

THE CUMBERLAND BASIN
OF DEPOSITION

by

WILLIAM SIMON SHAW

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Signature of Author
1. Shaw Department of Geology, May 13, 1951.

Certified by
Thesis Supervisor

.....
Chairman, Department Committee on Graduate Students



**Panoramic View of the Joggins Section
(from Coal Mine Point looking northward)**

Plate 1.

Biographical Note

William Simon Shaw, son of the late Simon Shaw and Johanna Shaw, nee Morrison, was born at Glace Bay, N.S., Canada, Oct. 20th, 1924. He graduated from St. Anne's High School in 1941 and in the same year entered St. Francis Xavier University at Antigonish, N.S. He was graduated from St. Francis Xavier in 1945 with the degree of B.Sc. (Physics major) and joined the Canadian army immediately afterward. In 1946 he was retired from the army with the rank of lieutenant and returned to St. Francis Xavier to teach courses in mathematics and physics.

He entered the Graduate School of the Massachusetts Institute of Technology in 1947 and spent the following two years there pursuing graduate studies in geology. During the summer seasons he was employed with the Geological Survey of Canada in geological work in the Yukon and in Nova Scotia. In 1949 he joined the staff of the Geological Survey and spent the following two years in a detailed investigation of the Cumberland coalfield in N.S. On April 22nd, 1950 he was married to Mary Barbara Palmer of Moncton, N.B.

Abstract

The chief problems posed by the Cumberland Basin of deposition were: (1) the sedimentary and structural development of the basin and (2) the nature of the controls exerted on the deposition of coal and oil. Coal is being mined on a large scale while the existence of large oil reserves is still hypothetical.

The Cumberland Basin of deposition is an intermontane basin which originated at some time between the Lower Devonian and Mississippian periods. The outlines of the basin probably were determined by the Acadian orogeny which seems to have reached its peak in the Maritime region in late Lower Devonian time.

The axis of the subsiding basin extends from the mouth of Chignecto Bay northeasterly across Prince Edward Island. The total thickness of Carboniferous strata near Joggins, in the axial region of the basin, is believed to have exceeded 30,000 feet. The upper two-thirds of this total is subject to accurate measurement and approximately 15,000 feet is exposed on the Joggins shore in one continuous, uniformly dipping section. Northeasterly the thickness probably increases. At Prince Edward Island and beyond the configuration of the basin becomes obscured and the relationship of the Cumberland Basin to the smaller basins of western Cape Breton is vague. The distribution and forms of the Carboniferous basins and uplands of the Maritime Provinces suggest a shear pattern. A theory of origin is presented and within it the role of the Cumberland basin is indicated.

The remnants of the uplands which bordered the Cumberland Basin of deposition are represented today by the Cobequid and Caledonian Uplands. Although their relative positions have been altered somewhat from the positions of the original uplands that controlled deposition during the Carboniferous period, they serve to indicate the approximate dimensions and form of the basin.

The greater part of this immense thickness of strata thins and feathers out on the flanks of these bordering uplands and within most time units a distinct lateral coarsening toward the upland borders can be observed. Sedimentation continued in the axial region throughout the Mississippian period and into late Pennsylvanian time without an observable break but, along the margins of the basin, unconformity is much in evidence.

The basin experienced two marine transgressions which attained their farthest extensions in mid-Horton and in mid-Windsor times: Marine strata represent only a small percentage of the total strata in the apical region of the basin but it is believed that, northeast of the Joggins area, a much larger proportion of marine strata occupy the axial region of the basin.

The best developed sedimentary unit of continental origin is the Cumberland group of mid-Pennsylvanian age. The latter has been subdivided, on the basis of distinctive lithologic characteristics, into five principal facies, described briefly, in order of decreasing age, as follows:

- (1) a lower, coarse, dominantly conglomerate, facies that marks the base of the Cumberland group over a large area.
- (2) a fine facies, dominantly sandstone and shale, enclosing a zone of coal seams of workable thickness and quality. This zone is contemporaneous with the upper part of (1).
- (3) a fine non-coal-bearing facies, dominantly sandstone with minor conglomerate, that is contemporaneous with the lower part of (4).
- (4) an upper, coarse, dominantly conglomerate and sandstone, facies.
- (5) a fine facies, dominantly red sandstone and shale that is, in part, contemporaneous with the upper part of (4).

Ideally, these five facies may be envisaged as a series of interlocking wedges with the thin edge of each of the fine facies lying along the margins of the bordering uplands.

Large scale and local structural control on deposition is particularly well demonstrated in the Cumberland group. The tectonically positive uplands, that bordered the basin, controlled the major features of deposition. In the Springhill district local control was exerted by a series of southeasterly trending folds that were recurrent during deposition. These folds were particularly effective in delimiting the areas of deposition of coal-forming peat and thus the coal reserves of the Springhill district will depend to a large extent on the extension of

these folds which have up to now limited the area of high quality coal in each seam to a narrow belt not exceeding 6,000 feet in width. Workable coal seams are confined exclusive to the coal-bearing facies of the Cumberland group. The latter is widely distributed over the basin area and offers strong possibilities for the existence of workable coal seams other than those being exploited at present.

The Cumberland Basin possesses in abundance most of the sedimentary and structural features which are considered to be particularly favourable for the existence of oil. A great volume of sediments; evidence of two marine transgressions; unconformities; a tectonically active basin and similarly active bordering platforms or ridges; and the probable existence of belts of porosity in the form of sand wedges or organic reefs all favour the formation and accumulation of oil. Probably the only unfavourable factor related to the possible existence of oil is the lack of evidences of oil or gas associated with the exposed marine strata. The most favourable area for future exploration has been deduced from a consideration of these factors.

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CHAPTER I

INTRODUCTION

Location and Importance

The Cumberland Basin of deposition occupies the major portion of Cumberland County in northern Nova Scotia. It extends easterly into Colchester County, and westwardly to occupy a narrow strip of land on the New Brunswick side of Chignecto Bay. The economic importance of this basin is attributed chiefly to its coal deposits, mined at Springhill and along a twenty-five mile belt extending from Joggins on Chignecto Bay eastward to North Springhill. The only other mineral found in mineable quantities is salt, which is presently mined at Nappan and Malagash.

During the past twenty-five years interest in the oil and gas possibilities of the basin has ebbed and flowed. The greatest activity in oil prospecting was experienced during the period 1944 to 1947 when two deep holes were drilled without success. The first, drilled in Hillsborough Bay just off the mouth of Charlottetown harbour, Prince Edward Island, bottomed, at 14,696 feet, in a sequence of flat-lying gypsum, salt, and red beds. In the upper part of the hole, the drill cut a monotonous series of red to chocolate shale, siltstone, and sandstone with minor grey coloured zones that included thin coal seams. The entire sequence was apparently without sharp breaks of any kind and lack of fossils left the correlation in doubt. It is generally assumed that the evaporites represent deposition in Windsor time and this on the assumption that there was no post-Windsor marine deposition in that area.

The second deep hole was drilled to a depth of 11,504 feet near

Nappan on the crest of the Minudie Anticline. It passed through more than 6,000 feet of contorted beds of salt, gypsum, anhydrite and red shale into an entirely continental facies made up dominantly of red to brown shale and sandstone and light grey sandstone. The change was apparently transitional. At 10,000 feet the drill penetrated a 12 foot bed of conglomerate consisting dominantly of pebbles of quartz and chert and at 10,221 feet it passed through a bed of volcanic ash. Although the evidence is not conclusive, these lower continental strata may represent the phase of deposition of coarser sediments that constitutes the Hillsborough and Weldon formations of Upper Horton age in New Brunswick. The volcanic ash also suggests this correlation, since similar deposits are unknown in this basin in sediments younger than Upper Horton. It is thought that this section also correlates with part of the River John group, exposed in Pictou and Colchester counties. The great thicknesses of salt encountered in this latter borehole led to the establishment of a modern plant for its extraction.

Of the two major coal mining districts in the Cumberland area, Springhill is the larger and more consistent producer. The present area of operations constitutes a rough square of approximately four square miles. Its eastern margin lies on the outskirts of Springhill.

The Springhill district is entirely controlled and operated by the Cumberland Steel and Coal Company, a subsidiary of the Dominion Steel and Coal Company. At the present time, four seams are being worked from two main slope entrances and the whole operation maintains a production ranging from 2,000 to 2,500 tons daily, barring serious disruptions in the continuity of the operation. One other workable seam exists which,

although not now being mined, is slated for exploitation in the near future.

The Joggins-Chignecto-North Springhill district supports a number of smaller, independent operations with the major portion of the mining presently concentrated in Joggins and River Hebert at the western extremity of the district. The present combined operations are capable of producing about eight hundred tons per day. Two new operations are undergoing development and are expected to increase this figure to about sixteen hundred tons per day.

History of Mining:

An old map of the Joggins Mines area indicates the oldest workings in the Cumberland Coal Basin by the notation "old French workings". Presumably this was the work of the French settlers of Fort Beausejour and Annapolis during the early part of the 18th century. These people could hardly have failed to note the coal seams outcropping in the prominent cliffs at Joggins. The first written account of mining in the area, known to the author, is that by Jackson and Alger (1828), who mention the mining of coal and quarrying of grindstone at Joggins.

The British government, in 1825, magnanimously granted to the Duke of York all the mineral rights in Nova Scotia that were not already reserved. The Duke exchanged the grant with his creditors in return for cancellation of large debts. These creditors formed the General Mining Association for the purpose of prospecting and exploiting their newly acquired wealth, but the Cumberland area was ignored for some years, and mining activity was restricted to 'bootlegging' on a small scale in the Joggins district.

Meanwhile, the coal seams in the Springhill district went unknown until about 1836, when, as related by Gesner, a seam about ten feet thick outcropping in a small brook and dipping northward, was being worked by a poor farmer (Gesner 1836). The direction of dip and the thickness seems to indicate that the seam referred to was the No. 2 seam where it outcrops on Mill Brook. However little interest was shown by the G.M.A. and nothing was done toward exploiting the deposit at this time.

By 1840, with population steadily increasing in northwestern Nova Scotia, the need for coal became acute and strong representations were made to the government of Nova Scotia that the G.M.A. produce coal or relinquish at least a portion of the area. The result was that in 1847 they did open the "Joggins Mines" but production was small and inadequate.

The turning point in the mining development of the region came in 1858, when, by mutual agreement with the Nova Scotia Government, the G.M.A. relinquished its rights to the coal areas of Cumberland County with the exception of four square miles in the Springhill district and a similar area in the Joggins district. Whether by chance or design, the Springhill area that they retained proved to be, by far, the most valuable piece of ground yet found in the entire area.

With large areas now open, a number of companies undertook operations and by 1863, the average annual production of the 'fifties' had been trebled in the Joggins-Chignecto-North Springhill district. In the Springhill district development was retarded even yet, principally because of the distance to navigable waters. However, the commencement of construction of the Intercolonial Railway gave new impetus to development

of the coal reserves since at once it provided a market and means of transportation to outlying areas. In 1872 the Springhill and Parrsboro Railway Company was incorporated and started development in two major slopes. By 1879 the G.M.A. relinquished all its rights in the Springhill district to the Springhill and Parrsboro Railway Company. A new slope was opened in 1882 and from that date progress was much in evidence. In 1884 the Springhill and Parrsboro Railway Company sold out to the Cumberland Railway and Coal Company, which progressed steadily. In 1911 the Dominion Coal Company took over the Cumberland Railway and Coal Company and have operated the mines up to the present.

In the Joggins district, after 1858, the greatest single impetus given to production was the construction of the Joggins-Maccan railway connection which led to the re-opening of many small collieries and enabled the mines to work through the winter. The effect was to increase production by twice or more, and later years saw production steadily increase. The most consistent and largest producers have been the operations owned by the Joggins Coal Mining Association and its successors (at present the Maritime Coal, Railway and Power Company).

Problem

Mineral development in northern Nova Scotia and southern New Brunswick has centred about three products of sedimentary deposition, namely, coal, oil, and salt. These products have been found in sediments that are widely separated in the stratigraphic section but are all contained within the Carboniferous period, and their deposition has been controlled by the Carboniferous subsiding basin of deposition that is designated as the Cumberland Basin of Deposition.

The coal deposits have been, to date, the most important from an economic standpoint. In the Springhill district each seam is characterized by a restricted band of high quality coal which extends, from the outcrop in each case, along a centreline that runs approximately southwesterly from Springhill. Underground workings have been limited on the north and on the south by rapidly deteriorating coal. In No. 2 seam, in which the workings have progressed over two miles along the dip of the seam, the high quality coal is apparently in danger of wedging out entirely, as serious deterioration has already limited development along a line that is drawing close to the south side of the auxiliary slope, while deterioration on the north side maintains its normal course that was well established in the older abandoned workings. In order to provide some guidance for the future development of these seams it was necessary to establish the significant trends in the coal seams. This necessitated an understanding of the physiographic and other environmental conditions which controlled the accumulation of the vegetable material which was the source of the coal.

The group of coal seams, which extends from Joggins to North Springhill, dips in a southerly direction toward the axis of a broad syncline. The seams are generally thin but, in one or two areas, the seams thicken usually as a result of the joining of two or more smaller seams. Deterioration in all seams is apparently erratic and can only be predicted over short distances. It is significant that some of these seams persist for long distances along their outcrops while operators are, in general, pessimistic about their continuance at depth. A great multitude of small

mines have robbed a narrow band parallel to the outcrop of each workable seam and rarely, if ever, has anyone developed more than 4,000 feet along the dip. A close examination does not reveal any significant change in the nature of the coal at depth, and stoppage of most operations can be ascribed, mainly, to increasing costs of power required for haulage and pumping as depth of mining increases.

The seams of the Springhill district dip northward toward the axis of the syncline that intervenes between it and the Joggins-North Springhill district, but along the outcrops of both groups of seams the coal grades laterally into barren rock in the northeast corner of the map-area (Map 3) and the relationship between the two coal groups is not readily apparent. Great speculation has arisen concerning the extension of these coal seams and their possible relationship across the intervening syncline.

At a point near Newville Lake, which lies about sixteen miles southwest of Springhill, a deep borehole cut a section of coal-bearing rocks which includes, reportedly, a seam of considerable thickness. Its possible relationship to the Springhill district is of great interest in so far as it may represent an extension of the coal-bearing sediments that outcrop there.

These problems, briefly outlined above, indicate that the distribution of coal deposits has not been clarified and past mining development possibly has nibbled only at the exposed parts of a much larger area. An understanding of the controls exerted on peat deposition in the basin is necessary to indicate the possible future areas for exploitation of the coal reserves.

Next to coal in their possibilities for future development, stand oil and natural gas. In a basin of sedimentary deposition which has experienced at least two invasions of marine waters, the probabilities of finding these valuable materials should be strong. The two major drilling operations, mentioned in an earlier section of this report, rendered valuable structural and stratigraphic information which should serve as a guide to future attempts.

The problem of locating oil reservoirs in this basin will be one of outlining the shape and extent of the basin, particularly during the period which saw the transgression and regression of the marine waters. In an area such as this, where a high degree of tectonic control on the sedimentation is in evidence, a thorough understanding of its structural make-up is essential. In recent years a considerable amount of gravity data has accumulated and, as will be shown, the evidence has an important bearing on the problem.

Salt has been found in large quantities in the Cumberland Basin of deposition. The probable nature of its accumulation has already been discussed by Dr. W. A. Bell (Bell, 1924 and 1944) and little can be added except in so far as the broad control of sedimentation may indicate the limits of deposition.

Work in the area and acknowledgments

The Cumberland Basin of deposition provides one of the show-pieces of North American geology in its well-known Joggins Section that, for over a hundred years, has elicited the attention and admiration of geologists.

The first record of geological investigation seems to have been that of Jackson and Alger in the year 1828 (Jackson and Alger 1828). About the same time two engineers, Brown and Smith, in the employ of the G.M.A., described the section along the shore (Brown and Smith, 1829) and they were the first to point out its similarity to the Carboniferous sequence in England. They correlated the limestones at the base of the section with the Lower Carboniferous of their native England; and the succeeding sandstones and coal-bearing zones with the English Millstone Grit and Coal Measures respectively.

Shortly afterward Gesner (1836) carried out geological explorations in an area which included the Springhill district. He was the first to record the occurrence of coal there.

