mine workings, but Horton shales and sandstones are exposed on the road about 300 feet north of the deposit.

The first limestone outcrop, going northwest from the mine, is met with at 1,800 feet; from this point the limestone makes a 90-degree swing to the south and is again exposed in a small abandoned quarry 2,500 feet west of the mine. The limestone in the quarry consists of thinly bedded, blue-grey limestone striking west and dipping 40 degrees south. The rock is joined and cut by seams of calcite, and is similar in appearance to the basal Windsor limestone known as the Macumber formation, which is exposed elsewhere in the Truro area along the Horton-Windsor contact.

The contact between the Horton sandstones and Macumber limestone is well exposed 1,200 feet west of the quarry. There platy, laminated grey limestone lies with apparent disconformity upon red and grey Horton sandstones that strike west and dip 50 degrees south. From this point the contact swings sharply south and crosses Smithfield River.

The strike of the line of shafts that have been sunk on the property is parallel to the strike of the Horton-Windsor contact in the vicinity of the mine. It is assumed that the ore zone is following the strike of the contact and therefore the strike of the bed of basal limestone.

The mineral deposit is not exposed at the surface; the following information has been derived mainly from drill-core records and an examination of a limited number of drill-core specimens.

The lead-zinc mineral deposit occurs in a limestone bed that lies at the base of the lower Windsor. The limestone lies disconformably upon beds of red sandstones and shales of Horton age. The sandstone has been replaced by a large pyrite body with low zinc content in the vicinity of the main orebody. Prior to deposition of the lead and zinc, the limestone was also mineralized with pyrite.

The Horton-Windsor contact trends in a northwestern direction across the property, and dips to the southeast with angles ranging from 40 to 75 degrees. Considerable faulting movements have occurred along the contact, and the ore-bearing limestone immediately overlying the Horton has been highly brecciated. The presence of a major fault, striking south 55 degrees east magnetic, and dipping northeast at about 65 degrees has been proved by diamond drilling. If projected upward along the dip, the fault trace would reach the surface at a point 735 feet from the road bridge, on a bearing of north 72 degrees east magnetic. At present the northeast and southwest limits of the fault are unknown. Both pre- and post-mineralization fault breccia indicate several periods of faulting.

An examination of ore specimens from the dump indicates that pyrite is the most abundant mineral and is associated with the galena. Specimens were examined consisting of alternate bands of pyrite and galena, each band being about one-quarter inch thick. A minor amount of barite is present. Minerals observed in the dump specimens were pyrite, galena, calcite, quartz, arsenopyrite, chalcopyrite, sphalerite, malachite, and azurite.

Several polished sections examined microscopically showed the sequence of mineral deposition to be as follows, from oldest to youngest:

chert and quartz
pyrite-marcasite
calcite
sphalerite
galena
barite
calcite
sphalerite and galena

The true relationship between the pyrite and marcasite could not be determined from the limited number of specimens available. The marcasite appears to have originated from zonal alteration of the pyrite, and is thought to be an alteration product of the latter mineral.

The ore is probably of hydrothermal origin. Following pyritization of the limestone, faulting movements brecciated many of the limestone beds, thereby providing channel-ways for the ascending hydrothermal solutions which carried the gangue minerals and metals. The ore formed both by replacement and cavity-filling processes. The presence of cockade banding, crustification, and fracture filling phenomena in polished sections indicates that cavity-filling predominated.

Limestone Deposits

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Limestones in the Truro map-area may be divided into two main types:

(1) Calcium limestones, or those that contain less than 10 per cent magnesium carbonate, calcium carbonate being the predominant mineral.

(2) Magnesian limestones, or those that contain between 10 and 40 per cent of magnesium carbonate. If the rock contains 40·00-45·65% of magnesium carbonate it is classed as a dolomite.

All limestones contain impurities in the form of sand, clay, etc. If the rock contains less than 5 per cent of impurities by volume, it is classed as a "pure" limestone. If impurities are present in excess of 50 per cent by volume, the rock is not classed as a limestone, but is given some other name.

Limestones in this area are predominantly grey. Locally they may vary from white through grey to black. Iron oxide, where present, imparts a yellow, brown, orange or red colour to the rock. Black limestones owe their colouring to the presence of carbonaceous material.

All limestones in the Truro area are of two general types:

(1) Bedded limestones of variable degrees of purity. These rocks may or may not be fossiliferous.

(2) Shell limestones, usually massive and highly fossiliferous.

Bedded limestones, that are usually well stratified, are predominantly calcium limestones. The deposits are lenticular, and seldom exceed 75 feet in thickness. Individual lenses may, however, be several miles long and grade off at their edges into sandstone or shale.

The bedded limestones range in composition from high calcium to high magnesium, with the former predominant.

The basal beds of the lower Windsor strata in the map-area are bedded limestones. The Horton group is overlain by the basal Macumber formation, which is a sandy, impure, grey, unfossiliferous, laminated limestone. This limestone is in turn overlain by the red, unfossiliferous, limestone conglomerate of the Pembroke formation. These formations have been previously described.

The largest deposit of bedded limestone is found in the area bordering Green's Creek. This limestone is locally fossiliferous.

Shell limestones consist of fragments of crinoid stems and marine shells set in a limestone matrix. Locally the rock assumes a coquinoid appearance. Cavities in the limestone render it susceptible to easy fracturing.

Deposits of shell limestone are commonly associated with gypsum and anhydrite. The ridge-like nature of the outcrops is indicative of reef structure. Usually shell limestone is very pure and high in calcium content, but the deposit 3 miles west of Hilden approaches the composition of dolomite. This deposit is the only well exposed outcrop of shell limestone encountered in the map-area.

No attempt is made in this report to describe every outcrop of limestone that might be of possible economic importance. Only those deposits from which limestone has been quarried are dealt with here.

At present no limestone is being quarried in the Truro area for either export or local use.

All limestones of possible commercial importance in the Truro map-area are of Windsor age. Bedded limestones may be of either upper or lower Windsor age, but the coquinoid shell limestones originated during lower Windsor time.

HILDEN LIMESTONE DEPOSIT

The Hilden deposit is the only exposure of pure shell limestone known in the map-area. A small amount of the rock was quarried many years ago and burned in a nearby pot kiln that is now in ruins.