Charles Lyell, in 1842, examined the section from Minudie to Joggins, described the fossil trees, and collected and named various fauna and flora. These observations were recorded in his book on his travels in North America (Lyell, 1845).

Sir William Logan, in 1843 his first year as director and only geologist of the newly formed Geological Survey of Canada, undertook to measure, bed by bed, the entire section (Logan 1843). Because of vigorous wave cutting activity upon the Joggins cliffs and great local variation of the strata, the section cannot now be exactly duplicated but his measurements are entirely representative of the section as it stands today. He divided the continuous section arbitrarily into eight divisions, basing the division on predominance of one or another features such as colour, presence of coal seams, relative coarseness, etc.

Sir William Dawson, after an initial visit to the Joggins section with Lyell, returned many times to enlarge on his collections of the fauna and flora. He has incorporated their descriptions in his excellent accounts of the general geology of the region (Dawson, 1855, 1894, etc.).

Scott Barlow (1873-74; 1875-76) made the first attempt at a detailed study of the area. In 1871 he began tracing the coal seams of the Springhill district and spent the greater part of the following six years in a study of the rocks of that district.

Walter McQuat began, in 1873, a study of the northern portion of the area which he continued till his death two years later.

R. W. Ells studied the regional geology of northern Nova Scotia and southern New Brunswick and published a report with a geological map which covers the area under discussion (Ells, 1885).

Of the many workers who have studied the rocks of this region, probably none exceeded in zeal, in perseverance, and in volume of data, the work of Hugh Fletcher. In 1892 he began a study of the Cumberland Coal Basin and much of the following sixteen years was spent in this area until his work was terminated by his death at Lower Cove in 1908. In the Springhill district he contributed greatly to knowledge of the rock structure by painfully tracing small seams outward from the worked areas and around the nose of the Claremont Anticline. He also published maps of areas lying along the southern margin of the Cumberland Basin (Fletcher, 1892-1909).

W. A. Bell made a detailed study of the Joggins section in 1911 and 1912. This work, together with later studies of the Carboniferous stratigraphy of the Maritime Provinces, culminated in a division of the Carboniferous stratigraphy in that region (Bell, 1911, 1912, 1913, 1924, 1927, 1944, etc.).

The most recent systematic mapping in the area, prior to the present investigation, was carried out by F.A. Kerr, in 1924, and I. W. Jones, in 1928. The former mapped and reported on the eastern half of the Springhill sheet and the latter on the western half. Their work was incorporated in one map-sheet which, after some revision by Bell, was published in 1935, (Bell, Jones, and Kerr, 1935).

The study of the Cumberland Basin of deposition was begun by the author in the spring of 1949 and has occupied his attention continuously since that time. Systematic detail mapping was restricted to the rocks underlying the Cumberland Coal Field which is bounded roughly as follows: on the north by latitude $45^{\circ} 45'$; on the south by the Cobequid Upland; on the east by longitude $64^{\circ} 00'$; and on the west by Chignecto Bay. A map covering this area, on a scale of 2 miles equals one inch, is presented with this report.

Numerous key sections and localities outside this map-area were visited, which include: the northward extension of the Joggins section; the shore of Maringouin Peninsula and of Albert County in New Brunswick; various brook sections along the northern margin of the Cumberland Uplands; the shore of Minas Basin particularly in the vicinity of Parrsboro and westward. Available to the author were various Geological Survey maps of the surrounding areas, notably, the recently published Albert and Hillsborough

sheets of New Brunswick and the Shinimecas, Oxford, Bass River, and Londonderry sheets in northern Nova Scotia; also were the many map-sheets published by Hugh Fletcher between 1890 and 1909. These, together with the unpublished reports of I.W. Jones and F.A. Kerr on the Springhill map-area, were very helpful in furthering the author's study. The area studied by the author in the field does not encompass the entire area occupied by the Cumberland Basin of deposition but, as will be more evident later, the area under detail discussion holds the key to the development of the basin. The significance of the features observed here can be extended to the entire basin of deposition. Complications that develop in its eastern extremity will be discussed only briefly, the area being too far out of the range of the author's work and having already been described in detail by Bell (1940).

The author gratefully acknowledges the encouragement and advice of Dr. W. A. Bell, Director of the Geological Survey of Canada, and Dr. W. L. Whitehead, professor of geology at the Massachusetts Institute of Technology. The author is also greatly indebted to all the workers who have contributed to the geological knowledge of the area in the past and he wishes to acknowledge his dependence on their great volume of information and ideas in forming his conception of the geology of the area.

Topography and Drainage

Three major physiographic elements are immediately obvious to one entering the area. They are commonly termed the Cobequid Upland, the Cumberland Lowland, and the Caledonian Upland. The two upland areas

enclose the Cumberland Lowland and, in plan view, present a decidedly angular aspect. The Caledonian Upland of Southern New Brunswick trends a few degrees north of east, in northwestern Nova Scotia. Chignecto Bay, an arm of the Bay of Fundy cuts through the apical zone and stretches northeastward almost thirty miles before it is split, by Maringouin Peninsula, into two arms known as Shepody Bay and Cumberland Basin, on the west and east respectively.

The Cohequid Upland is a long, narrow, flat-topped highland that extends from Cape Chignecto about 100 miles in a direction about N. 85 E. into Pictou County. Over its length it ranges in height from 800' to 1,000' and rarely exceeds 12 miles in width. Its steep flanks are deeply incised by rapid flowing streams that tumble over a multitude of falls till they reach the lowland where they merge to form gently flowing rivers.

The Caledonian Upland rises from the shores of Chignecto Bay at a point opposite Cape Chignecto and extends, with an average width of 15 miles, northeastward about forty-five miles and ends abruptly a few miles west of the Petiteodiac River. Although rising to a slightly higher elevations the upland is similar to the Covequid Upland in its even skyline, its flat top, and steep slopes.

These major upland areas are co-extensive with areas of pre-Carboniferous rocks that consist of intrusive rocks and metamorphosed sediments and volcanics. These rocks are hard and resistant in contrast with the softer Carboniferous rocks that floor the Cumberland Lowland. It is notable that, in the upland areas, the flat surface truncates all rocks, intrusives, and metamorphics alike without appreciable topographic

expression of their differences in hardness. This feature has been noted by almost every worker in the general area and the surface of the uplands has been recognized as part of a regional peneplain which culminated in Cretaceous times (Goldthwait, 1924). The present relief is attributed to Tertiary uplift with subsequent deeper erosion of the softer rocks that occupy the lowland areas.

The Cumberland Lowland extends from the base of the uplands northeastward to the shores of Northumberland Strait. Its gentle, rolling surface of mature relief rises to elevations averaging little over 200 feet with few interruptions. The hill occupied by the town of Springhill, Claremont Hill and the Salem Hills form the important eminences which breach the general level.

Springhill, rising to 610 feet, is situated on the southwesterly plunging nose of the Claremont Anticline where the tough grey sandstones and shales at the base of the coal-bearing zone are brought to the surface. The dominantly red, loosely cemented conglomerates, sandstones and shales that flank the structure have been easily eroded to the level of similar rocks that spread out to the west from Springhill.

Claremont Hill is a long narrow ridge that extends for about three miles along the outcrop of vertically dipping beds of the Claremont conglomerate. It rises about two miles northeast of Springhill and maintains an elevation of about 500 feet for a large part of its length. The hill is flanked on the north by the soft red shales, gypsum, and salt beds of the Windsor group and on the south by the southward dipping beds of the Boss Pt. formation.

The Salem Hills lie just north of the northern margin of the map-area and their trend approximately parallels the margin. They consist of four summits that rise to elevations exceeding 500 feet and are separated by gently sloped saddles. They are genetically related to the low rounded ridge that extends eastward from Boss Pt. on Chignecto Bay to the village of Chignecto where the ridge rises to higher elevations to form the Salem Hills that extend as far as Little River, a few miles northwest of the town of Oxford. Except at the points where the Maccan River and River Hebert cut through, the ridge forms the drainage divide over its length.

The tough, resistant, rocks of the Boss Pt. formation underlie the ridge. They lie with medium dips in the south flank of the Minudie Anticline. Their superior resistance to erosion is well illustrated in the shore section where it protrudes in great reefs to form the jagged promontory of Boss Pt. The soft red shales and red sandstones of the Maringouin and Windsor formations on the north and the equally soft red sandstones and shales of the lower part of the Joggins formations were no match for the tough Boss Pt. rocks when subjected to the vigorous action of the waves.

Throughout the lowland area and particularly in the vicinity of Chignecto Bay numerous low parallel ridges mark the outcrop of bands of massive grey sandstones. These show up well in aerial photographs which were used to great advantage by the author in tracing the rock structure in that area. Eastward from Chignecto Bay they become fewer and less pronounced, their relief being clamped out by sheets of glacial drift

which cover the inland areas. It may be noted also that the zone in which the ridges are most pronounced was the scene for one of the most devastating forest fires in this part of the country. Consequent rapid erosion of the unprotected soil left bare rocky ridges that show remarkably clear on the photographs.

Occupying the greater part of the central area, between the Boss Pt. Ridge and the Cobequid Upland, are the relatively soft rocks of the Shulic formation which were preserved from deeper erosion by the broad open synclinal fold that has been named the Athol Syncline by Fletcher. These rocks have been worn down to form a broad valley which is roughly coincident with the synclinal axis. In Pleistocene time the entire area was covered by a mantle of glacial drift, thickest in the region between the Maccan River and River Hebert where morainal deposits are everywhere in evidence.

The drainage of the map-area (Map 2) does not fall into a well-defined pattern. Over the greater part it presents a dendritic aspect. In the eastern part of the area the Maccan River is the major channel. Flowing westward along the base of the Cobequid Upland it collects the waters of a multitude of sub-parallel streams that flow rapidly from the steep slope. At Southampton the river turns abruptly and flows northward across the general strike of the rocks, collecting on its way the waters of its two major tributaries East Brook and Little Forks River, and empties into Cumberland Basin a short distance north of the northern margin of the map-area. A small area bordering the eastern margin of the map-area is drained by Black River and Polly Brook which flow eastward to join River Phillip and thence to the Northumberland Strait.

The central area is drained by the northward flowing River Hebert. It is fed by the waters of three principal tributaries, namely, Halfway River, Kelly River, and Atkinson Brook. Halfway River, flowing easterly along the base of the Cobequid Upland, collects the waters draining from the slopes of the upland and empties into Newville Lake which forms the head of River Hebert. Kelly River and Atkinson Brook, both flowing northeasterly, join River Hebert at points lying about 3.2 and 4.4 miles, respectively, upstream from the village of River Hebert.

The western portion of the map-area lying east of Chignecto Bay is drained mainly by the Apple River, Sand River, and Shulie River, all of which empty into Chignecto Bay. At the shore the mouths of these rivers are separated by intervals of about six miles, while inland they converge till their upper reaches are practically fused.

One broad generalization may be made concerning the relationship of drainage to geological structure and that concerns the consistency with which the major channels maintain a direction normal to the general strike of the rocks. The tributary streams parallel the strike in many instances but in general present an irregular, dendritic configuration.

General Geologic Relationships:

The Cumberland Basin of deposition is an intermontane basin which originated at some time between the Lower Devonian and early Carboniferous periods. The outlines of the basin were most probably determined by the Acadian orogeny which, in the Maritime district, seems to have reached its peak in late Lower Devonian time. The remnants of the bordering uplands are represented today by the Cobequid and Caledonian

Uplands and, while their relative positions have been somewhat altered from the positions of the original uplands that controlled Carboniferous deposition, they serve to indicate the approximate dimensions and shape of the basin.

The generalized stratigraphic column (Fig. 1) indicates the sequence, age, thickness and lithologic characteristics in the basin with a graphical representation of the facies relationships within given time units. The rocks of the upland areas have been combined into one group under the heading "pre-Carboniferous" mainly because it was not possible, in the time available, to study these rocks in detail.

It is quite possible that unmetamorphosed sedimentary rocks of Middle and Upper Devonian age lie buried in the axial region of the basin but the total lack of exposures of such rock anywhere in the basin render it safer to exclude it from the sections.

The total thickness of the Carboniferous rocks in the axial region of the basin at a point near Joggins is believed to have exceeded 30,000 feet. The upper two-thirds of this thickness is subject to accurate measurement and, in fact, approximately 15,000 feet of strata may be measured in one continuous section. In a northeasterly direction the axis probably continues to pitch deeper. At Prince Edward Island, and beyond, the configuration of the basement becomes less definite and the relationship of the Cumberland Basin to the smaller basins of western Cape Breton is still vague.

By far the greater part of this immense thickness of strata thins and feathers out on the flanks of the bordering uplands and within

most time units a distinct lateral coarsening toward the uplands can be detected. The periodic rejuvenation of uplift of the bordering masses and complementary subsidence of the basin area is clearly illustrated in the generalized stratigraphic column (Fig. 1) by the periodic influx of coarse sediments. During certain periods of regional subsidence and/or extreme aggradation of the bordering masses sediments were probably deposited over the crests of the uplands and the limits of the basin probably were defined only by isolated islands along the general trend of the positive axes. This condition existed at least during the marine transgression of early Windsor time and possibly to a lesser extent for a part of the period during which the Albert formation was deposited. As noted in the Joggins section, the transition from marine to continental deposition was affected in late Windsor time. There and in the area enclosed by the bordering upland areas to the south and to the west no further evidence of marine transgression has been found in the later sediments. It is assumed that non-marine sedimentation kept pace with subsidence and maintained the Carboniferous seashore some distance north of the Joggins' locality, a distance which undoubtedly varied under the control of intermittent movements of the crustal masses.

The large area to the north, presently inundated by the waters of the Gulf of St. Lawrence or covered by the wholly continental beds of the Pictou group, holds the secret of the post-Windsor history of the Carboniferous sea and it is not yet known with assurance whether it was maintained in a large embayment in that area or whether it was drained entirely during the renewal of uplift in the bordering uplands. The final answer to this question bears strongly on the oil possibilities of the region.

The only hint of a marine environment later than Windsor comes in the coal-bearing sequence of the Joggins area where black bituminous shale, bearing shells and fish remains, are found overlying many of the coal seams. The actual environment significance of the contained fossils is controversial but a brackish condition is probable and a good case may be made for a lagoonal environment during the deposition of this particular facies.

Little information is to be had concerning the igneous activity of the Carboniferous period in this area. In New Brunswick a volcanic ash bed has been found in the Hillsborough formation of Upper Horton age. Volcanic flows have been noted in the River John group, also of Upper Horton age, which is exposed on the northern margin of the Cobequid Upland near its eastern extremity. An ash bed was also out in the Nappan borehole, as was mentioned earlier in this report, and the strata associated with it is considered to be of Upper Horton age. M.Y. Williams notes that in the Arisaig district diabase intrusives cut the McAras Brook formation of Lower Windsor age but not the overlying Ardness formation that is also Windsor age (Williams, 1914). Further evidence of early Windsor igneous activity is noted by Bell on the Magdalen Islands where he has described basic lavas and fragmental and tuffaceous volcanic rocks interbedded with gypsum, limestone, calcareous shale, red and grey siltstone, and mudstone of lower Windsor age (Bell, 1949). No evidence of later igneous activity has, to date, been found in the sediments constituting the Cumberland Basin of Deposition. It must be mentioned however, that little detail work has been carried out in the complex

that forms the bordering upland areas. In the Cobequid Upland particularly, there is good reason to doubt that all of the metamorphosed sedimentary and volcanic rocks present are older than Carboniferous. Bell has found an argillite horizon bearing upper Windsor fauna in an exposure on Harrington River, north of Five Islands. He also observed sheets of pink rhyolitic rock intruded into interbedded quartzites and argillites of similar lithology to that bearing the Windsor fossils (Bell, 1927). This indicates, quite definitely, igneous activity in Upper Windsor or in a later period. The possibility that it may be ascribed to the igneous activity of the Triassic period is suggested by the proximity of this locality to the scene of well developed Triassic extrusives a short distance to the south. Because of this uncertainty the latter igneous activity cannot be definitely associated with the development of the Cumberland Basin of deposition.

Technique:

The study carried out in the Cumberland Basin may be divided, for the purpose of description, into two main phases: (1) a regional study of the sedimentary and structural features of the rocks constituting the Cumberland Basin in order that a more complete understanding of its origin and development might be had. (2) a detail study of the coal deposits in order that the significant trends in the quality of the coal together with the structural features may be defined and in particular to indicate how these features will affect the progress of extraction.

The first mentioned phase was carried out by systematic

mapping on a base map on a scale of $\frac{1}{2}$ mile equals 1 inch within the area outlined above. Rapid lateral variation of rock facies within given time units made precise location of formations impossible except when definite unconformities or fault traces were located. The coal seams of wide extent formed the only well defined "time lines" and while these seams are restricted to a comparatively short interval in the stratigraphic section they were of great value in outlining the structural trends, as in the case of the Forty Brine - Chignecto seam which provided a reference horizon for a distance of about twenty miles across the northern margin of the map area. Also of great value in facilitating the establishment of structural trends were the long strike ridges formed by the massive sandstones. These were of particular importance in the area south of the village of Joggins where the long ridges bend around a broad embayment in the north flank of the Athol syncline.

Throughout the mapping program particular emphasis was placed on the lithological characteristics such as colour, grain size roundness and constitution of the rock. In the Cumberland group this attack proved particularly profitable in that it enabled the author to subdivide the group into its coarse and fine components. As will be seen later the transgressive and regressive characteristics so well outlined in the rock provide an illuminating picture of the tectonic history of the basin.

The second phase of the investigation, that of a detail study of the coal seams, was begun in both districts by a long period of compilation of all the available data from bore hole records, mine plans, mine officials, etc., supplemented by actual measurement over all parts of the mine workings still accessible.

In the Springhill district, where there was a great concentration of data, the preliminary work was carried out on a scale of 400' = 1". On this scale two types of maps were constructed for each mineable seam: (1) coal facies map on which representative sections of the seam were plotted. On the basis of these sections and a multitude of supplementary thickness measurements isopachs were drawn using a thickness interval of 6 inches. (2) contour map with contours plotted for the pavement of the seam. These were carried beyond the worked area for long distances where dependable structure-sections could be constructed. The contour interval was always 100'.

Facies maps were also compiled for important sections of the strata, usually limited on top and bottom by readily recognized coal seams.

(1) and (2) were reduced to a scale of 1,000' = 1" and the individual sheets were brought together on one map so that both structural contours and seam isopachs might be viewed together.

In the Joggins district a similar procedure was followed for the more important sections of the district, but in general the information was compiled on the 1,000' scale, the density of information not being sufficient to warrant use of the larger scale over the entire district.

In both districts surface "master plans" were constructed showing seam outcrops and mine openings together with the detail geology of the respective areas. These are accompanied by batteries of cross-sections constructed at regular intervals to demonstrate the sedimentary

and structural relationships in the subsurface. The last mentioned map and sections have been included in this report since they vividly demonstrate on a large scale the marginal phenomena associated with coal deposition and particularly coal deposition close in to the base of a rising upland.

Chapter II
Stratigraphy

General Statement:

The rocks involved in the development of the Cumberland Basin of deposition are readily divisible into major groups: (1) the crystalline rocks that constitute the bordering masses of the Cobequid and Caledonian Uplands and (2) the unmetamorphosed sedimentary rocks that occupy the intervening Cumberland Lowland. The distribution of these rocks outlines approximately the original positive and negative elements that controlled the formation of the thick wedge of sediments that constitutes the Cumberland Basin of Deposition.

For mapping purposes the rocks of the upland areas have been grouped under "pre-Carboniferous" since no attempt was made by the author to differentiate them. Portions of these areas have been mapped and descriptions may be found in the reports accompanying the maps (Kerr, 1924; Jones, 1928; Norman, 1941; Weeks, 1948). The rocks have been broadly differentiated in the Table of Formations, (p.11) and will be described briefly.

The Carboniferous rocks of the basin area have received the greatest attention and will require detailed description. The continuous exposure in the Joggins section illustrates, in a general way, depositional conditions in the axial region, although it is certain that the axis of the subsiding trough shifted considerably during deposition. The rocks that may be intimately examined in this section range from Middle Windsor well into the upper part of the Cumberland group. Throughout this section there are no well defined breaks in the sedimentation. Sharp differentiation between adjacent

formations is not possible and consequently the position of formational boundaries must be considered as arbitrary. Divisions are, however, essential to analysis and description.

From the axial region outwards toward the marginal areas of the basin rapid coarsening in grain size is evident, marked unconformities appear and thinning over the bordering land masses is well defined, particularly in the Cumberland Group. In the coarser sediments, where the constituents are readily recognizable, the various lithologic types can generally be associated with a parent rock in the source area. Close to the contact with the crystalline rocks the clastic Carboniferous sediments are composed almost exclusively of the rock immediately underlying it. In general the clastic material in contact with the basement is a strongly cemented breccia that probably represents the product of "in situ" weathering before burial by the overlapping fluvial deposits.

With increasing distance from the source area the sediments are characterized by a higher degree of rounding and greater heterogeneity that is consequent upon longer transport and fluxing of materials eroded from a large area exposing a variety of rock types.

The correlation of the formations is taken unchanged from the work of Bell who has presented the fossil evidence in detail form and need not be repeated here, (Bell, 1944).

The author's chief aim is to describe the development and the nature of the facies changes, changes which are intimately related to the structural evolution of the region.

TABLE OF FORMATIONS

ERA	PERIOD	GROUP	FORMATION
CENOZOIC	QUATERNARY	Unconformity	
MESOZOIC	TRIASSIC	Unconformity	
PALAEOZOIC	PENNSYLVANIAN	PICTOU Unconformity	
		CUMBERLAND	(5) (4) (3)
		Disconformity and	(2) (1)
		Unconformity RIVERSDALE	BOSS POINT CLAREMONT
	?	Disconformity and	
	MISSISSIPPIAN	Unconformity	
		CANSO	SHEPODY
		?	?
		WINDSOR Disconformity	MARIGOUIN ZONE C ZONE B ZONE A
		and	
	Unconformity		
	HORTON	HILLSBOROUGH WELDON ALBERT MEMRAMCOOK	
	Unconformity		
	PRE-CARBONIFEROUS (Mainly)	COBEQUID COMPLEX	<u>INTRUSIVE ROCKS</u> <u>METAMORPHIC ROCKS</u>
?		?	?
PALAEOZOIC OR PRECAMBRIAN		CALEDONIAN INTRUSIVE ROCKS	
PRECAMBRIAN		CALEDONIAN METAMORPHIC ROCKS	

Pre-Carboniferous

General Statement:

There are two major areas of pre-Carboniferous rocks which, as noted above, are co-extensive with the Cobequid and Caledonian Uplands. The long axis of these areas, if projected, would intersect in the Bay of Fundy near the mouth of Chignecto Bay. The nature of their joining is somewhat speculative because the larger part of the Caledonian Upland is composed of metamorphosed sedimentary and volcanic rocks that are much older than the metamorphic rocks of the Cobequid Upland. Also it is noted that, in the Cobequid Upland, intrusive rocks are exposed over a much greater area, proportionately, than they are in the Caledonian Upland. In fact, the Caledonian intrusives are exposed only in relatively small linear areas scattered rather uniformly over the entire upland.

Determination of the relative age of the intrusive series becomes of great importance in deciphering the pre-Carboniferous history. Its significance will be considered after the general description of the rocks.

Caledonian Upland Area:

1. Metamorphic rocks: Distributed rather uniformly over the upland is a series of bedded rocks, dominantly volcanics, with minor amounts of interbedded non-fossiliferous sedimentary rocks. The volcanics rocks, consisting of flows, tuffs, and breccias, are for the most part highly schistose and much altered to chlorite, epidote, uralite and white mica. The sedimentary rocks are altered to quartz sericite schists, quartzite

with some conglomerate. Obscured structural relationships have precluded estimates on the thickness of the series. The lithologic similarity of this group of rocks to the Coldbrook group that underlies the Lower Cambrian strata near St. John New Brunswick, at the southwestern extension of the upland, places the group in the Precambrian (Norman, 1941).

2. Intrusive rocks: The metamorphic rocks are cut by intrusive rocks that are exposed in relatively small northeasterly trending linear areas that are well distributed over the surface of the upland. Mainly, they consist of quartz diorite and albite granite, the latter being the most prevalent. According to Norman (1941), the diorite grades into the granite in places but in other localities granite dykes cut the diorite. Granites of two types can be differentiated on the basis of their content of ferromagnesian minerals. One type contains nearly twenty per cent biotite and hornblende, whereas the other is practically free from ferromagnesian. At the margins of the intrusive bodies sills and dykes invade the metamorphic rocks and locally there is evidence of intense shearing. In the Caledonian Upland area these intrusives have been observed to cut only Precambrian rocks. Unmetamorphosed Mississippian and Pennsylvanian rocks flank the upland. The age of these intrusive rocks is therefore bracketed between Precambrian and Lower Mississippian.

Cobequid Upland Area:

1. Metamorphic rocks: The metamorphic rocks are exposed over a much smaller area than the intrusive rocks, the ratio being roughly 1 to 3,

that is, considering the entire expanse of the upland. It may be significant to note also that the metamorphic rocks occupy narrow, fairly continuous areas concentrated on the southern margin of the upland (See Map 1). Where the exposure of crystalline rocks narrows down in the western extremity of the upland, metamorphic rocks predominate but still maintain the same trend. At its western extremity the upland apparently was overlapped from the north a much greater distance than is true farther eastward or else the eastern part of the upland was uplifted farther in post-Cumberland time, than the western extremity and the overlapping formations eroded.

The rocks of this series are composed of grey to green argillites and quartzites, few impure grey limestones interbedded with grey, green and reddish flows, tuffs and breccias. These latter volcanic rocks apparently constitute a major portion of the total thickness. Locally, the rocks are highly sheared and schistose.

On West and Brown Brooks, near the contact with the unmetamorphosed Cumberland rocks, impure grey limestone beds have been found which carry Silurian fossils (Jones, 1928). Toward the eastern extremity of the upland other horizons have been definitely correlated as Silurian. The general similarity of the rocks throughout the metamorphic series would seem to place them all in the Silurian. However, a serious objection to such a generalization has been raised by Bell's discovery of Upper Windsor fossils in an argillite horizon on Harrington River, just north of Five Islands, (Bell, 1927, p.94). This would seem to indicate that metamorphism

affected all strata which became involved in the tectonically active belt marked by the Cobequid Upland. Sheets of pink rhyolitic rock are also noted by Bell to have intruded rocks that are similar to those enclosing the Windsor fossil horizon and would seem to indicate that the metamorphism was furthered by igneous intrusion.

2. Intrusive rocks: A rather heterogeneous group of rock types form the intrusive series. No area is exposed sufficiently well to indicate definite lines of gradation but, in general, there seems to have been a great deal of assimilation of the metamorphic rocks and this factor is probably largely responsible for the variations. Probably the most common type observable on the northern margin, away from the areas of metamorphic rocks, is a coarse grained granite made up almost entirely of quartz and pink to red orthoclase. The Pennsylvanian sediments that flank this area on the north have a great abundance of this material mixed with lesser amounts of green-tinted metamorphosed sediments and volcanic rock. The most basic intrusive rock that occurs fairly extensively is a greenish rock made up largely of grey feldspars and ferromagnesian minerals, mainly, hornblende and biotite. All gradations exist between the acid and basic types of intrusives.

Summary and Significance

It has been indicated above that the bedded rocks exposed on the bordering uplands are widely separated in age from one Upland to the other. The bedded rocks of the Caledonian Upland are dated as late Precambrian while the oldest exposed rocks in the Cobequid Upland are apparently not older than Silurian. The lower contact of this latter group is not observable so nothing is known directly of the pre-Silurian history of the Cobequid Upland.

A brief survey of the pre-Carboniferous rocks throughout the Maritime region will be necessary before attempting to interpret the older history of the area with which we are chiefly concerned. The pre-Carboniferous record is a disconnected one and must be deduced in a general way from a few localities.

Scattered exposures of the Green Head group and George River group, both Archaean in age and found in southern N.B. and on Cape Breton Island respectively, exhibit large amounts of dolomite and limestone with associated volcanic rocks. In these areas, at least, a marine environment existed for a part of Archaean time and they were also a site of volcanic activity. The Coldbrook group, which includes the dominantly volcanic rocks of the Caledonian Upland, lies unconformably on rocks of the Green Head group. Near Loch Lomond, in southern N.B., a coarse conglomerate interbedded with the volcanic rocks contains boulders of Green Head rocks, white quartz, and massive red granite and thus suggests intrusion of the Green Head group before

deposition of the Coldbrook group. The great thickness of volcanic rocks in the Coldbrook group indicate a period of sustained volcanism in the area of Southern N.B. Its unconformable relationship between rocks of the Green Head group below and Cambrian rocks above fix its age as late Precambrian.

The early history of the region has been very much clouded by the existence of some 30,000 feet of non-fossiliferous quartzites and slates which underlie a large part of area over the Southern Highland of N.S. The whole is termed the Meguma series and is divided into two major formations. The lower Goldenville formation consists dominantly of quartzite with interbedded slates and in Queen's county is about 24,000 feet thick. The upper or Halifax formation is conformable with the Goldenville and is made up chiefly of slates interbedded with some quartzitic beds and measures about 12,000 feet in thickness. The fine grained members of the Halifax formation are characterized by minute graded bedding and crossbedding of microscopic dimensions that strongly suggest deposition under quiet shallow conditions. The crossbedding would seem to indicate very gentle currents and the uniformity of the entire sequence of fine grained rocks point to unusual uniformity of conditions over a tremendous period of time. To date no fossils have been found in rocks that are definitely known to belong to the Meguma series and it seems more than probable that relics of organic life would have been abundant if the group was deposited after preservable forms were initiated. This, together with a strong lithologic similarity to quartzites and slates that

underlie Cambrian rocks on Avalon Peninsula in Newfoundland make a Precambrian age acceptable for the Megana series. It could only otherwise be implied that peculiar climatic conditions, of which we are not yet aware, persisted for a long period in early Paleozoic time.

The widespread distribution of the series across the length of the U.S. mainland and possibly into southeastern Newfoundland implies a major basin of deposition. The positions of the basin margins are vague and remain so because no attempt has yet been made to apply the techniques of modern sedimentology toward an appraisal of this vast sequence of sediments. If the series can be correlated even approximately with the Coldbrook group of southern New Brunswick it would imply a northern margin lying across that general area of volcanic activity and coarse sedimentation. The southern margin, if there was any, has usually been referred to a vaguely located land mass termed Appalachia.

The rocks of early Paleozoic time provide more definite information because, while sparsely distributed, their distribution in time has been ascertained with greater assurance from their fossil content.

Coarse Cambrian sediments lie unconformably on the bedded metamorphic rocks of the Caledonian Upland at its southwestern extremity near St. John, N.B. The coarse sediments underlie a thick sequence of marine Cambrian sediments and the whole apparently represents the transgression of a shallow sea upon a upland area. The

limits of the Cambrian sea are not known here but no recognizable remnants have been found over the Caledonian Upland northeast of the Hanford Brook area. The only other locality of Cambrian exposure in the Maritimes is in southeastern Cape Breton where Hutchinson (personal communication) has recognized a transgression of the Cambrian sea upon an upland area lying in the direction of central Cape Breton Island. Since no further exposures of Cambrian are to be found in the intervening area it cannot yet be inferred that these Cambrian Upland areas were parts of a continuous land area such as that visualized by Schuchert in his New Brunswick geanticline (Schuchert, 1930) though it certainly lends support to the theory.

The Ordovician record is also a disconnected one. In the Arisaig district shallow marine deposition in the Lower Ordovician was followed by igneous activity at the close of the period. Thus activity was accompanied by uplift in that region with consequent deposition of coarse conglomerate in the Middle Ordovician. In the St. John region marine beds of Lower Ordovician age are definitely known. To the northwest of the St. John Area and stretching in a belt from the Maine New Brunswick border to Bathurst, N.B. is a thick series of metamorphosed sedimentary and associated volcanic rocks which are thought to be, in part at least, Ordovician in age.