The deposit is situated on the west side of the road, about 1½ miles south of Irwin Lake. The rock is a coquina-type limestone composed almost entirely of shells and crinoid stems. Many of the fossil shells are in an excellent state of preservation, but extraction of fossils is very difficult because the rock has a tendency to break across, rather than around, the individual shells. Thus it is easier to collect small shells which are more readily extracted. This fact leads to the erroneous conclusion that the small shells are present in dominant numbers.

The back wall of the quarry is a face with a vertical height of 26 feet. The ridge, about 30 feet wide, strikes approximately west, and outcrops for a distance of 135 feet. Several small outcrops of the limestone are exposed east of the road. The outcrop is very contorted.

The original calcium in the shells has been replaced by a dark grey, massive, crystalline dolomite. The matrix is also dolomite. Some of the rock has locally developed a pink hue, due to the presence of tiny crystals of red calcite. The lower part of the outcrop is pure, but becomes more sandy towards the top. Much free quartz is present in the form of small lenses, which contain quartz grains up to 1 mm. in diameter.

The following analyses are from chip samples collected from the quarry (Goudge, 1934, p. 48).

Location	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
South side	1·20	1·72	0·70	0·11	58·67	37·33	99·73
North side	1·80	1·72	0·70	0·13	54·31	41·55	100·17

GREEN'S CREEK LIMESTONE DEPOSIT

The ridge of bedded limestone that follows the arc of Green's Creek is the largest deposit of limestone in the area. The band is more than 2 miles long and averages 50 feet in width. The west end of the ridge outcrops near the mouth of Andrew Brook, 2 miles from Green Oaks station. From this point the band strikes in a general easterly direction along the south shore of, and parallel to, Green's Creek. The ridge may be traced eastward to a point approximately 2 miles to the east of Andrew Brook, but the deposit continues southeast off the map-area. The general location of the deposit is shown in Figure 1, page 37.

The bedded limestone blankets the north face of a ridge that averages 75 feet in height. The rock dips to the north, with dips varying from 10 degrees to vertical.

The western terminus of the ridge, where exposed on Andrew Brook, consists of soft, grey, fine-grained, well bedded limestone, which has been extensively drag-folded. From there the limestone ridge strikes eastward and crosses to the south side of Green's Creek at the mill pond just north of the bridge where the Brookfield road crosses Green's Creek. At this point about 30 feet of shaly grey limestone dipping north at 25 degrees, is exposed on the north face of a hill. The deposit can then be traced eastward for about one-half mile to a faulted area about 300 yards wide. At this point a small creek enters Green's Creek from the south. The limestones exposed along the small creek are of the soft, grey, well bedded variety. They have variable attitudes, but, in general, dip towards the southeast.

The limestone band outcrops again a short distance upstream from the mouth of Plaster Brook, where it forms a 50-foot-high ridge that dips north at 80 degrees. Just east of this point, the deposit is exposed along the north face of a north-dipping ridge on the south side of Green's Creek. This ridge continues along the south side of the creek in a gentle arc to a point near the mouth of Pleasant Brook.

The limestone in the Green's Creek deposit is, in general, dense-textured, greyish brown, and interbedded with lenses of calcareous shale. The rock is well bedded, and occurs in thin, rubbly beds, that gradually become more shaly near the base of the deposit.

The deposit is uniformly low in magnesium carbonate and high in impurities. The limestone is too impure for metallurgical or agricultural purposes. It could possibly be used in the manufacture of Portland cement, provided the low Al_2O_3 content be augmented by the addition of shale or clay.

An average of the analyses listed by Goudge (1934, p. 48) for the deposit is as follows:

SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total	S	CaO	MgO
6·57	0·66	1·57	0·8	89·21	1·01	99·10	0·13	50·01	0·48

Approximately 500 yards north of this deposit, and parallel to the curve of Green's Creek, a 30-foot band of soft, impure, dark brown magnesian limestone, dipping steeply northward, is exposed on Pleasant, Maynard and Plaster Brooks. This limestone is overlain by a 10-foot-thick bed of impure, sandy, shaly, grey limestone, that is in turn overlain by red shales. The magnesian limestone is underlain by grey sandstone.

A sample analysis of the magnesian limestone indicates that the rock contains 37·54 per cent of $CaCO_3$, and 25·06 per cent of $MgCO_3$ (Goudge, 1934, p. 48).

The Green's Creek limestone deposit is of upper Windsor age.

SOUTH MAITLAND LIMESTONE DEPOSIT

In 1904 a quarry was opened in a limestone deposit one-quarter mile north of the railway station at South Maitland, and the limestone was used as a flux in the blast furnace at Londonderry iron mines.

The limestone is dominantly grey but is weathered red on all exposed surfaces. It has a stratigraphic thickness of 35 feet, strikes north 70 degrees east magnetic, and dips north at 25 degrees. The upper strata are well bedded, and contain lenses of shale and sandstone. The lower beds include a large amount of calcareous sandstone.

The upper beds are medium to dense in texture, grey-brown, and contain numerous vugs of calcite. A small brook crosses the deposit at right angles to the regional strike of the rocks, and a section of the strata is revealed in the east bank. The limestone is overlain by coarse, red, gritty sandstone and is underlain by red, sandy shale.

In 1947 a diamond drill-hole 48 feet deep was put down by the Nova Scotia Department of Mines. The average lime content of the deposit for this depth was 67·5 per cent, which is too low grade for agricultural purposes.

This limestone is of lower Windsor age, and appears to form a part of the Pembroke formation.

EAST MOUNTAIN LIMESTONE DEPOSITS

One-half mile northwest of the East Mountain manganese mine, and 6 miles northeast of Truro, a quarry has been opened in a deposit of limestone a few hundred feet south of the Truro-Pictou highway. A small amount of the rock has been crushed for local use as fertilizer.

The deposit consists of a hill of dense to fine-grained, grey, fossiliferous, massive limestone, that is cut by numerous stringers of calcite. The exposure is about 150 feet long and 60 feet wide.

The limestone in the deposit is high in calcium, with an average content of 96·10 per cent $CaCO_3$, and 0·69 per cent $MgCO_3$ (Goudge, 1934, p. 48).