There is little evidence on which to base the paleogeography of Ordovician time. The Ordovician of the Arisaig district implies quiet, shallow, marine deposition in the Lower Ordovician followed by a period of uplift and continental deposition in the Middle Ordovician. The St. John district gives evidence of similar marine

conditions persisting from Cambrian time through the Lower Ordovician (Alcock, 1947, p. 110). The stratigraphic position within the Ordovician, of the Charlotte group of argillites which are exposed in the southwestern part of New Brunswick, is not known and little can be deduced from them.

It may be reasonably concluded that in general Ordovician paleogeography in the region was characterized by shallow seas surrounding several islands. The entire region was disrupted in Upper Ordovician time by movements related to the Taconic orogeny. No Upper Ordovician has been recognized to date in the area south of the Matapedia district of northern New Brunswick. Local uplift occurred through Lower and Middle Ordovician time such as is indicated in the Arisaig sequence and in all probability the volcanic rocks associated with the sequence are related to these minor movements.

The Silurian rocks have a somewhat wider distribution than those of Ordovician age. They are exposed in the Arisaig district, in a small area near Kentville, N.S., in the Cobequid Upland and in southern, northern and west-central New Brunswick.

The Arisaig district exposes a section of some 3,800 feet of sandstone, calcareous sandstone and shale termed, by M.Y. Williams, the Arisaig Series. It lies unconformably on Ordovician beds. (Williams, 1914). The Kentville area exhibits fossiliferous light and dark-colored slates. In the Cobequid Upland the Silurian strata is made up of argillites with interbedded impure limestones and great thicknesses of volcanic rocks. The Silurian exposures in southern New Brunswick are also characterized by

great quantities of volcanic rocks with interbedded sediments. At Oak Bay, just north of St. Andrews in southern N.B., the base is marked by a coarse conglomerate lying unconformably on the Charlotte group of Ordovician age. In general the Silurian rocks indicate deposition in a shallow sea transgressing scattered land areas. In the Cobequid Upland area and in Southern N.B., vigorous volcanic activity is in evidence and may represent a prelude to the intense orogeny of late Lower Devonian time.

The nearest Devonian exposures are at Arisaig, Cape Breton Island, the Nictaux-Torbrook area of Annapolis and Kings counties in N.S., in northern and southwestern New Brunswick, and in the Gaspé region of Quebec.

In Cape Breton fresh water arkoses and conglomerates of the MacAdam Lake formation lie unconformably on Precambrian rocks in the area between East Bay and St. Andrew's Channel. The formation is considered to be Lower or Middle Devonian in age.

At Arisaig, about 1,000 feet of red arenaceous shales and grey sandstones of the Enoydart formation, lie unconformably on Silurian strata. The formation, on the basis of a few fish remains, is considered to belong to the Lower Devonian.

In the Nictaux-Torbrook area a series of fossiliferous slates and quartzites with associated ferruginous beds are dated as Lower Devonian. These latter rocks are strongly folded and metamorphosed as a consequence of the orogeny that closely followed their deposition.

The Lower Devonian rocks of northern New Brunswick and the Gaspé consist of highly fossiliferous marine sediments, interbedded with volcanic flows and tuffs, the volcanic rocks being predominant in the upper part.

Middle Devonian sediments are found on the Gaspé peninsula and in the Matapédia Valley. The transition from Lower to Middle Devonian in the Gaspé region is marked by a sharp change from limestones to sandstones and conglomerates which are, in part, of marine origin.

The Upper Devonian period is represented in the Chaleur Bay region and in southwestern New Brunswick. On the north side of Chaleur bay is a series of alternating thick conglomerate and sandstone beds. The uppermost part of the series consists dominantly of grey shales and sandstones carrying abundant fish and plant remains. In southwestern N.B. in the St. Andrew's region a series of red sandstones and conglomerates rest unconformably on Silurian rocks. This latter group is correlated with the Ferry conglomerate of Maine which carries an Upper Devonian flora.

From the meagre record it may be concluded that the Devonian period began with widespread marine deposition upon a surface that had been tilted and folded in late Silurian time. The land areas of Silurian time were somewhat modified and seemingly greatly enlarged so that Devonian deposition was restricted to narrow seaways. The intense orogenic disturbances of late Lower Devonian time resulted in extensive deformation which was accompanied by intrusion of the great masses of granite and associated rocks that are now exposed

over the Central Highlands of New Brunswick and the Southern Upland of Nova Scotia. The greater part of the intrusions exposed over the Cobequid Upland also belong to this group of intrusive rocks. The age of the intrusive rocks of the Caledonian Upland cannot be so definitely fixed and here radioactive age determinations might be used to advantage. The biotite-rich rocks exposed there should lend themselves readily to the recently developed method of radioactive age determinations on this type of rock.

The Middle Devonian witnessed the deposition of great thicknesses of coarse clastics in the Gaspé region and in northern New Brunswick but no record of the Middle Devonian has been found in Nova Scotia or in southern N.B. The entire area was undergoing erosion or else the remnants are covered by the Carboniferous and later sediments. The Upper Devonian is represented by remnants that are dominantly continental in origin. So meagre is the entire Devonian record in the Maritime region that it is more than dangerous to extrapolate far on sedimentary evidence alone.

However, if the structural configuration that controlled Carboniferous deposition was defined by the Acadian (Shickshockian) orogeny, as the late Lower Devonian disturbance has been termed, and the positive and negative elements activated shortly afterward, late Devonian sediments would have been deposited in the basins that persisted into the Carboniferous period, and would have been covered by overlapping younger strata.

The problem of the origin and development of the Carboniferous basins and uplands will be taken up in a later chapter but

it may be mentioned here, in relation to the Acadian orogeny, that simple southeast-northwest compression does not adequately explain the structural makeup of the Carboniferous basin and upland region of the Maritime Provinces.

Within the limitations imposed by the meagre record of pre-Carboniferous time it may be discerned that the area of the Cumberland Basin was one of marine deposition in Archaean time. During the Proterozoic era it was, in its northern part at least, a scene of intense volcanic activity and possibly it laid astride the northern margin of the basin in which the Meguma series was deposited.

At the outset of the Palaeozoic era the Caledonian Upland area was seemingly a land area flanked by the Cambrian sea. No evidence is available to determine whether the sea ever covered the Caledonian Upland area but by Silurian time, at the latest, marine waters covered the area of the Cobequid Upland. There and in the area flanking the Caledonian Upland on its northwest side great thickness of volcanic rocks interbedded with marine beds indicate intense volcanic activity within a shallow sea environment. Uplift near the end of the Silurian period may have entirely excluded the sea from the area as no Lower Devonian sediments have been found closer than the Arisaig and Nictaux-Torbrook areas.

The orogeny of late Lower Devonian time reorganized the structural makeup of the region and, as has been mentioned, if late Devonian sedimentation progressed in the area of the Cumberland Basin the sediments would have been carried into the newly formed basin and subsequently covered by Carboniferous strata.

Horton Group

General Statement:

The Horton group of Lower Mississippian age was named for the type locality near Horton Bluffs at the mouth of Avon River near Windsor, Nova Scotia. Here Bell divided the group into two formations. The lower formation, the Horton Bluff, consists of dark grey shales and grey feldspathic sandstones. Its characteristic flora is Lepidodendron corrugatum Dawson and Aneimites acadica Dawson. Its restricted fauna consists mainly of ostracoda and bony parts of fishes. The upper formation, the Cheverie, consists of grey arkose and shale. A poor floral content seems to include Aneimites acadica; Estheria and Leia are found in several horizons (Bell, 1929).

Rocks of the Horton Group are nowhere exposed in the map-area but they constitute an important part of the section in the subsurface. Within the Cumberland Basin of deposition Horton rocks are exposed in two areas. The best section of these rocks is to be seen in the Hillsborough area of southern New Brunswick where the group has been subdivided on a lithological basis into four formations; the Memramcook, Albert, Weldon and Hillsborough formations in order of decreasing age (Norman, 1941). In the vicinity of West Branch River John, near the eastern extremity of the Cobequid Upland in Nova Scotia, a section of Horton rocks termed the River John Group lie unconformably on a basement of Pre-Carboniferous rocks in the same manner as the Horton Group of New Brunswick. Further direct evidence of this group is to be had in the Nappan borehole, in which several thousand feet of Upper Horton sediments were cut.

Memramcook Formation:

The formation is named for the locality of its best exposure at Memramcook, New Brunswick. There Norman estimates that approximately 1500 feet of interbedded red shales and sandstones make up the section which either overlies, or grades into, red strata containing much arkose and conglomerate that rest on granite 3 miles north of Memramcook. (Norman 1941). Along the contact with the pre-Carboniferous rock on the northern side of Caledonian Upland the Memramcook formation is hidden by overlapping of younger Horton strata until it appears again about 18 miles west of Stoney Creek as a coarse conglomerate resting directly on the pre-Carboniferous basement. Along the southern margin of the Caledonian Upland, which faces the axial region of the Cumberland Basin, the Memramcook formation does not appear and the sediments in contact with the basement are everywhere later than Memramcook in age. No strata of equivalent age has been recognized elsewhere in the area underlain by the rocks of the Cumberland basin.

Albert Formation:

The Albert formation succeeds the Memramcook formation with apparent conformity and, as nearly as can be determined, with an entirely gradational contact. It consists dominantly of dark grey shale interbedded with discontinuous sandstone members. Highly bituminous oil shales are interbedded with relatively barren grey shales and are particularly abundant near the lower part of the formation. Near Gautreau, N.B., boreholes, drilled for oil, have encountered thick beds of salt, possibly up to 1000 feet in thickness, near the upper part

of the formation. A few thin impure limestones also occur in the formation.

The formation is best exposed in the Memramcook district of New Brunswick but more accurate thickness data is to be had from the logs of the wells bored into the formation for oil and gas in the Stoney Creek field. Here it measures about 4,000 feet in thickness. Farther west along the contact with the basement rock the Albert formation is observed to overlap the Memramcook and to lie directly on the pre-Carboniferous basement rock. This feature is best observed at Rosevale. From Dorchester, N.B., eastward the Albert formation has nowhere been recognized within the area underlain by the rocks of the Cumberland Basin.

Weldon Formation:

A thick sequence, consisting chiefly of red shales and sandstones succeed the Albert formation and where the contact may be observed it is entirely gradational. Where the Weldon formation overlaps the pre-Carboniferous rocks of the Caledonian Upland it is much coarser in texture. This part of the formation is apparently a near source phase and may or may not represent significant movement at the close of deposition of the Albert formation. Near the base of the formation on Boyd Creek one bed of volcanic ash has been noted. The thickness of its typical ensemble of red shale and sandstone has been estimated at approximately 1,500 feet, (Norman 1941).

Hillsborough Formation:

Overlying the Weldon formation in the Hillsborough area is a thick conglomerate group called, by Norman, the Hillsborough formation (Norman, 1941). No angular discordance between them is perceptible but on Boyd Creek, near Gautreau, fragments of volcanic ash, similar to that contained in the underlying Weldon formation, have been found (Norman, 1941). The erosion supplying the fragments of ash was probably localized and does not necessarily represent a sudden regional uplift. The Hillsborough conglomerate group is exposed around the northeast end of the Caledonian Upland and extends southward as far as Albert Mines.

Where the Weldon formation grades coarser and becomes indistinguishable, lithologically, from the Hillsborough formation the strata is referred to as the Monoton group. The thickness of the conglomerate facies varies markedly over short distances and no attempt was made to estimate it.

River John Group:

At the eastern extremity of the Cobequid Upland, along the headwaters of River John, a very thick sequence of red to chocolate shales and sandstones with massive grey conglomerate is exposed. Where a non-faulted contact can be observed the group lies with angular unconformity on the pre-Carboniferous rocks of the upland. In the lower part of the sequence there are several interbedded basic flows. Higher up Stewart has observed a felsitic igneous rock, of apparently limited distribution, underlain by a volcanic ash bed (Stewart, 1931). It is notable that the

conglomerates of the River John group are lacking in pebbles of igneous rock while the overlying Millsville conglomerate of early Pennsylvanian age contains a large proportion of pebbles derived from intrusive rocks.

The thickness of the River John group is uncertain. Bell has indicated that it is in excess of 6,000 feet, (Bell, 1944). He correlates the sequence with the Horton group but its position within the Horton group is uncertain. The sequence is similar in lithology to the Upper Horton of southern New Brunswick. In common with the Upper Horton also is its content of volcanic materials. One volcanic ash bed has been observed in the Upper Horton of southern New Brunswick as compared to several flows and ash beds in the River John sequence. Whether these occurrences are closely related in time is a question.

Summary and Significance:

It is difficult to assay the significance of the Horton Group in so far as the basin proper is concerned. The exposures of the group are all confined to margins of the basin and in Southern New Brunswick they represent deposition in depressions within the bordering positive area that we have termed the "Caledonia positive axis". The thicknesses measured from these exposures have little or no relationship to the thickness of the group in the axial region of the Cumberland basin. However, the nature of the sedimentation as noted in these areas reflect in a broad sense the conditions to be expected in the axial region.

The base of the group is marked in southern N.B., by a group of coarse red sediments (Memramcook formation) which grades into a dominantly

grey shale facies (Albert formation) which also encloses some oil shales. The latter formation is considered to be, for the most part, lacustrine in origin. However, near the top of the latter formation beds of salt, of considerable thickness, indicate periodic inundation by marine waters, parts of which were probably trapped in the depressions on the broad crest of the "Caledonian positive axis" when the main body of marine waters receded. It would appear more than probable that normal marine equivalents of the Albert formation were deposited in the axial region of the Cumberland Basin.

The grey shale facies grades upward into coarser red sediments (Weldon formation) and finally into a conglomerate group (Hillsborough formation). Local erosion of underlying sediments occurred while in other places no break is discernible. At various stages throughout the deposition of the group, the strata are seen to overlap, in places, earlier deposited sediments and to lay directly on the pre-Carboniferous basement, thereby giving clear testimony to the irregularity of the surface upon which they were deposited.

If we can assume that the River John group of Nova Scotia is approximately equivalent in age to the Upper Horton of N.B., (Weldon and Hillsborough formations) then it fits in the picture nicely as the debris eroded from the "Cobequid positive axis" which rose, more or less in unison with the "Caledonian positive axis". The volcanic flows incorporated in the group may have had their source in deeply penetrating faults along the hinge line between the rising and subsiding elements.

Below the Lower Windsor marine sediments the Nappan borehole cut more than 5,000 feet of red and grey continental deposits and the hole was abandoned without any marked change being noted in the sequence. These continental sediments are believed to represent the influx of debris consequent upon the renewed uplift and erosion of the bordering land masses in Upper Horton time. The Carboniferous sea, which transgressed furthest in Upper Albert time, had now receded into deeper parts of the basin and although the basin was actively subsiding the influx of stream borne sediment kept pace with the subsidence, and during the Upper Horton maintained the shores of the Carboniferous sea some distance to the north or northeast of the borehole location at Nappan. In short, the thickness of the Horton section in the axial region of the basin may be expected to be much thicker than is indicated in the areas in which it is presently exposed and, quite possibly, it includes, in that part equivalent to the middle and upper part of the Albert formation, a thick sequence of marine sediments.

Windsor Group

General Statement:

The type locality of the Windsor group is at Windsor, N.S., where the section comprises about 1,550 feet of marine sediments. Here Bell divided the group into two major faunal zones; an upper, characterized by Martinia galatasa and a lower zone characterized by Compositia dawsoni. The two major zones are again divided into faunal sub-zones. Sub-zones A and B belong to the lower part and sub-zones C, D, and E constitute the upper part. The section at Windsor exhibits four or five distinct stages of calcium sulphate deposits separated by varying thicknesses of red shale,

fossiliferous limestone, thin magnesian sandy shales and oolites, (Bell, 1929, p. 45).

The group is widespread throughout the Maritime provinces, but it exhibits a wide variation in the lithologic constitution, as might well be expected of deposition from a sea transgressing a land area whose topography was being continuously modified by structural adjustments within the underlying crustal mass.

In the region of the Cumberland Basin the group is exposed mainly over a few linear areas where it is brought to the surface on the crest of major anticlinal folds such as the Minudie and Claremont anticlines. Limited exposures in irregularly shaped areas are also found in the structurally complex Salt Springs area north of Springhill and also in the Hillsborough area at the northeastern extremity of the Caledonian Upland. The stratigraphy of the Windsor group will be discussed by areas since the variation exhibited from place to place does not permit exact correlation of lithologic divisions made in one area with those of another. Several outlying areas that provide information regarding the control on the environmental conditions and extent of Windsor sedimentation will be discussed briefly.

Minudie Anticline Area:

The Minudie anticline, which lies immediately north of and roughly parallel to the northern margin of the map-area, has been the scene of detail geologic investigation for many years. The various exposures of the Windsor group together with two deep boreholes and several diamond drill holes has provided a fairly good section of the

Windsor group in this area. It will be noted that this area lies in the axial region of the Cumberland basin and therefore the section to be derived is particularly significant.

The marine section may be divided into four lithologic zones as follows from the base upward. (1) A thin calcareous zone, possibly similar in part to the "laminated" limestone noted elsewhere at the base of the Windsor. The limestones are interbedded with red to brown shales and light grey sandstones and probably represent a transition phase from the non-marine Hillsborough formation of Upper Horton age. (2) Gypsum, anhydrite and salt member of uncertain thickness. The Haysan borehole cut a continuous section of gypsum, anhydrite salt and minor red shale from a depth of 145 feet to 6,072 feet. The structurally incompetent salines were undoubtedly squeezed into the zone of least stress in the anticline and thus piled up to an enormous thickness along the axis. (3) A zone in which real shale predominates - approximately 800 feet thick. (4) A calcareous zone consisting of interbedded grey limestone, silty limestone and calcareous shale totalling about 300 feet. The latter zone is fossiliferous and Bell correlates the zone with parts of sub-zones B and C of the Windsor group in the type area. (Bell, 1944, p. 46).

In the Joggins' section the Windsor marine strata is succeeded by approximately 1,600 feet of much rippled, non-fossiliferous red sandstones and shales which in turn grade upwards into a zone, about 725 feet thick, that is distinguished by the appearance of grey sandstones and poorly preserved remains of Calamites. The top of the latter zone is well marked at the base of a conglomerate zone which is considered to be a coarse basal phase of the Riverdale group.

In the Joggins sections, the top of the Windsor group lies somewhere between the topmost calcareous zone of the Windsor marine strata and the base of the Riversdale Group. The position of the Windsor-Canso contact was tentatively fixed by Bell, (1944, p.8) at the base of the lowest observable grey sandstone. This criterion has been used to map the same contact westward across Maringouin Peninsula and thence southwestward along the northwest shore of Chignecto Bay where the lithology is seemingly identical. The entirely red, non-marine unit is therefore assumed to be equivalent to a part of the Windsor faunal sub-zone C and also sub-zone D and E. The unit has been called, by Norman, (1941), the Maringouin formation, and the succeeding zone, bearing grey sandstone has been correlated with the Canso group and named, also by Norman, the Shepody formation.

Eastward along the Minudie Anticline, toward Little River, the red strata overlying the marine calcareous zone becomes somewhat coarser in texture and includes, locally, some conglomerate near the base. Toward the top of the red strata a few thin beds of flaggy grey sandstone are observable and it is then succeeded by coarser sediments belonging to the base of the Riversdale group. The entire sequence between the uppermost marine beds and the Riversdale group has been called, in this area, the Middleborough formation. The section is generally similar to that of Minudie and it is thought that the upper zone containing grey sandstone represents the Canso group and is therefore equivalent to the Shepody formation while the lower, entirely red zone is equivalent to the Maringouin.

Claremont Anticline Area:

The Claremont anticline extends from Springhill on the west to Malagash Point in the east, a distance of about forty miles. The structure is cross-faulted and thrust-faulted in several places along its length and has thereby rendered the stratigraphic sequence obscure, particularly within the Windsor group. The lower contact is nowhere observable but it is evident, in the Wallace River section and at Malagash, that the general lithologic sequence of the upper part of the group remain generally similar to that in the Minudie anticline area. At the Malagash salt mine the thickness of the sulphate-salt member has been estimated as between 150 and 300 feet. The boundaries are faults however and it is not known whether the thickness is representative of the entire member. (Bell, 1944, p. 54).

Northern Margin of the Cobequid Upland:

Along the northern margin of the Cobequid Upland, from Chignecto Bay to Pictou County, the pre-Carboniferous rocks are unconformably overlapped by Carboniferous sediments of Cumberland, Riversdale, and Upper Horton age. Strata of the Windsor group do not appear anywhere along the margin of the upland for its entire length and, at its eastern extremity, do not appear between the Upper Horton (River John Group) and the unconformably overlying Riversdale (Millville conglomerate) strata. The entire Windsor group is absent in this latter locality either as a result of post-Windsor erosion or because of non-deposition. It seems probable that a tectonically positive axis was initiated here during late Horton or early Windsor time and extended northeasterly from the eastern extremity

of the Cobequid Upland to form a barrier between the Stellarton-Arisaig area on the east and the main part of the Cumberland Basin on the west. Certainly the coarse conglomerate of the Millville formation indicates overlap upon an area that was uplifted at some point in Windsor or Canso time and, lacking any evidence to the contrary, it is assumed that the Windsor sea did not submerge it. It was mentioned earlier that strata, bearing Windsor fossils, were found in the Harrington River area so it cannot be said that the Windsor sea did not submerge at least a portion of the Cobequid Upland area. It is possible, however, that the Harrington River strata of Windsor age belong to a Minas Basin facies which overlapped the upland from the south.

Arisaig Area:

In the Arisaig district, 860 feet of red conglomerate, sandstone, and sandy shale of the McAras Brook formation, of Windsor age, lie unconformably on all older rocks. Conformably overlying the McAras Brook formation is the Ardness formation consisting of some 1250 feet of limestone, gypsum, sandstone, sandy shale, etc. It is to be noted that diabase sills and dykes intrude the basal members of the McAras Brook formation while no evidence of igneous activity has been found associated with the Ardness formation.

McGregor Mountain Area:

In the McGregor Mountain area, which lies south of the Fictou coalfield, the Windsor sequence is generally similar to that of the Arisaig region in so far as a lower series of coarse clastics lie unconformably on the older rocks and is succeeded by a calcareous zone. The thicknesses

are highly variable and indicate deposition over an irregular land surface. So poor are the exposures and fossil contact of these rocks that their position with the Windsor group cannot be fixed. Bell regards it as probable that all the Windsor strata of the McGregor Mountain area belong to the Upper Windsor (Bell, 1940, p. 11).

Hillsborough Area:

The Hillsborough area of Albert County, N.B., includes a number of isolated patches of Windsor exposures. One lies southwest of Hillsborough, another near Albert Mines and a linear area running parallel to the Riverside fault which trends northeasterly through a point lying immediately north of Shepody Mountain (see G.S.C. Map 647A). From these exposures a fairly good composite section may be built up to represent the conditions of Windsor sedimentation along the southern margin of the Caledonian Upland.

A basal limestone carrying a few sub-zone B fossils rests conformably on Hillsborough strata of Upper Horton age but, in places, notably at a point 2 miles southwest of Albert Mines, the limestone overlaps the Hillsborough strata and rests directly on the pre-Carboniferous rocks. The limestone is overlain by about 200 feet of red shale and sandstone which in turn is overlain by an anhydrite-gypsum member measuring about 500 feet in thickness (Wright, 1922, p. 18). In the area of Shepody Mountain the anhydrite-gypsum member is overlain by the Hopewell conglomerate group. Near the base of the conglomerate group two interbeds of impure limestone were found carrying sub-zone C fossils (Bell, 1944, p. 54). Limestone cobbles were found within the conglomerate

bearing fossils belong to sub-zone B (Wright, 1922, p. 19). Here we have definite evidence of uplift in the Caledonian Upland area closely following the deposition of sub-zone B.

Westward from the Hillsborough Area along the northern margin of the Caledonian Upland, the Windsor group is frequently exposed and exhibits variable relationships. In places it lies conformably on the Hillsborough strata, in other places unconformably and in places it overlaps onto the pre-Carboniferous rocks. In many places it cannot be determined with assurance whether part of the non-marine strata, mapped as Hillsborough formation, is not actually Lower Windsor and vice versa. In general the Upper Horton and Lower Windsor strata of the southern New Brunswick region suggests transgression of marine waters over an irregular, land surface.

Salt Springs Area:

Because this area lies with the scope of the author's field investigations it will be described in greater detail than that accorded to the foregoing areas. Lying north and northeast of Springhill area groups of more or less disconnected areas indicated on the map (Map 3) as being underlain by Windsor Rocks. Actually there are only four or five small exposures of Windsor strata, the remainder of the surface distribution being inferred from the topography and from structural considerations.

At a point approximately one and a quarter miles northerly along the Springhill and Parrsboro Railway from Springhill Station is

an outcrop of grey, impure concretionary limestone that is exposed on the south side of the railway embankment. Fossils collected from the outcrop by Kerr were identified by Bell as follows: Productus lyelli de Verneuil; Pugnax dawsonianus, Davidson. These fossils indicate a probable lower Windsor age (Kerr, 1924). It is noted by Fletcher that this limestone was once quarried and burned for lime. Nearby, gypsum of good quality was also quarried though, except for a considerable topographic depression, no further evidence of the quarrying may be observed at present.

On the Canadian National Railway, about one-half mile south of Black River Station a limestone similar to that mentioned above and yielding similar fossils is exposed. Here it is associated with soft friable red sandstone.

On Black River, immediately west of Springhill, Dr. Bell has identified fossils in a calcareous shale indicating Windsor age (G.S.C. Map 337A).

The occurrences of gypsum indicated on the map (Map 3) represent a compilation of those indicated by Fletcher (G.S.C. Map 812, 1903) and those actually observed by the author. Some occurrences noted by Fletcher are no longer observable but that is hardly to be questioned in view of the weathering characteristics of the material. In other areas, shown to be underlain by Windsor strata, the inference is based on brine springs, flat, swampy ground, and sinkhole topography where these occurrences appear to satisfy the structural considerations to be taken

up in a later chapter.

It is notable that strata corresponding to the Maringouin and Shepody formations have nowhere been found in association with the outcrops of marine Windsor strata in this area. Though no contacts are exposed it is assumed that where the coarse basal Riversdale beds (Claremont formation) overlie the Windsor beds the relation is one of angular unconformity which is complicated, in places, by faulting as indicated on the map. This relationship is particularly evident on the westwardly pitching nose of the Claremont Anticline.

The area of Windsor exposure, shown immediately south of the headwaters of Little Forks River is bounded, with both unconformable and faulted contacts, by younger rocks of the Riversdale and Cumberland groups. The arguments, upon which the author's conclusions regarding these relationships have been based, are largely dependent on the peculiarities noted in the deposition of these younger sediments and must therefore await descriptions of these groups before stating the case.

Summary and Significance:

For a graphic summary of Windsor sedimentation in the Cumberland Basin the reader is referred to the Generalized Stratigraphic Column (Fig. 1). As indicated in the marginal notes accompanying the figure, the left-hand margin represents the sequence in the axial region of the subsiding basin while the right-hand margin represents the sedimentary sequence along the margins of the Carboniferous uplands that bordered the basin. The left margin is, in fact, a generalized representation of the Windsor group in the Joggins section where an unbroken sequence

indicates an area of continuous sedimentation and though it may not be on the exact geometric axis of the basin it is entirely representative of axial sedimentation.

The sedimentary sequence in the marginal region of the basin, i.e. along the bordering uplands, has been derived largely from exposures in the Hillsborough area of New Brunswick and in a strict sense applies only to the bordering upland on the northwest that is presently represented, in part, by the Caledonian Upland. It is thought that the sequence along the southern borderland is generally similar though the evidence supporting this view is largely negative.

Drilling on the Minudie anticline has indicated a transitional contact between the non-marine Upper Horton strata and the marine Windsor strata. In this area marine deposition persisted in Windsor time until sub-zone C when, as observed in the Joggins section, a reverse transition takes place and the marine strata grades upward into the non-marine sediments of the Maringouin formation. Increasing coarseness is evident in the younger Shepody formation and conglomerate was deposited for a short interval in early Riversdale time. The conglomerate is succeeded by the relatively finer-grained sediments of the Boss Point formation of later Riversdale age.

The relationships of the basal Windsor marine strata in the Hillsborough region indicate general structural conformity with an underlying coarse facies (Hillsborough formation) of Upper Horton age which it overlaps in places to rest directly on pre-Carboniferous rocks. It is notable that part of the strata assigned to an Upper Horton age may actually

be Lower Windsor. Coinciding, in time, with the transition from marine sediments to the non-marine Maringouin strata of the Joggins section is the pronounced rapid transition from marine sediments to coarse fluvial deposits in the area of Shepody Mountain. A thick conglomerate group which is considered to belong to the same coarse phase noted in the Shepody Mountain area is extensively developed along the southern margin of the Caledonian Upland from Alma on the southwest to Dorchester on the northeast. Where the upper contact of this unit of coarse sediments can be observed it is seen to be overlain conformably by the finer-grained sediments of Riversdale age (Boss Point Formation). It seems apparent, that along the southern margin of the Caledonian Upland which is roughly coincident with with southern margin of the Carboniferous upland in this region, a coarse facies was deposited from the Windsor sub-zone C time through Canso time to early Riversdale. In the Joggins section, on Maringouin Peninsula, and in the Cape Enrage area the coarse phase is represented by a relatively thin conglomerate zone considered to be early Riversdale in age. As has been noted above, strata of Windsor age have not been recognized along the margin of the bordering upland on the south side of the Cumberland Basin and therefore it cannot be ascertained to what extent the Windsor sea advanced in that direction. The relatively coarser texture of the Maringouin equivalent of the eastern extremity of the Minudie Anticline area is suggestive of greater proximity to the source area. The absence of Windsor strata between the Millville conglomerate and Upper Horton strata in the River John area is also suggestive of a land area in that

locality. The Windsor history of the eastern portion of the Cobequid Upland area remains obscure.

In general the Windsor group presents a fairly clear picture of marine transgression and subsequent withdrawal over a subsiding basin. The transgression seemingly was initiated by regional subsidence of the entire area including the bordering Carboniferous uplands which were submerged, in part at least, by the invading sea waters. The withdrawal was brought about by renewed uplift in the upland regions which flushed great quantities of detritus into the basin and gradually forced the margin of the sea outwards from the border of the basin.

It is not necessary to postulate uplift in the axial region of the basin to satisfy the fact of withdrawal of marine waters. The more probable circumstances is that the rapid influx of stream-borne detritus raised the basin area above sea level and maintained it there through the late Windsor and throughout all of Pennsylvanian time in that area of the basin lying south of the Minudie Anticline.

That the basin was subsiding rapidly throughout the period following the marine transgression is well illustrated in the 15,000 feet of younger rocks that lie above the marine beds in a continuous conformable sequence.

In the foregoing discussion the Lower Windsor marine strata has been treated as representative of continuous marine sedimentation. It must be noted, however, that the interbedded red shales, which are often very thick and practically unfossiliferous, may represent oscillations from marine to deltaic environments. A comparison of the general

description of the marine section in the Minudie area with its counterpart in the Hillsborough area will serve to demonstrate the wide lateral variation in the marine sequence. The anhydrite-gypsum member in the Hillsborough area can hardly be correlated with the salt-anhydrite-gypsum member of the Minudie area. If any correlation were to be attempted the thick red shale facies lying above the salt-anhydrite-gypsum member in the Minudie area would be most reasonably correlated with the coarser red facies lying immediately below the anhydrite-gypsum member of the Hillsborough area. The basal calcareous zone in both areas are most likely correlative.

Canso Group

General Statement:

The Canso group has been defined by Bell as follows: "The Canso group comprises non-marine, red and grey shales and sandstones that overlie the marine Windsor group or non-marine rocks of equivalent age" (Bell, 1944).