Fossils are poorly preserved, but are probably of upper Windsor age.

One thousand feet west of Clifford Brook, immediately opposite the East Mountain manganese mine, a quarry has been opened in a deposit of grey, laminated, platy limestone. A considerable amount of this limestone has been quarried for agricultural use.

It is probably of lower Windsor age, as it is similar in appearance to lower Windsor limestones found elsewhere in the area.

Several smaller outliers of red Pembroke limestone, from which small tonnages have been quarried for local use, are found in the vicinity of East Mountain. This limestone is thought to overlie the basal Macumber limestone of lower Windsor age.

SMITHFIELD LIMESTONE DEPOSIT

A few tons of limestone have been quarried from a deposit of grey, well bedded limestone lying about 2,500 feet west of the Smithfield lead mine.

The rock is dark grey, medium grained, and well bedded. A sample from the face of the quarry averaged 81·22 per cent $CaCO_3$. From the general appearance of the rock exposed in the quarry, the limestone is too impure for agricultural purposes.

The age of this deposit is in doubt. However, its stratigraphic position, coupled with an absence of fossils, would indicate an early lower Windsor age.

Manganese Deposits

The manganese properties in the Truro map-area have long been known. Practically all the deposits have been described in reports written prior to 1900.

With the exception of the Manganese Mines property, all deposits of manganese in the area are of the replacement type and consist of the minerals pyrolusite (MnO_2), psilomelane (MnO_2, BaO, H_2O, etc.), and manganite ($Mn_2O_3H_2O$). The deposits invariably are at or near the contact with the underlying Horton sandstones and shales. At Manganese Mines, the ore is found within sediments of Horton age.

In 1925 Dr. W. L. Uglow of the Geological Survey of Canada began an examination of the various occurrences of manganese in the Maritimes. The results of his investigation were not fully realized because of his untimely death the following year. In 1927 W. V. Smitheringale, also of the Survey, completed the project begun by Dr. Uglow. His findings were submitted to the Survey in manuscript form. In 1932 Dr. George Hanson, of the Survey, published a report on the manganese deposits of Canada.

During the field seasons of 1950 and 1951, the writer visited and examined all known occurrences of manganese within the Truro map-area. Unfortunately, all pits and shafts on the various properties were flooded, and as a result no underground examinations could be made. The following descriptions of properties are of necessity largely a compilation of the works of previous writers who had free access to the underground workings. Much information was received from various people who had resided in the vicinity while the different properties were under development.

No development work has been carried out within recent years upon any property except the Munroe-Chisholm property of East Mountain.

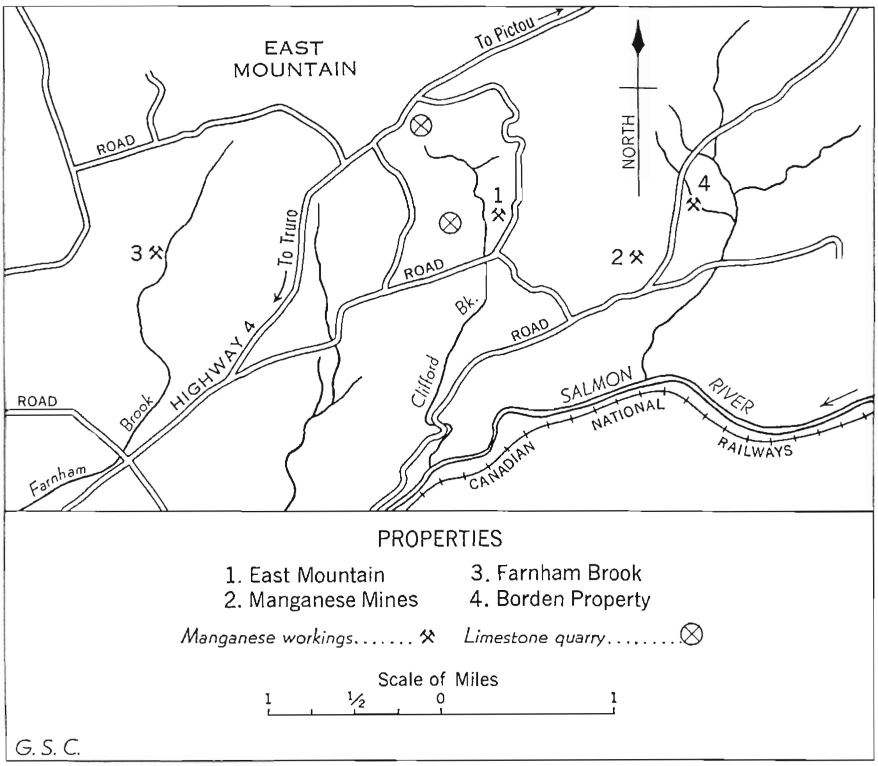

Figure 7. Plan showing locations of manganese properties in the vicinity of East Mountain, Colchester county, N.S.

EAST MOUNTAIN MANGANESE MINE

References:

Flynn, A. E.
1939: Survey of Minas Basin Manganese Deposits; N.S. Dept. of Mines, Ann. Rept., pt. 2, pp. 105-106.

Hanson, G.
1932: Manganese Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser., No. 12, p. 33.

Smitheringale, W. V.
1928: The Manganese Occurrences of the Maritime Provinces, Canada; manuscript report written in 1928.

Uglow, W. L.
1920: Manganese Mines, Colchester County, Nova Scotia; Munitions Resources Commission, Final Report, p. 88.
N.S. Dept. of Mines, Ann. Repts.: 1884, p. 33; 1938, pp. 162-166; 1940, p. 58; 1941, p. 50.
Geol. Surv., Canada, Ann. Repts.: vol. XV, pt. S, p. 157 (1907); vol. V, pp. 91, 184 (1892).

The East Mountain mine is 6½ miles northeast of Truro, and about one-half mile northwest of Manganese Mines post office. Access to the property is by a good gravel road that joins the Truro-Pictou highway about 2 miles north of the deposit.

The property was first discovered about 1897. A shaft was sunk vertical for 5 feet and then on an incline of 55 degrees to the northwest for 20 feet. In 1897, 100 tons of ore are said to have been produced.

No further work was done on the property until 1918, when the old shaft was pumped out and deepened 5 feet. About 10 tons of ore were obtained at this time, and operations then ceased.

Work was renewed on the property in 1938, by Messrs. Munroe and McLennan. A small slope, striking approximately north 35 degrees west, was opened on the east side of the road. This slope was opened on the contact between the red ferruginous Horton sandstone and the overlying younger Pembroke limestone. The dip of the contact is about 30 degrees.

The main slope was sunk 50 feet, and from there a tunnel was driven for 100 feet. At this point a winze was sunk to a depth of 10 feet. About 6 feet was taken horizontally off the north side of the winze. All this work was carried out in mineralized limestone that contained manganese ore either in replacement form or along joint planes. From the foot of the main slope a tunnel was broken off to the south to the contact and followed along it northward for about 20 feet. From a point in the main tunnel 50 feet north from the foot of the slope another tunnel was driven to the left towards the contact and was produced southward to join the former tunnel following along the contact to the north. Another tunnel driven to the right from the foot of the main slope for a distance of 40 feet intersected no ore and was entirely in shales. The winze was raised through to the surface a distance of 37 feet, of which 27 feet were in limestone and the rest in overburden.

During the period 1939 to 1941 intermittent development work was carried out on the deposit. The overburden was excavated for 200 feet at an average width of 40 feet and a depth of 30 feet. The eastern extremity of the open-cut passed through the slope of the original mine, and about 5 tons of ore were removed from the roof of the slope. A 10-foot-thick bed of limestone, red shale, and conglomerate of Pembroke age was exposed in the northeast corner of the excavation, and 2½ tons of manganese ore were obtained from a pocket in this limestone near the contact with Horton sandstones. A small amount of ore was mined from the bottom of the cut late in the year, and operations ceased shortly afterward.

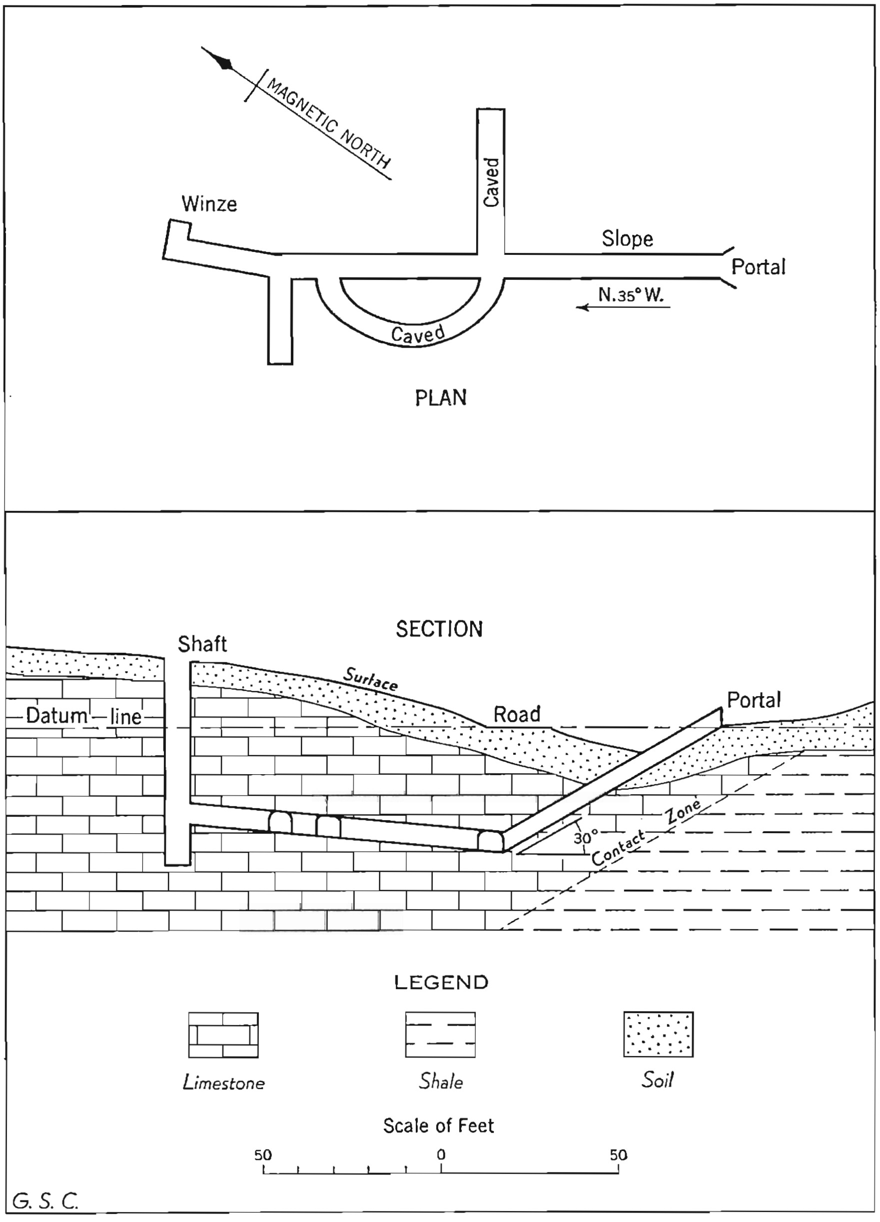

Figure 8. *Plan and vertical section of underground workings at East Mountain manganese mine. (From data provided by Nova Scotia Department of Mines, 1947.)*