The type section of Canso strata is exposed on the Strait of Canso near Port Hastings. It comprises about 1,384 feet of alternating thick grey and red shale members with scattered sandstone beds up to 15 feet thick. Several thick beds of finely laminated grey shales characterize the section. Ripples, mud-cracks and rain-pits are abundant. The Strait of Canso section is typical of the Canso group sediments in the Minas Basin of deposition and have been termed the "Minas facies" as distinguished from the "Cumberland facies". The latter

facies, characterizing the Canso group in the Cumberland Basin of deposition, comprises red shales and thick red and grey sandstones and are on the whole coarser in texture than the Minas facies. Ripple marks, mud-cracks, rain-pits, etc., are abundant. Fossils of any sort are rare in the Cumberland facies. The fauna includes *Leaia* and *Satheria*. The recognizable flora is restricted to poorly preserved Calamites. The Windsor-Canso contact is difficult to fix in the Cumberland Basin of deposition. Following the recession of the sea in mid-Windsor time a thick series of non-marine sediments were deposited that bear few diagnostic fossil remains. The first definite determination in the sequence overlying the marine Windsor beds is in the Riversdale group of Pennsylvanian age. The base of the Riversdale group is marked in several areas by a widespread coarse phase called the Claremont formation which thereby marks the upper contact of the Canso group. In no locality has the base of the Canso group been located with any great degree of accuracy.

Minudie Anticline Area:

The base of the Canso group has been designated arbitrarily as the base of the lowest observed grey sandstone in the Joggins' sections. The top of the group is fixed at the base of the lowest conglomerate bed. The total thickness of the group thus designated is about 725 feet (Bell, 1944). The lithology of the group in this area is typical of the Cumberland facies, in its thick, red and grey sandstones interbedded with dominantly red shales.

On Maringouin Peninsula and near Cape Enrage are exposed strata,

called the Shepody formation by Norman (Geological Survey Map 648A), that are identical in lithology, and undoubtedly are equivalent to the Canso group of the Minudie anticline area. The name "Shepody" has been retained to designate the Canso group in the basin. Near Cape Barrage several bands of grey shale carry Leaia and Etheria. The grey sandstones carry poorly preserved Calamites.

At the eastern extremity of the Minudie anticline area, the entire sequence of strata between the marine Windsor and the base of the Riversdale group has been designated as the Middleborough formation (Geological Survey Map 842A). A few thin flaggy grey sandstones near the top of the latter formation may indicate a correlation with the Canso group (Shepody formation) of the Joggins section.

Claremont Anticline Area:

Where River Wallace transects the southern limb of the Claremont (Malagash) anticline some 2,800 feet of red sandstone and shale are enclosed between conformable contacts with the underlying marine Windsor group and the overlying Claremont formation of lower Riversdale age, thus occupying a position identical with the combined Maringouin and Shepody formations of the Minudie anticline area. Since red sandstones and shales predominate throughout, the grey sandstone criterion used elsewhere is not applicable. It seems reasonable, however, in view of the entire lack of evidence to support a suggestion of non-deposition in this area during Canso time, to assume that the upper part is equivalent to the Shepody formation. It is impossible, on the basis of present

information, to designate what thickness should be assigned to the assumed Canso group in this area.

Northern Margin of the Cobequid Upland:

Canso strata are nowhere recognizable along the northern margin of the upland. As in case of the Windsor group there is no satisfactory evidence to indicate that the sediments were deposited over the crest of the "Cobequid positive axis" which is now represented, in part, by the Cobequid Upland. New West Branch River John the Canso group is also missing between the River John group of Horton age and the unconformably overlying Millsville conglomerate of early Riversdale age.

Arisaig Area:

A section of Canso strata is exposed near Lismore in the Arisaig area and comprises about 2,800 feet of thick grey and red sandstones interbedded with red shales (Bell, 1926). The strata overlies the marine Ardness formation of Windsor age conformably and apparently with a gradational contact. The upper contact is not exposed near Lismore, but the formation extends southwestward into the New Glasgow area where it is overlain unconformably by the New Glasgow conglomerate (Bell, 1940, p.13).

Hillsborough Area:

In the foregoing discussion of the Windsor group in this area it was noted that deposition of coarse fluviatile sediments began in mid-Windsor time and apparently continued till early Riversdale time. The limits of Canso strata cannot be defined within the conglomerate group which has been named, by Norman (Geological Survey Map No. 647A), the Hopewell

group.

Summary and Significance:

The graphical illustration of the relationships of the Canso group given in the generalized stratigraphic column (Fig. 1) is only strictly applicable to the sequence bordering the Caledonian Upland. The evidence favouring the rising of the "Cobequid positive axis" in Canso time is largely negative. It appears probable that the area of West Branch River John was one of non-deposition and probably indicates an upwarped region that separated the Arisaig-New Glasgow area from the main part of the Cumberland Basin.

It is significant that, in the vicinity of Parrsboro, relatively fine-grained sediments of Canso age lie along the southern margin of the Cobequid Upland (Bell, 1944, p. 9). The latter sediments are typical of the "Minas facies" and their nearness to the "Cobequid positive axis" would seem to indicate that no uplift other than gentle warping was effected along the latter positive axis for at least a portion of Canso time. The Canso strata are overlain with angular unconformity by basal conglomerate of the Parrsboro formation which is correlated, by Bell (1944), with the Riversdale group. It seems probable that the movements indicated by this contact, which were apparently initiated in late Canso time, mark the renewal of strong uplift along the "Cobequid positive axis".

In general, the sediments of the Canso group in the Cumberland basin indicate widespread continental sedimentation consequent upon continuing uplift along the bordering positive axes.

Riversdale Group:

General Statement:

The Riversdale group has been designated by Bell to include the strata lying stratigraphically above the Canoe group and below the Cumberland group. The type section is exposed in the Riversdale area of Colchester county. There it comprises a thick continental series of alternating red and grey sandstones and shales and locally a basal conglomerate. Its diagnostic fossil remains are Neuropteris smithii and Whittleseyia desiderata. The latter identify the Riversdale group with Westphalian A zone of Europe (Bell, 1944, p.12 and 26).

Strata of Riversdale age are well exposed in several areas within the area of the Cumberland Basin and afford a fairly good picture of its distribution and gross characteristics.

The best exposures are found on the south limbs of the Minnie and Claremont anticlines, along the northern margin of the Cobequid Upland, notably at the headwaters of River Phillip, River Wallace and River John, in disconnected areas of the Salt Springs district lying north of Springhill, and on the New Brunswick shore of Chignecto Bay.

In the Cumberland Basin the group is divisible into two formations on the basis of lithology; a lower, dominantly conglomerate facies, called the Claremont (Milleville) formation and an upper, finer-grained facies named the Boss Point formation. Both formations exhibit greater variability in thickness from place to place which reflect, in part, variable rates of subsidence and uplift over the basin area combined

with the irregularities inherent in deposits formed by stream-borne debris carried from an upland area and deposited in coalescing alluvial fans across an upland front.

The areas of exposure of Riversdale strata lying within the scope of the author's field investigation will be described in some detail followed by more general descriptions of the outlying areas.

Minudie Anticline Area:

A linear area of Riversdale strata, averaging about 8,000 feet in width, stretches from Maringouin Peninsula in an easterly direction and intersects with a small angle the northern margin of the map-area (Map 3), at a point lying immediately north of Springhill Junction. The Riversdale group lies, with dips ranging between 30 and 70 degrees, in the south limb of the Minudie anticline. It is well exposed in the Jiggins section and around the head of Maringouin Peninsula, where the tough thick grey sandstones form long reefs extending into Chignecto Bay from both shores. Inland, the group is poorly exposed as far as the village of Chignecto; but fairly good exposures are to be found on Baird Brook and St. Georges Brook which lie immediately east of Chignecto. Farther eastward and north of the map-area exposures are found in several road cuts and in one abandoned quarry situated on the south side of the road midway between Salem and West Leicester.

Along its entire length the group forms a well marked ridge that rises in the eastern region to elevations of 500 feet or more, and has thus provided ready means of tracing the strata across extensive areas of

little exposure.

In the Joggins section the group was measured and described in minute detail by Logan (1843) along with the entire section between Shule and Mill Cove. In his grouping the Riversdale strata are represented by all of his Divisions VI and all but the basal 35 feet of Division VII. In the Joggins section the group is divisible into a lower red conglomerate formation measuring about 330 feet in thickness, and an upper, finer-grained, formation measuring about 3,525 feet, (Bell, 1944, p.15).

The lower formation is known as the Claremont formation and here comprises several thick beds of rounded to sub-rounded pebble conglomerate interbedded with brick-red sandstone and shale. The pebbles consist mainly of quartzite and vein quartz with lesser amounts of granitic and volcanic rocks.

The upper formation is known as the Boss Point formation. Its general features, as displayed in the Joggins section, are as follows: Immediately overlying the Claremont formation is a zone, about 250 feet thick, of thinly bedded red shales and grey sandstones with occasional beds of bituminous limestone. Succeeding this, is a zone over 2,500 feet thick, made up dominantly of grey and greenish-grey, buff-weathering quartzose sandstone with minor thicknesses of grey and red shales, and thin streaks of coal and carbonaceous shale. The sandstone members are often very thick, ranging up to 125 feet, and characterized by much current-bedding and at many horizons by patches of limestone concretions.

The sandstone bearing the concretions has, as Logan expressed it: "much the aspect of a conglomerate". Closer examination, however, reveal

the irregular bulbous outline of the "pebbles". The material constituting the concretions is similar to the remainder of the rock excepting in their higher lime content which binds the grains into the concretion. These concretions are characteristic of the Boss Point formation in many localities throughout the basin. The uppermost zone of the Boss Point formation comprises about 600 feet of red shales and sandstones with few beds of well-bedded greenish-grey sandstone. Some of the latter sandstone beds are of grindstone quality and have been quarried in the past for that purpose.

The contact of the Riversdale group with the Canso group has been discussed in foregoing pages and it was seen to be an arbitrary contact placed at the point of a notable lithologic transition. The upper contact of the Riversdale group has been placed in Lower Cove at the base of Logans Division V. The latter division comprised a zone of entirely red sandstone and shale in contrast to the grey and greenish grey colours that predominate in the underlying strata of the Boss Point formation. No angular discordance is discernible at the contact and there are no apparent sedimentary features that indicate a long period of non-deposition.

On Maringouin peninsula, where the south limb of the Minadie anticline crosses the head of the peninsula, the group is identical with that on the Minadie shore. Standing on either shore the various coloured zones within the group can be readily matched by eye across the intervening water. The eye is greatly aided by the long strike reefs that stretch out from both shores at low tide.

The exposures observed on Baird and St. George Brooks near the village of Chignecto, together with those noted farther inland on the ridge north of the map-area, do not form a sufficiently continuous section to note any differences in the constitution of the group. All the exposures could be compared with rocks noted in the shore section.

On Little River, near the eastern extremity of the Minudie anticline Bell has noted that the thickness of the basal course phase (Claremont formation) is represented by as little as 100 feet of arkosic grit. The total thickness of the group has decreased remarkably and does not total much above 2,000 feet. The group is overlain, with apparent structural conformity by a basal conglomerate phase of the Cumberland group (see Geological Survey Map 842A).

A notable change in the nature of the contact between the Boss Point formation and the overlying Cumberland group becomes evident in the vicinity of the Macan River and eastward. There the basal part of the Cumberland group comprises a well defined conglomerate phase which becomes thicker and coarser in an easterly direction. Along the southern limb of the Minudie anticline there is, however, no indication of an angular unconformity between the Riversdale and Cumberland groups, though in the Salt Springs area, and in the area bordering the pre-Carboniferous rocks southeast of Springhill, pronounced angular unconformity is evident.

Salt Springs Area:

As a result of a complex structural development the Riversdale group is exposed in several small disconnected areas, none of which provide

a clear picture of the entire group (see Map 3). The dominant features are the unconformable contacts at both the base and the top of the group and the increased thickness of the basal conglomerate phase (Claremont formation).

The best section of the Riversdale group, in this area, is exposed on Black River downstream from the highway bridge. The exposures on Black River together with those on Deep Brook provide a fair representation of the lower part of the group. The surface exposures are supplemented by a borehole, located on the bank of Black River at a point lying approximately 1,000 feet downstream from the highway bridge. The hole was drilled in 1942, by the Nova Scotia Department of Mines, in search of salt, the presence of which was suggested by nearby brine springs. The borehole was drilled to a depth of 501 feet through alternating beds of gypsum, anhydrite and red shale of Windsor age.

The Windsor rocks are overlain by a thick sequence of poorly sorted, red, arkosic conglomerate and sandstone. The pebbles of the conglomerate are angular to sub-angular and are made up mainly of red granite with subordinate quantities of green and red argillite, reddish quartzite, chert, red sandstone and shale. The sandstone and shale constituents are usually very poorly cemented and may constitute a large proportion of the smaller sizes within the conglomerate which is, itself, a weakly cemented, friable rock. It is difficult to estimate precisely the thickness of the conglomerate but a rough approximation would place it at about 1,200 feet.

Overlying the conglomerate is a sequence of grey, greenish-grey and red sandstone and shale with minor conglomerate. The pebbles in the latter are more rounded than those in the underlying conglomerate sequence but the constituents are otherwise similar. The grey sandstone beds are characterized, in places, by patches of limy concretions that are altogether similar to those found in the Boss Point formation of the Joggins section.

Further downstream the latter sequence is overlain, with pronounced unconformity, by coarse sediments that mark the base of the Cumberland group in this area. At the contact the Riversdale strata dip approximately vertical, or are slightly overturned to the north, and the Cumberland strata dip gently at about 25 degrees northward. Thus an angular discordance of about 65° is indicated. About 1,400 feet of this finer-grained zone are exposed between the unconformity and the top of Riversdale conglomerate facies. The total thickness may be far in excess of this figure but the upper part lies hidden under the Cumberland strata and therefore is not measurable.

In the broken southern limb of the northwesterly trending anticlinal structure that intersects the Claremont anticline on the S Ringhill-Oxford highway, scattered exposures indicated a similar sequence of strata. The basal sediments of the Cumberland group overlie the Riversdale group with pronounced unconformity that is particularly evident in a sharp truncation of the Riversdale structure a short distance west of the graveyard that is situated on the south side of the highway.

The area lying across the Canadian National Railway near Black River station, that is indicated as being underlain by Riversdale strata, contains a few scattered outcrops of gray sandstone, mainly on Rutledge Brook. Windsor rocks are exposed north of this area as indicated by a limestone outcrop, gypsum occurrences and a brine spring. No indication of the thick red conglomerate of the Black River section was found and it is not certain whether the contact is an unconformable one or whether a fault separates the areas. It seems probable that movement actually took place and it is believed that diapiric action in the soft Windsor sequence may be partly responsible for the relationship. Downstream on Rutledge Brook at the contact between the Riversdale and Cumberland groups, gray sandstones of the latter group overlie the Riversdale strata with an angular discordance. The coarse basal sediments of the Cumberland group noted in the Black River section are not present here. It is believed that their absence is due to a recurrent anticlinal structure whose southwesterly trending axis was located some distance north of the locality. The Cumberland group apparently overlapped the structure after it had been sufficiently eroded. The dampening of the relief as a result of erosion is believed responsible for the finer texture at the horizon where the overlap is exposed in this area. A similar effect may account for the absence of the Riversdale conglomerate discussed if it may be assumed that the folded structure was initiated during or before Riversdale time. The absence of a thick basal conglomerate in the Riversdale group on Little River together with the remarkable overall thinning noted there may indicate an extension of the recurrent fold

assumed to be present in the Salt Springs area. A line joining these localities approximately parallels the axis of the Claremont Anticline which is considered, on much stronger evidence, to have been initiated in Canso or early Riversdale time and activated several times afterward.

Poorly sorted conglomerate beds dip steeply to the south along the crest of Claremont hill. The thickness and content of the conglomerate sequence are similar to that on Black River. The conglomerate is overlain by a series of finer-grained rocks similar to those on Black River. At least 3,300 of the latter sequence is indicated here. In the eastward extension of this group, where it intersects the Fugwash River, Norman (Geological Survey Map 410A) has collected flora (Whittleseyia desiderata and Neuropteris schelani) indicating Riversdale age. Pronounced angular discordance with the overlying Cumberland group exists near the highway immediately south of the western end of Claremont hill, but farther eastward the angular discordance apparently decreases.

In the deep depression lying below the steep northern slope of Claremont hill greatly disturbed Windsor sediments are exposed and the Riversdale strata are presumed to be either in unconformable or fault contact with the Windsor group.

Northern Margin of the Cobequid Upland:

Near Collingwood Corner, about 7 miles southeast of Springhill, Riversdale strata belong to the upper fine phase appear unconformably beneath basal conglomerate of the Cumberland group and overlap the pre-Carboniferous rocks of the Cobequid Upland (see Map 2). Similar rocks

stretch in a narrow band across the margin of the upland easterly as far as West New Annan. The apparent thickness of the exposed Riversdale strata is about 3,400 feet. The actual thickness of the group depends on the configuration of the land surface upon which the sediments were deposited and therefore probably varies considerably across the margin of the upland area.