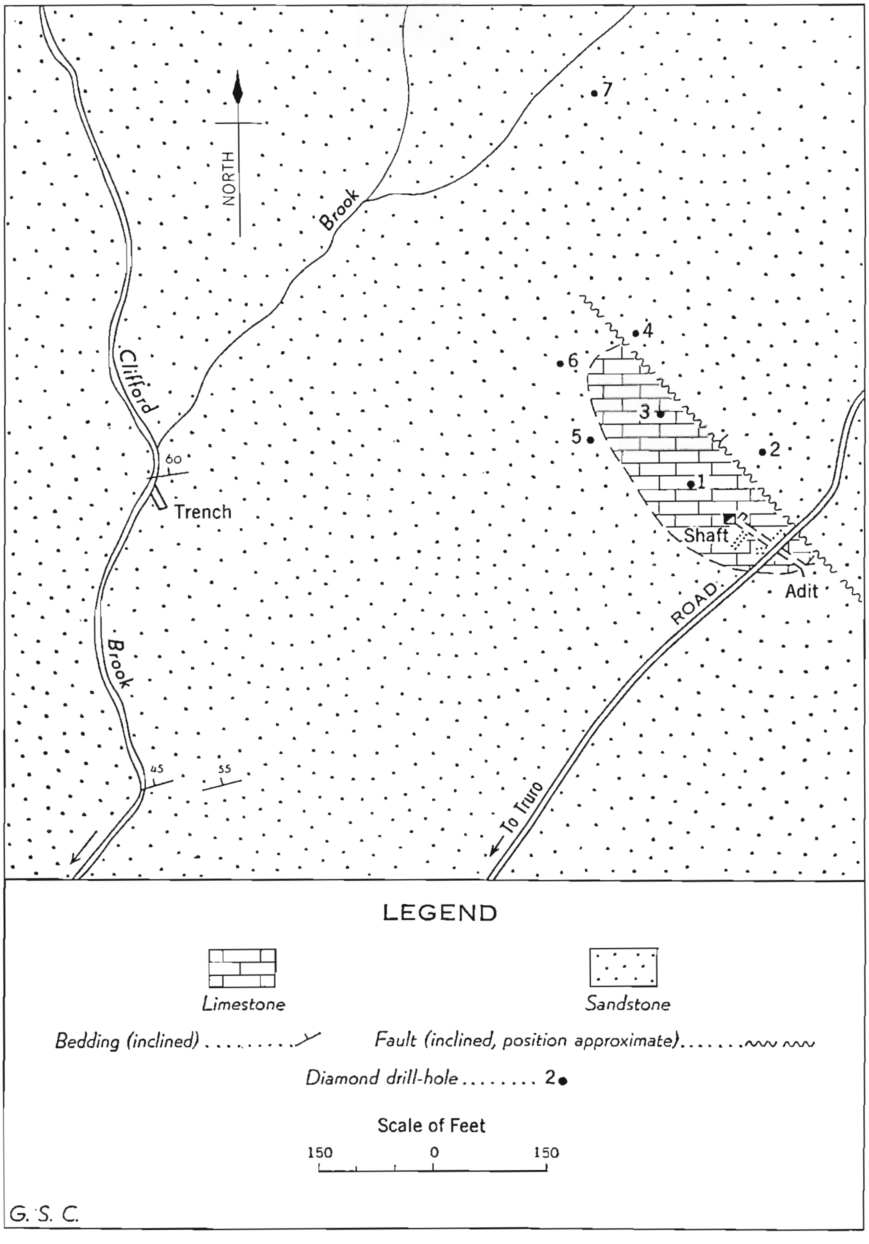

Figure 9. Plan of East Mountain manganese property, Colchester county, N.S., showing location of diamond drill-holes.

Early in 1941 a small plant for the manufacture of metallic manganese was completed on trunk highway No. 4, about 4 miles from Truro. About 7,500 pounds of metallic manganese were manufactured during 1941, and the plant then became inoperative.

The property has remained inactive since 1941, and at present the entrance to the underground workings is caved.

During the summer of 1939, seven diamond drill-holes were drilled vertically to determine the limits of the productive limestone bed.

The ore is contained in a block of ground approximately 300 feet by 100 feet in area. The east side of the block is cut off by a fault that strikes 20 degrees west of north. The east side of the fault has been downthrown about 50 feet. Ore has not been found in the downthrown block.

The ore is contained in a shallow, flat-lying outlier of red and grey lower Windsor limestone and limestone conglomerate of the Macumber and Pembroke formations. According to old reports, the ore is said to have occurred in three layers, each about 1 foot thick separated by 3 or 4 feet of limestone containing nodular ore. The nodules varied from pea size up to 4 inches in diameter.

With the possible exception of a slight coating of manganese on bedding planes in Horton sandstones on Clifford Brook, at a point due west of the deposit, no further extension of the orebody is indicated.

The ore occurs in large masses, occasionally nodular in shape, in the limestone conglomerate. The deposit is mainly of the replacement type, coupled with fissure filling. The origin of the manganese is not known. It may have been an original constituent of the limestone, and solution and oxidation resulted in the formation of vugs and the subsequent precipitation of the manganese oxides.

Examination of specimens of ore from the dump indicates the ore to be pyrolusite with minor amounts of manganite. The writer was unable to identify any psilomelane but earlier writers have mentioned its presence.

MANGANESE MINES PROPERTY

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Dawson, J. W.
1891: Acadian Geology, (Fourth Edition), p. 275.

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Smitheringale, W. V.
1928: The Manganese Occurrences of the Maritime Provinces, Canada; manuscript report written in 1928.

N.S. Dept. of Mines, Ann. Repts.: 1882, p. 52; 1884, pp. 33, 72; 1885, pp. 34, 72; 1886, pp. 21, 63; 1887, p. 61; 1888, p. B.B.; 1891, p. 50; 1894, p. 74; 1896, p. 76; 1938, p. 166.

Geol. Surv., Canada, Ann. Repts.: vol. III, p. 98 (1889); vol. V, p. 898 (1892-93); vol. VI, pt. S, p. 89 (1895); vol. XV, pt. S, p. 154 (1907).

The Manganese Mines property is situated 6 miles northeast of Truro, three-quarters of a mile north of the Canadian National Railways, and $1\frac{1}{2}$ miles south of the Truro-Pictou highway. The workings may be reached from Truro by automobile.

Residents in the district claim that the property was worked continually for 15 years, beginning in 1880. During that period about 2,000 tons of ore were mined and shipped. From 1896 to 1905 only intermittent work was carried out, and from 1905 to 1938 the mine was idle. In 1938 the pit was pumped out, and the old workings examined, but no development work was undertaken.

The property has been idle since that time, and at present the workings are flooded.

According to Fletcher (1891, p. 184) the principal workings were carried out in red sandstones and quartzites that dipped steeply southward. The ore was found in joints and along bedding planes of these rocks. Westerly dipping joint planes were the richest, and in places up to a foot of pure pyrolusite was obtained. A considerable amount of ore was obtained from the soil in the immediate vicinity of the property.

The main open-cut, which is about 100 feet long by 50 feet wide at the surface, strikes west. The examination in 1938 indicated the pit to be 50 feet deep. At a depth of 40 feet in the open-cut scaffolding was encountered. At the east end of the pits a drift extended in under the scaffolding for a distance of 18 feet, and at the north another drift extended for 12 feet. At a depth of 35 feet in the pit, a 15-foot drift was driven in a westerly direction. No body of ore was found in the bottom of the pit, and only a trace of manganese was found in the 15-foot drift.

Much of the rock exposure in the open-cut has been obscured by overburden that has fallen into the pit. The strata on the south side of the pit are composed of red, ferruginous sandstone which dips vertically. Small stringers of manganese occur along the bedding planes. At the west end of the north side of the pit similar rocks strike northeast and dip 30 degrees northwest. It is probable that the junction of these beds with the vertical ones on the south side marks a fault plane that is now obscured by drift. This fault could have served as host for the main orebody, from which stringers of manganese radiated outwards along joints and bedding planes in the Horton sandstones. The trend of the old workings is on strike with the direction of the fault plane.

A shaft, said to be 70 feet deep, is visible a short distance west of the main pit. Evidently this shaft was put down in an effort to prove the westerly dip of the orebody. No ore could be found in the dump at the mouth of the shaft.

Hanson (1932, p. 36) stated that the ore was chiefly pyrolusite, occurring as compact masses of small, interlocking prisms or as veinlets of fine, acicular crystals up to an inch in length growing perpendicular to the walls of the veinlets. Small grains of manganite also occur. The manganese minerals are associated with calcite.

According to Smitheringale (1928), the ore occurs as veinlets up to 2 inches wide that are found along the bedding planes and joint planes in the Horton sandstones. In places an ore breccia may be observed that consists of fragments of sandstone cemented by pyrolusite. The presence of this breccia suggests that during or immediately subsequent to the consolidation of the sandstone, the region was subjected to faulting movements. The resulting brecciated fragments of sandstone were then recemented by finer material similar in composition to the original sediment. This finer matrix was then permeated by ore-bearing solutions that deposited their mineral content in the form of pyrolusite.

Very few specimens of ore can at present be found on the surface. The dump about the pit is large, and the amount of ore obtained must have been small in comparison to the volume of rock handled.

There is no direct evidence regarding the source of the manganese but the character of the deposit indicates the ore was deposited by migrating meteoric waters.

BLACK ROCK MANGANESE OCCURRENCE

References:

Faribault, E. R.
1918: Investigations in Western Nova Scotia; Geol. Surv., Canada, Sum. Rept., pt. F, pp. 1, 2.

Hanson, G.
1932: Manganese Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser., No. 12, pp. 38, 39.

Ingall, E. D.
1902: Geol. Surv., Canada, Section of Mines, Ann. Rept., p. 157S.

Smitheringale, W. V.
1928: The Manganese Occurrences of the Maritime Provinces, Canada; manuscript report written in 1928.

Geol. Surv., Canada, Ann. Repts.: vol. V, p. 95 (1892); vol. XV, pt. S, p. 157 (1907).

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Geol. Surv., Canada, Mineral Resources of Canada, No. 858, p. 14 (1904).

The Black Rock manganese deposit is on the east bank of Shubenacadie River, 300 feet west of the remains of the ferry wharf at Black Rock. The deposit lies between low and high tide levels which at this point have a rise and fall of about 45 feet.

The manganese occurs in the laminated, dark grey, fine-grained Macumber limestone which is overlain by reddish Pembroke limestone conglomerate. The Macumber limestone is warped into small folds striking and plunging west. The rocks are cut by numerous joints and fractures that have been filled with calcite.

All evidence of former development has been removed by the tide. Small pieces of manganese ore may be picked up in the drift along the shore. The writer visited the area several times, but only one small vein of pyrolusite, about 3 inches wide, could be located.

The following information is quoted from Faribault's report: "The deposit occurs in the form of a fissure vein (which) . . . cuts the rocks vertically in a southwesterly direction towards the river, in the course of which it divides into two veins extending to low-water mark. The main vein is exposed for a length of 180 feet, from mud flats near the high tide to the low tide; and the branch or north vein for 143 feet from the point of divide to low-water mark, where the two veins are 30 feet apart. The two veins are lenticular, and vary in width from 1 to 30 inches, but for the greater part of their length they are from 2 to 6 inches. One lens of ore that occurs at a bend on the main veins, has a width of 12 to 30 inches for a length of 50 feet, and a smaller lens on a branch vein measures 15 to 24 inches for 15 feet. At their extremities the veins thin out to nothing. The ore consists of manganese oxides, with a few small pockets or streaks of crystallized pyrolusite and includes calcite, iron oxides and fragments of wall-rock."

Smitheringale adds that small replacement stringers containing manganese oxides occur in the Macumber limestone. The most common minerals present in these stringers are limonite, calcite, pyrolusite, manganite, and huasmannite. Manganite is the main manganese mineral present, and pyrolusite is rare. It is probable that the manganese has been deposited from meteoric waters that percolated through the limestones.

Faribault gives the following average analyses of the veins as sampled at 5-foot intervals:

	%
Mn	31·70
Fe	4·22
Ca	8·14
P	0·011
S	0·120
Insoluble	16·41

The ore at the surface is of inferior quality.

BORDEN MANGANESE OCCURRENCE

References:

Hanson, G.
1932: Manganese Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser., No. 12, p. 33.

Smitheringale, W. V.
1928: The Manganese Occurrences of the Maritime Provinces, Canada; manuscript report written in 1928.

The Borden occurrence, which is said to have been the site of the original discovery of manganese in the vicinity of East Mountain, is situated about 1,000 yards northeast of the deposit at Manganese Mines. No development work of any importance has been carried out on the property for a great number of years.

At present the only visible workings consist of a narrow cut in a hill on the west side of a small gully that strikes north through the property. A few pieces of manganese ore lies at the mouth of the cut. Several badly caved, shallow trenches are scattered irregularly about the area.