At West Branch River John 900 feet of the basal conglomerate phase (Hillsville formation) of the Riversdale group lie unconformably on the River John group of Horton age. The conglomerate is distinguished from the conglomerate of the River John group by its content of igneous, mainly granite, pebbles (Stewart, 1931). The conglomerate sequence grades upward into a finer phase made up dominantly of grey and red sandstones interbedded with brownish red shale and commonly marked by patches of limy concretions similar to those described in an earlier section. The upper fine phase of the Riversdale group is approximately 3,300 feet in thickness (Bell, 1944).

On River Wallace the Riversdale group is well exposed in the southern limb of the Claremont anticline. A coarse and fine phase are again recognizable. The lower conglomerate phase (Claremont formation) succeeds the red sandstones and shales of the Middleborough formation (upper part of which is considered to be Canso) with structural conformity. The conglomerate phase is much finer than at West Branch River John. The pebbles rarely exceed 4 inches in diameter and the thickness measures only about 400 feet.

The overlying, finer phase (Boss Point formation) is about 4,000 feet thick and is overlain with structural conformity by a rather thin basal conglomerate of the Cumberland group. The total thickness of the Riversdale group at River Wallace (4,400 feet) is comparable to the total for the West Branch River John section (4,200 feet).

Southern Margin of the Caledonian Uplands:

The long reefs of resistant gray sandstone that extend from the shores of Boss Point and Maringouin Peninsula may be observed to coincide with similar reefs that extend from both sides of Grindstone Island and from Mary's Point on the New Brunswick mainland. The gray sandstones curve smoothly through Mary's Point and trend southwestward, paralleling the shore as far as Cape Enrage where they again dip into the waters of Chignecto Bay in long narrow reefs. Along the shore the sandstone members dip southeastward with inclinations ranging between 50° and 85°.

The correlation of the upper phase (Boss Point formation) across Chignecto Bay is bolstered by the contained flora (Whittleseyia desiderata and Neuropteris schelani) of Riversdale age. This latter phase is underlain by a poorly exposed section of interbedded red conglomerate, sandstone and shale that is similar to the coarse phase (Claremont formation) at the Joggins section. It appears to be somewhat thicker, and is variously estimated between 500 and 800 feet.

Northwest of the Cape Enrage locality Riversdale strata overlap the pre-Carboniferous rocks of the Caledonian Upland. Over long

distances the upper finer phase (Boss Point formation) is seen to rest directly on the pre-Carboniferous rocks while in places conglomerate phase is seen to intervene and lie on the pre-Carboniferous. Here, the apparent thickness of the basal conglomerate is very small and it is considered to be the feather edge of an overlapping coarse facies that grades upward and outward into a finer sandy facies in response to the diminishing relief during deposition.

Similar relations are observable farther northeastward, near Albert Mines, although here the lower coarse facies lies, in places, unconformably on truncated edges of Mississippian strata as well as on the pre-Carboniferous rocks.

A thick conglomerate sequence (Hopewell group) is exposed on Shepody Mountain and at Dorchester Cape. On Dorchester Cape, which lies at the head of Shepody Bay, the conglomerate underlies the upper fine phase (Boss Point formation) of the Riversdale group but its base is hidden by strata of Pictou age which lie on it unconformably. The Shepody Mountain area has already been described in reference to the Windsor group. It was noted that the base of the conglomerate contained interbeds of impure limestone of Windsor age and it was implied that an uplift was effected at this time along the "Caledonian positive axis". If we are correct in the presumption that this Windsor conglomerate is part of the same

conglomerate facies that constitutes the basal Riversdale group, then it must be inferred that coarse continental sedimentation proceeded along the margin of the "Caledonian positive axis" from Windsor time through to early Riversdale time. Presumably the stream-borne debris was deposited in coalescing alluvial fans and considerable variation is to be expected across the upland front. The decrease in the thickness of the coarse facies from something in excess of 1,500 feet at Shepody Mountain to about 500 feet at the head of the Maringouin Peninsula, a distance of six miles, is not considered excessive in view of the mode of deposition.

Summary and Significance:

It was noted that the Riversdale group is constituted of two facies, a lower coarse facies and an upper, finer facies, designated the Claremont formation and Boss Point formation respectively.

The coarse facies, included in the Riversdale group, apparently belongs to a much larger unit of coarse sediments which were eroded from the bordering "positive axes" during an uplift which was initiated in late Windsor time and reached a peak during early Riversdale time. This inference is based on the strata exposed in the axial region of the basin where the marine Windsor strata grades upward into continental sediments that become progressively coarser

and reach their greatest coarseness in early Riversdale time. The finer facies that constitutes the upper part of the Riversdale group seemingly indicate decreasing vigor in the positive movement of the bordering uplands as it eventually overlapped the coarse facies in many places along the basin margins and transgressed well up onto the crests of the uplands.

While sedimentation continued in the axial region without serious interruption, the same is not true for the areas adjacent to the bordering uplands. The Maringouin and Shepody formations are missing between the marine Windsor strata and the Riversdale group at Salt Springs and along the western part of the Claremont anticline. Several lines of evidence point to folding movements in this area in Canso or early Riversdale time.

In the Hillsborough and Albert Mines areas of New Brunswick the basal Riversdale strata lies unconformably on all pre-Riversdale strata that has been recognized. The Maringouin and Shepody equivalents are nowhere in evidence in these areas but farther south, in the Shepody Mountain area, they apparently are represented within the thick conglomerate facies (Hopewell group) exposed there.

Cumberland Group:

General Statement:

The Cumberland group is by far the best developed unit of sedimentary rocks that is exposed in the Cumberland Basin. The group includes the coal-bearing strata of the Springhill and Joggins coalfields and therefore it is a unit of great economic importance.

Bell has introduced the group to include strata that lie disconformably above the Riversdale group and unconformably below the Pictou group (Bell, 1944 p.19). The type section lies along the shore of Chignecto Bay, extending for thirty miles from Lower Cove on the northeast to Squally Point on the southwest. The flora has been studied in detail by Bell and he has presented the fossil lists and the correlation with European and American chronology (Bell, 1944 pp. 26-29). Strata definitely correlated with the Cumberland group has been recognized only in the Cumberland Basin and in the Stellarton structural gap (Bell 1940, p.16).

The lithology of the type section has been measured and described in minute detail by Logan and Fletcher (1908 pp. 417-550) and later summarized by Bell (1941 pp. 364, 368, 369). The lithology of the group, as it is exposed in the shore section, is considered to illustrate the sedimentation in the "axial region" of the Cumberland subsiding basin of deposition in an excellent manner. Rapid lateral variations toward the margins of the basin have proved to be mappable in broad lithologic divisions which provide a rather illuminating picture of the development of the basin during Cumberland time.

The position of the coal bearing strata within the group is of great significance since its probable areal distribution in the subsurface may be deduced with considerable confidence, and thereby serves as a basis for exploration in search of further reserves.

Within the map-area (Map 2) the Cumberland group constitutes a vast wedge of non-marine sediments that, in the Joggins area, must have reached an original thickness in excess of 12,000 feet. Strata that belong to the uppermost part of the group overlap, as a thin veneer, a large section of the Cobequid Upland. In several places, notably toward the western extremity of the upland, small areas of pre-Carboniferous rocks protude through the veneer. In a northwesterly direction Cumberland strata outcrop in the bottom of Chignecto Bay and do not appear in New Brunswick on the strip of lowland that lies along the Caledonian Upland. The latter circumstance is unfortunate in that it leaves the northwestern border of the basin incomplete, and the sedimentation there must be interpreted from broader relationships.

The great wedge of sediments that constitutes the Cumberland group may be broken down, on a lithological basis, into five distinctive parts or facies, none of which are considered to be bounded by "time planes" but rather constitute a series of interfingering facies. They have been mapped and illustrated as such for two principal reasons: (1) they indicate most clearly the tectonic control that governed the development of the basin in Cumberland time, and (2) they show the distribution of the particular facies which may include coal seams of workable quality.

The two most significant facies from a tectonic view point are (1) a lower coarse conglomerate facies which marks the base of the Cumberland group over most of the area, and (2) an upper coarse, mixed conglomerate and sandstone facies which lies near the top of the group. Both coarse facies reach great thickness near the margins of the basin and decrease in thickness to zero in the axial region. Where the coarse facies overlapped onto the bordering uplands in Cumberland time they are seen to thin markedly and feather out.

In the area of low dips, at Newville Lake and westward along the margin of the Cobequid Upland, the two coarse facies merge and are largely indistinguishable from each other. Eastwardly from Newville Lake where the strata has been tilted to a steeper position and, in the Springhill area where the strata has been folded in the westerly pitching nose of the Claremont Anticline, a finer grained facies appears between the two coarse facies. The latter fine facies is exposed northward from Springhill and, at Little Forks River, it sweeps around a broad southwesterly pitching syncline and thence stretches westerly, in a band of ever-increasing width, to the shore of Chignecto Bay. These three facies may be visualized, in a very broad sense as three interlocking wedges with the butt end of the middle fine facies lying in the "axial region" of the basin.

This middle fine facies had been further divided into two facies on the basis of the presence or lack of coal seams. In the Springhill area it was found that, if the horizon marking the top of the highest coal seam were traced southwestward, it coincided as closely as could be determined, with the junction of the two coarse facies where they begin to merge at a point located about five miles

southwest of Mapleton. In the Joggins area the horizon marking the top of the highest coal seam was carried eastward, largely on structural lines defined in air photographs, and was found to coincide within reasonable limits of precision with the northward projection of the highest coal horizon defined in the Springhill area. In both areas a notable lithologic change at this horizon was noted in an increasingly higher proportion of thick, dominantly grey, sandstones. This last plane of division probably approaches a "time plane" more closely than any other.

The fifth facies to be distinguished is a dominantly red shale and sandstone group that lies along the axis of the broad syncline that trends southwesterly through the central region of the map-area. Rather ill-defined structural conditions seem to indicate that it is considerably thicker in the northern limb than it is in the southern limb of the syncline.

Briefly the five principal facies may be outlined as follows:

- (1) a lower, coarse, dominantly conglomerate facies that marks the base of the Cumberland group over a large area.
- (2) a fine facies, dominantly sandstone and shale, enclosing a zone of coal seams of workable thickness and quality. This zone is contemporaneous with the upper part of (1).
- (3) a fine non-coal-bearing facies, dominantly sandstone with minor conglomerate, that is contemporaneous with the lower part of (4).
- (4) an upper, coarse, dominantly conglomerate and sandstone facies.
- (5) a fine facies, dominantly red sandstone and shale that is, in part, contemporaneous with the upper part of (4).

These lithologic units are graphically illustrated in the generalized stratigraphic column (Fig. 1). The reader is referred also to Map No.2 (2 mi. = 1 in.) for the distribution of the facies over the basin and to Map No.3 (1/40,000) for greater detail in the Joggins - Springhill areas. The lithology and other points of interest will be described in the same order as they are given above, which is, broadly, in order of decreasing age.

(1) Lower Coarse Facies:

In the southwestern portion of the map-area, the lower coarse facies is well exposed in the banks of the streams that drain the northern margin of the Cobequid Upland and in the north it is seen in the beds of streams that drain the ridge of the northern margin of the map-area. In the Salt Springs area it is seen principally in the section along Black River.

Along the margin of the Cobequid Upland this facies lies directly on the pre-Carboniferous rocks from a point near Newville Lake eastward to Collingwood where Boss Point strata of the Riversdale group intervene. A small part of the lower coarse facies also lies on the pre-Carboniferous rock at the western extremity of the Cobequid Upland and is exposed on the shore of Spicer Cove. Here and at one point on the Eatonville - New Yarmouth road, within the same area of exposure, were the only localities where the pre-Carboniferous contact was observed directly. In most cases, however, the contact could be bracketed, by outcrops and by large angular blocks in the drift, within several hundred feet.

The most characteristic feature in the area of exposure bordering the upland is the progressive increase in grain size and angularity together with an increasingly poorer sorting toward the pre-Carboniferous contact. Near the contact the conglomerate in many places, notably in the head-waters of Halliday Brook, is a typical basal sharpstone conglomerate. Sharp angular blocks range up to six feet in longest dimension, with great quantities of such blocks measuring in the neighborhood of one, two and three feet in longest dimension. Northward from the contact the conglomerate becomes finer, more rounded and there is a larger proportion of sandstone, usually in the form of lenses interbedded with the conglomerate.

That the conglomerate at the contact is not always extremely coarse is demonstrated at Spicer Cove where interbedded sandstone and pebble conglomerate lie on the pre-Carboniferous rocks with only a small thickness of residual basal sharpstone intervening (Plate 2). A similar relationship was noted where the



Plate 2 Contact at Spicer Cove

contact is exposed on Eatonville Brook at a point approximately 2 miles inland from Spicer Cove. It is believed however that

the horizons of these particular contacts are near the top of the Lower coarse facies and represent overlap on the upland where it had been eroded down close to its lowest level shortly before the renewal of uplift which initiated the upper coarse facies.

The constituents are mainly red granite, green and grey diorite, red and green chert, grey and reddish quartzite, and green, grey and pink mica schist. The red granite pebbles seem to dominate in relative abundance while the other constituents are present in highly variable proportions. The matrix is composed of coarse angular grains of the same material but there is a considerable abundance of monomineralic grains, particularly quartz and feldspar which have been separated from the larger granite pebbles as a result of the breaking action imposed during transport.

A. A. Brown made a representative collection of specimens from the area lying between Polly Brook and Lawrence Brook while working as chief assistant to the author during the field season of 1949. During the following academic year he carried out a microscopic study of the specimens as part of a thesis he submitted for the M.Sc. degree at the University of New Brunswick. (Brown, 1950). The specimens were taken from the finer grained matrix of the conglomerate and from the sandstone lenses. Several photomicrographs, taken by Brown, have been included in this report as illustrative of the mineral content and textural characteristics of these rocks. (Plates 6 -14).

The colours of the conglomerate are dominantly grey, green, and red in that order of prevalence. The grey and green colours are directly related to the colour of the constituent rocks. The red colour in the coarse conglomerate is generally due to red feldspar, while in the finer grained material it is usually a result of heavy hematite staining.

The maximum thickness of the conglomerate along the upland margin is estimated at about 4,500 feet. This figure is probably close to the actual thickness in the area immediately south of Springhill, but it is believed that it thins considerably in a westerly direction as it approaches Chignecto Bay and the intersection of the original Carboniferous uplands. Here the gradient from the upland to the basin area was probably somewhat smaller since it lies in the apical part of the basin. Direct evidence bearing on this point is furnished by a borehole, bored near Spicer Cove about fifty years ago and recorded by Fletcher (Logan and Fletcher, 1908). The borehole is located approximately 6,000 feet north of the contact with the pre-Carboniferous rocks. It penetrated the pre-Carboniferous basement rock at 893 feet 6 inches. The average dip in the area is about $5\frac{1}{2}$ degrees northeast. Assuming that no fault of great displacement intervenes, an original slope of 4 degrees is indicated. If the dip of the strata is partially original, the original slope may have been slightly steeper. The thickness of strata missing at the contact because of overlap from the borehole locality, is approximately 400 feet.

The apparent decrease in thickness noted at South Brook and westward is considered to be due entirely to the fact that that area has not been tilted up as far as the area immediately south of Springhill and therefore the maximum thickness is not truncated there. As indicated earlier, this lower coarse facies overlapped the upland border and eventually feathered out over the crest of the upland. With decreasing dip from South Brook westward the age of the contact horizon is progressively younger, and the narrowing band at the surface merely indicates burial of the older conglomerate horizons by overlap.

The lower coarse facies is exposed around the southwesterly pitching nose of the Claremont Anticline. On its southern limb not more than 2,000 feet are exposed and it apparently continues to thin around the fold and finally feathers out entirely at a point immediately north of Springhill. The conglomerate is very similar to that along the margin of the Cobequid Upland excepting that the pebbles are smaller and somewhat rounded.