A surface examination of the property indicates that the ore occurs under conditions similar to those at Manganese Mines. In the stream gully immediately north of the cut, grey, schisted Horton sandstones, striking north 30 degrees west and dipping steeply northeast are exposed. The rocks in the vicinity have been extensively faulted.

FARNHAM BROOK MANGANESE OCCURRENCE

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Fletcher, H.
1891: Geol. Surv., Canada, Ann. Rept., vol. V, pt. P, p. 184.
Ingall, E. D.
1902: Geol. Surv., Canada, Sect. of Mines, Ann. Rept., p. 157S.
Geol. Surv., Canada, Mineral Resources of Canada, No. 858, p. 14 (1904).
Geol. Surv., Canada, Ann. Rept., vol. XV, pt. S, p. 157 (1907).
N.S. Dept. of Mines, Ann. Rept., 1938, p. 167.

The Farnham Brook manganese prospect is situated on the upper reaches of Farnham Brook about 2 miles west of the East Mountain manganese mine.

In the vicinity of the deposit, Farnham Brook runs through a narrow valley with steep drift-covered banks about 50 feet high. Extensive red Pembroke limestone talus occurs on the west side of the brook and also for several hundreds of feet downstream on the east bank. The limestone has a peculiar mottled effect, due to the weathering of red hematite that is disseminated throughout the rock.

Two caved pits were found on the east side of the bank, but no manganese ore could be located. At the upper limestone, on the west side of the brook, there is evidence of an old dump and small pieces of manganese ore are scattered in the vicinity of the dump. The old tunnel was evidently driven in the west bank of the stream, but the opening is now obscured by slumping.

A small amount of manganese ore was produced from the property about 1880.

The limestone is similar in appearance to that at the East Mountain property, and the manganese is probably of the same type.

Gravel and Sand Deposits

The extensive gravel deposits in the area are referred to on page 57. At present only the gravel at Debert is being used commercially.

This deposit was opened in the spring of 1947 by the Rayner Construction Company Limited. The average output of crushed, screened, and washed gravel is 200 tons/hour. The company employs about 28 men for the 6 months during the summer when the plant is operative (*see* Plate V B).

Much of the gravel produced is used by the Canadian National Railways for ballast, but gravel is also shipped from Debert to various points throughout the Maritimes.

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A. Anticline in Macumber formation, underlying limestone conglomerate of Pembroke formation. Five Mile River, near South Maitland.

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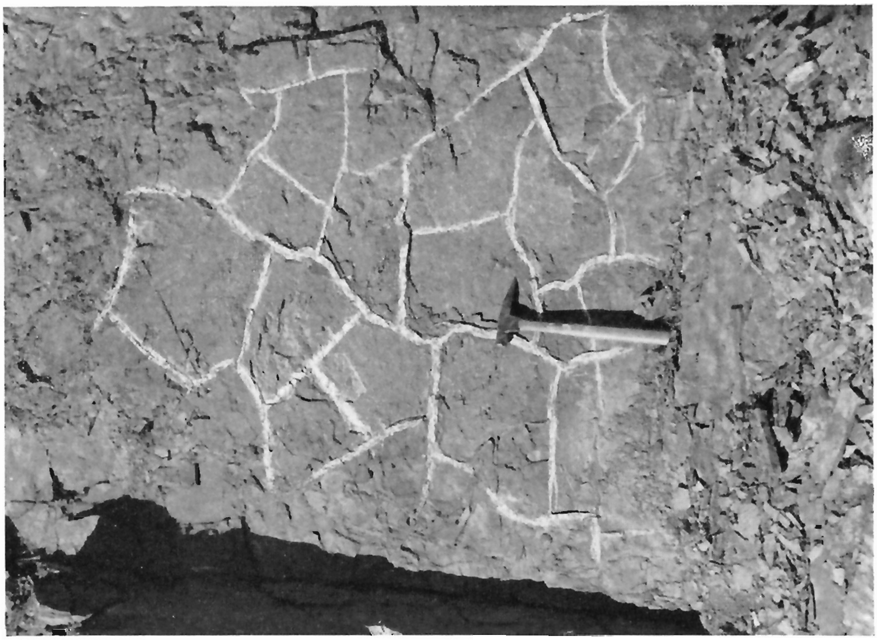
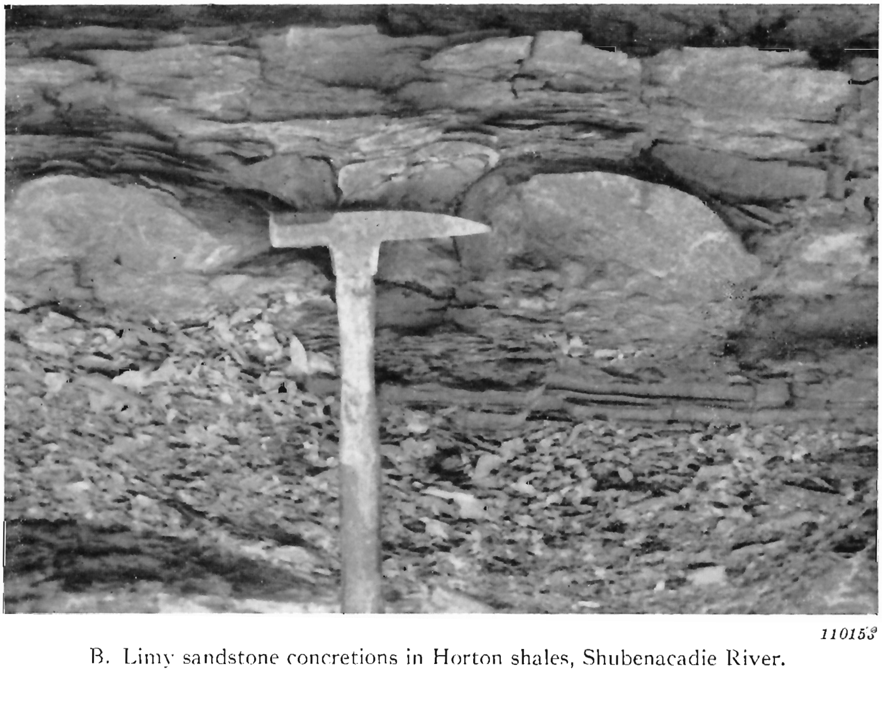
B. Contact between Macumber and Pembroke formations. Black Rock, at mouth of Shubenacadie River.

PLATE III



I.M.S. 1-1-53

A. Mud-cracks in grey Riversdale shales, South North River.



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B. Limy sandstone concretions in Horton shales, Shubenacadie River.

PLATE IV

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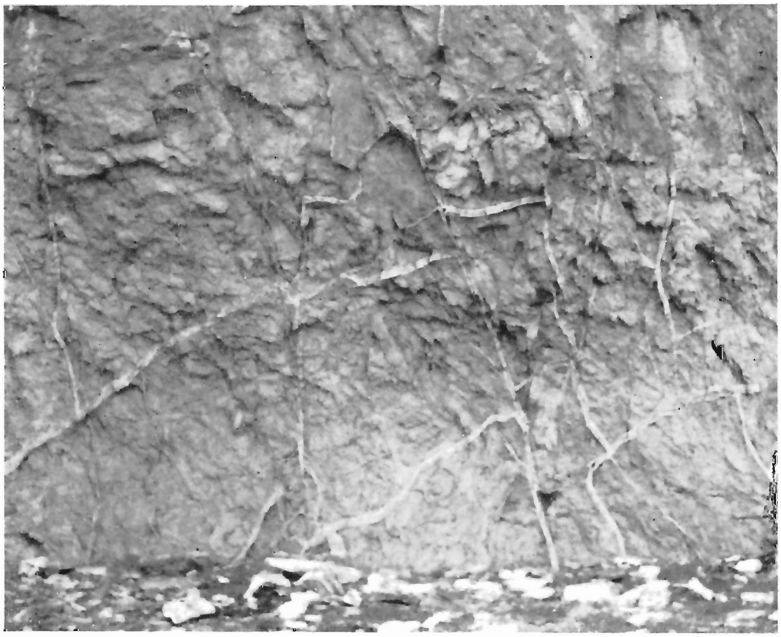
A. Gypsum quarry on Graham property, Shubenacadie River.



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B. Veins of gypsum in red Windsor shales. Shubenacadie River, near mouth of Pitch Brook.

PLATE V

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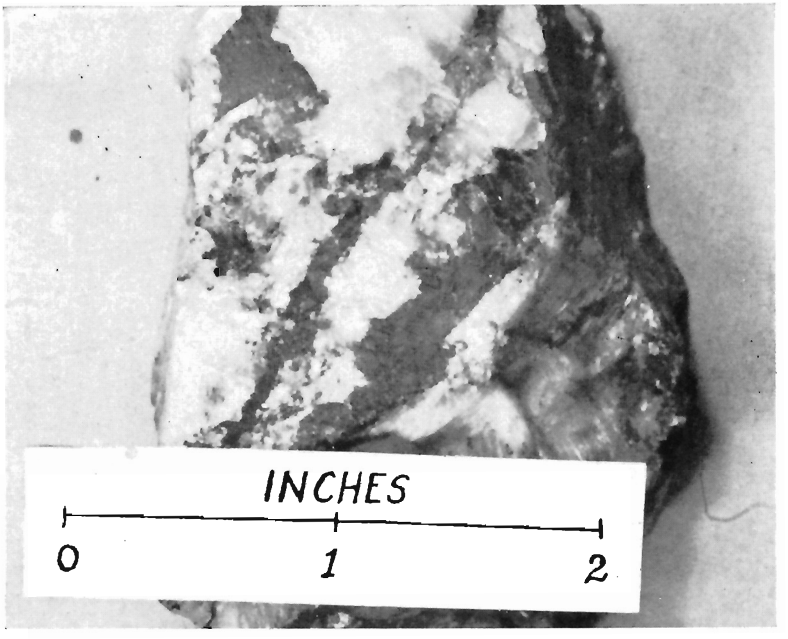
A. Rosettes of selenite in compact, grey gypsum, Shubenacadie River.

I.M.S. 1-5-53

B. Gravel crushing and screening equipment at Debert, Nova Scotia.



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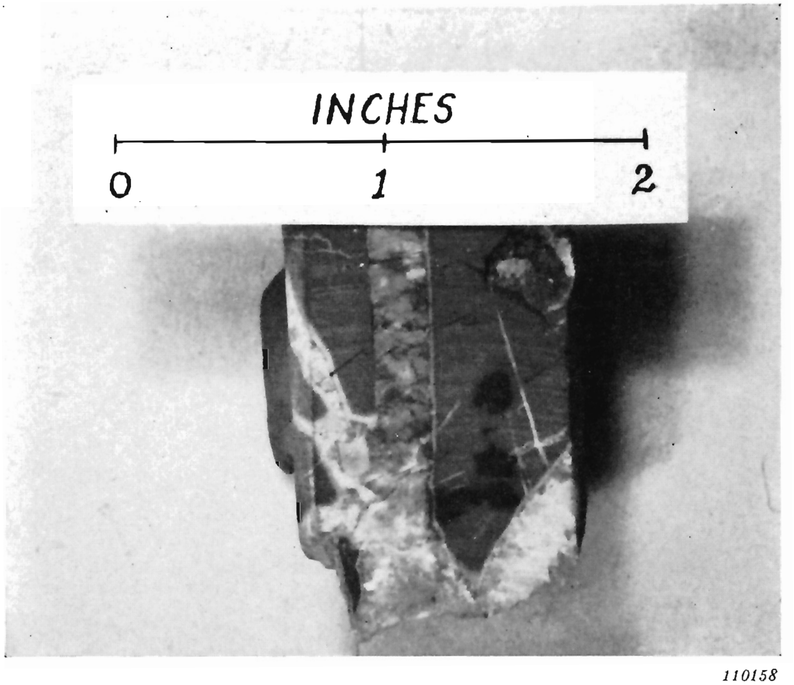
A. Specimen of barite ore from Brookfield deposit. White mineral is barite, dark mineral siderite.



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B. Section of drill-core from Brookfield deposit, showing barite filling fractures in grey Horton shale. Note slight alteration along edge of fractures.

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