A small area of exposure extends across Black River near the mouth of Deep Brook. On Black River about 275 feet of interbedded conglomerate and sandstone underlie the coal bearing facies, and rest with pronounced angular uniformity on Boss Point strata of the Riversdale group. Here the lower coarse facies is much finer and better rounded than elsewhere in the map-area but the constituents remain the same and indicate a common source.

A large area of exposure lies along the northern margin of the map-area. Here the lower coarse facies lies, with apparent structural conformity, on Boss Point strata of the Riversdale Group, though the abrupt transition may indicate a disconformity. However, the sudden lithologic change does not necessarily indicate an hiatus but possibly reflects a relatively rapid uplift in the bordering uplands.

On Little Forks River a rather restricted area of exposure indicates a sequence of coarse sandstone and conglomerate. The rock content of the conglomerate is largely similar to that in the conglomerate flanking the Cobequid Upland. A small percentage of red cross-bedded sandstone pebbles was noted which could have been

derived from any of the underlying Carboniferous formations. The constituent pebbles range up to three inches in longest diameter and are almost all well rounded.

Considerable difficulty has arisen concerning the stratigraphic position of these latter conglomerate beds on Little Forks River, resulting from the fact that they lie along the eastward projection of the strike of finer grained strata that lie above the Chignecto coal seams. Previous workers have indicated that a north-south trending fault has displaced the lower coarse facies on Little Forks River. Lack of outcrop make a certain decision impossible in this area, particularly since, in the area lying directly on the eastward projection of the strike of the coarse facies that underlies the Chignecto seams, there are no exposures whatever. It will be noted that the author has interpreted the succession without a fault and considers the coarse facies exposed on Little Forks River as a tongue of coarse grained material that projects from the main unit of the lower coarse facies. Several facts support this interpretation: (1) there is no apparent break in the long narrow ridge that is underlain by Boss Point strata and lies immediately north of the map-area. A displacement of the magnitude required for a fault interpretation would seemingly require a displacement of the ridge. (2) Boss Point strata exposed in the ridge, near the assumed fault, strike across without apparent deflection. (3) A conglomeratic facies is exposed on Styles Brook in an interval that lies approximately on the westward projection of the strike of this "tongue" of coarse facies exposed on Little Forks River. (4) Eastward from Little Forks River and beyond the

map-area a much thicker section of coarse facies (G.S.C. Map 842A) seems sufficient to account for the necessary increase in thickness in that direction. (5) The Chignecto group of coal seams deteriorate rapidly eastward from Styles Brook and disappear in coarse sediments.

On Styles Brook a more complete section is exposed and the lower coarse facies here consists of coarse sandstone and conglomerate with constituents similar to that on Little Forks River. The thickness in the Styles Brook section is about 1,850 feet. The lower coarse facies extends westward from Styles Brook with a fairly uniform thickness for a considerable distance. At At. Georges Brook the thickness appears to have increased to about 2,400 feet. At Baird Brook the thickness is maintained at about 2,400 feet but a much larger proportion of sandstone was observed. Westward from Baird Brook the lower coarse facies decreases in thickness and in coarseness and disappears before reaching Lower Cove on the shore of Chignecto Bay. At the shore a thick series (2,100 feet) of red sandstone and shale overlie the Boss Point strata with structural conformity. These red strata are considered to be equivalent in age to the lower part of the lower coarse facies.

East of the map-area the lower coarse facies is exposed along the northern margin of the Cobequid Upland where it lies unconformably on Boss Point strata of Riversdale age, and grades upward and outward into a finer sandstone and shale facies bearing one or two thin coal seams. This latter fine facies is separated from similar strata in the Springhill area by a wide area of exposure of

the lower coarse facies which has been brought to the surface on the crest of a broad arch in the area of Polly Brook. The lower coarse facies is also exposed in the south flank of the Claremont Anticline, where it is considerably thinner, in conformity with the general northward thinning away from the Cobequid Upland that was noted within the author's map area.

Farther westward the finer facies that overlies the lower coarse facies disappears and the lower coarse facies is overlain, probably disconformably but without angular discordance, by strata of the Pictou group. At Wallace River the lower coarse facies is considerably thinner and eastward it presumably feathers out under the cover of Pictou sediments (G.S.C. Maps 410A, 409A). On the West Branch River John the Cumberland group is entirely absent between the Boss Point strata of the Riversdale group and the unconformably overlying Pictou group (Bell, 1944, p.21).

In the area of the Pictou Harbour syncline Cumberland strata (New Glasgow conglomerate) again appear disconformably beneath the Pictou group (Bell 1944, p.21). It seems probable that the broad arch postulated as existing in the River John area during Windsor and Canso time was re-activated during Cumberland time and formed a low upland barrier between the Pictou coalfield and the main portion of the Cumberland Basin.

(2) Coal-bearing facies:

The upper boundary of the coal bearing facies was fixed,

as noted earlier, by the uppermost horizons of coal in the Joggins and Springhill areas. The near coincidence of these horizons when projected, on structural trends, around the intervening syncline suggests a correlation in time. The southwestward projection of the uppermost coal horizon in the Springhill area coincided with the point at which the two coarse facies merged along the Cobequid Upland and thereby lends support to the hypothesis that the initiation of the upper coarse facies marked the disruption of the drainage characteristics of the basin and ended the period during which widespread peat bogs could take root over the surface of the subsiding basin.

The base of the coal-bearing facies has been arbitrarily placed at the top of the lower coarse facies and except where interfingering occurs parallel to the strike of the strata, as at Little Forks River, this boundary is readily mapped. A great quantity of information on this coal-bearing facies and its included coal seams is available from mine workings, borehole records and outcrops.

Possibly the best representation of the gross character of the facies is to be had in the Joggins shore section. Here the base of the coal bearing facies is marked by some 2,100 feet of red shales and sandstones (Logan's Division 5). It was noted earlier that this strata is considered to be equivalent in age to the lower part of the lower coarse facies. The Joggins area occupies a position in the axial region of the basin and these red sediments owe their relatively fine texture to their distance from the source areas. During a period of uplift in early Cumberland time the

drainage system was sufficiently active to inhibit the establishment of peat bogs. Later, as the vigour of the uplift decreased and as the basin area was levelled off by the great volume of sediment that was washed into it, the peat bogs gradually took root and were later widespread at the peak of peat deposition.

The red sediments are succeeded by almost 5,000 feet (Logan's Division 3 and 4) of alternating grey and chocolate thinly bedded shales and arenaceous shales; grey and greenish grey thickly bedded soft shales; grey and chocolate shales with ironstone concretions; carbonaceous shales; grey, greenish-grey and red sandstones as thin beds and thick massive lenses; beds of bituminous shale carrying great quantities of shells and fish remains; underclays penetrated by rootlets; and coal in seams ranging from a few inches to several feet in thickness (See Plate 3).

The entire section was measured in detail by Logan (1843) and his data has been incorporated, by the author, into a graphical illustration of the gross relationships between coal and the clastic sediments (Fig. 2). The diagram will serve to demonstrate the relative abundance of each type of clastic sediment with respect to the occurrence of coal. The section from 0 to 6,675 feet corresponds to the "coal-bearing facies" as defined in this report. Several points are illustrated by the diagram; (1) the inverse ratio of coal to red sediments and its direct relationship to the grey and greenish sediments. This is entirely expectable since the colour of the finer sediments here depend almost exclusively on the oxidation state of the iron. (2) The peak coal content does not coincide exactly with the peak in fine-grained sediments, which lags somewhat. (3) The



A. Massive sandstone lens splitting into several thin sandstone beds; in the Joggins section, about 1,000 feet south of McCarrens River bridge.



B. Closeup at one end of the sandstone lens in A.



C. Outcrop of resistant, bituminous shale bearing shell and fish remains; in the Joggins section at Coal Mine Point.



D. Thin coal seams in a typical sequence of grey shales, under clays, sandstones etc., at Coal Mine Point.

introduction of conglomerate coincides fairly to the termination of coal deposition. (4) The peak in coal content coincides exactly with the zone of workable coals.

The characteristics of the coal-bearing facies in the Joggins section are largely representative of the Springhill and Salt Springs area. The only missing type of sediment in the Springhill area is the bituminous shell-bearing shale noted in the Joggins section. One bed of similar strata is exposed on Black River in the Salt Springs area where it underlies the Sandrun Seam at a short distance. Almost invariably, the coal seams are immediately underlain by underclays that are penetrated by rootlets which testify to the "in situ" origin of the coal deposits. At Springhill these underclays are best observed in the mine dumps where the "pavement brushings" have been discarded.

The coal-bearing facies, because of the excellent structural information available from the boreholes, the mine workings and coal seam outcrops, provide more detail on the structural evolution and configuration of the basin floor than any other part of the Cumberland group. Evidence of thinning over relatively "positive" areas is abundant and the very definite control exerted on the distribution of the coal deposits is much in evidence.

The Joggins group of coal seams have been correlated from the Joggins shore to Maccan and the seam correlation chart (Fig.6) is highly significant in placing the axis of the subsiding basin in Cumberland time.

From a perusal of this correlation chart it is apparent that in the shore section the thickness of sediments between the Joggins and Forty Brine seams is approximately 300 per cent greater than the thickness of the same stratigraphic interval in the Maccan area. The thickening is progressive in a westward direction and it is concluded therefore that the major axis of subsidence must lie west of the shore at Joggins. The average orientation of the massive sandstone lenses exposed in the cliffs and the evidence supplied by current-bedding support this conclusion. The large number of determinations of current directions that were made along the shore section from Joggins to Spicer Cover indicates that present position of the major subsiding axis in Cumberland time extends from a point near the mouth of Apple River approximately N 48 degrees E (See Fig. 3).

The bordering positive axes, represented in part by the Cobequid Upland on the south and the Caledonian Upland on the north, clearly represent the margins of the subsiding basin. The rapid lateral variation in a direction perpendicular to the Cobequid axis is vividly demonstrated in the area south of Springhill (See Map 4 and accompanying battery of sections).

Several lines of evidence point to tectonic control of deposition on a smaller scale also. It may be observed on Map No. 3 that the coal bearing facies thins considerably across the region immediately west of Black River Station, which lies about three miles north of Springhill. It may be noted also that here the coal-bearing facies overlies the Windsor and Riversdale strata unconformably. A few miles farther north, in the

region between Styles Brook and Little Forks River, the Chignecto group of coal seams deteriorate and disappear in barren coarse sediments. Within the Springhill area, notable thinning occurs in the stratigraphic intervals between prominent coal seams in both a northerly and southerly direction. An axis of greater subsidence which trends roughly south 65 degrees west through a point near the Springhill railway station is indicated and the belt of best quality coal coincides with this trend. In addition, the thickest coal along the crop of the Sandrun seam, in the Salt Springs area, lies on the projection of this axis. The unconformable contact between the Cumberland group and older strata in both limbs of the Claremont anticline has already been described.

The author's interpretation of these observations is that the thickness and distribution of the coal-bearing facies was controlled by folded structures which were active during deposition. The present Claremont anticlinal axis was the site of a "positive axis" and was succeeded on the north by a "negative axis" which was succeeded in turn by a second "positive axis". The three tectonic elements have been named the "Claremont positive axis", the "Springhill negative axis" and the "Black River positive axis" respectively.

The Springhill negative axis coincides with the belt of best quality coal and within the present mine workings the limites of workable coal are determined by the tectonic elements outlined above, but as the workings are carried southwestward beyond the influence of the Black River positive axis it is expected that the area of coal deposition will widen

in a northerly direction. Beyond the influence of the Claremont positive axis the southern limit will be controlled by the northern margin of the major Cobequid positive axis. These features are illustrated in Fig. 3, which also indicates the probable original distribution of the coal-bearing facies throughout the basin area. The area that lies within the limits indicated and which has not been subjected to deep erosion holds the best prospects for future coal reserves. The limit in depth imposed by mining methods will, of course, eliminate a large part of otherwise potential coal reserves.

(3) Fine non-coal-bearing facies:

This facies is distinguished from the underlying facies principally by its lack of coal seams and a generally coarser texture. Massive grey sandstones are common and in places there are conglomerate beds, generally in the form of lenses. The pebbles in these conglomerates rarely exceed two inches in longest diameter and are usually well-rounded. Near the base of this facies the finer textured shales and arenaceous shales are dominantly grey and greenish-grey in colour but toward the top a marked transition toward red colours may be observed though the total content of shale and arenaceous shale decreases considerably in that direction. The general characteristics of the entire facies are illustrated in the Joggins shore section from Ragged Reef Point (Peter's Point) to the mouth of Sand River. A graphical analysis of a part of the facies is given in Fig. 2.

In the exposed sections and particularly on the shore a wide variety of sedimentary features include scour-and-fill structures on both large and small scale, current bedding, ripple mark, raindrop impressions and drift plant material, all in great profusion.

A series of boreholes were drilled along the Athol-Maclean road in 1893 under the direction of Hugh Fletcher (Kerr, 1924). Several of these holes cut this facies and provide an excellent representation of the facies in this region. Thin and thickly bedded, fine and coarse grey sandstones interbedded with red shales with minor conglomerate members indicate a section generally similar to that exposed in the shore section.

The thickness of the facies varies from about 4,000 feet in the axial region of the basin to zero along the margin of Cobequid Upland where it grades laterally into the coarser sediments assigned to the lower part of the upper coarse facies.

(4) Upper Coarse Facies:

This facies is a well defined unit of mixed conglomerate and sandstone that is distinguished from the lower coarse facies chiefly in its greater content of sandstone. It is exposed along the northern margin of the Cobequid Upland where it lies in the gently dipping southern limb of the broad syncline that dominates the map-area; it extends around each end of the syncline to points lying approximately on the synclinal axis, where it feathers out into finer sediments that have been mapped as separate facies.

From Newville Lake westward to New Yarmouth it lies directly on the pre-Carboniferous rocks of the Cobequid Uplands. At no point was the contact observed directly, but at most places it could be bracketed with fair precision. Near the contact the upper coarse facies exhibited the same angular, poorly sorted characteristics of the lower coarse facies and differ only in the relative size of the constituents which in the upper coarse facies seldom exceeded 12 inches in longest diameter, compared with the much larger blocks, ranging up to six feet across, that were noted in the lower coarse facies. Northward from the contact the pebbles become much smaller and better rounded and in most outcrops the conglomerate is intimately associated with irregular lenses of sandstone such as is illustrated in Plate 4.



A. Upper coarse facies
Location: New Salem



B. Upper coarse facies
Location: South Branch Apple River

The upper coarse facies was cut in the two boreholes near Newville Lake and the position of the latter facies in these borings is illustrated in the cross-section which has been drawn through that area (See Map 3 and cross-section).

The thickness of the upper coarse facies is highly variable. A maximum thickness of 2,000 feet is estimated in the area adjoining the Cobequid Upland and it thins northward to zero as it grades into finer facies in a distance of about 10 miles from the present contact of the Cumberland group with the pre-Carboniferous rocks of the Cobequid Upland.

(5) Fine, dominantly red, facies:

This facies is exposed only along the axial region of the major synclinal structure noted earlier. In the eastern half of the synclinal trough the rocks included in this unit are almost entirely red sandstones, arenaceous shales and shales, but in the western half some grey sandstones enter the sequence.

A representative section of this facies is to be had in the record of a borehole, 1217 feet in depth, that was drilled on Whetstone Brook which empties into the Maccan River about 1 mile north of Southampton (N.S. Dept. of Mines, 1910, p. 173). Two beds of conglomerate, each about 3 feet thick, were cut near the bottom of the hole. Overlying these beds are red shales interbedded with lesser amounts of red and grey sandstones. It is probable that the bottom of the hole cut the transitional zone between this facies and the upper coarse facies. A second borehole, drilled on Reid Brook (Bennets Brook) near the crossing of the old Athol-Springhill road (N.S. Dept. of Mines Rept., 1928) to a depth of 287 feet in horizontal

strata, cut a sequence of almost entirely red shale and sandstone with narrow bands of grey sandstone near the top of the hole.

A maximum thickness of 1500 feet is estimated for this facies. The maximum is represented in the north limb of the major syncline. In a southerly direction, toward the Cobequid Upland it grades laterally into the coarse sediments of the upper part of the upper coarse facies.

Summary and Significance:

The Cumberland group is a vast wedge of non-marine sediments that were deposited in a subsiding trough that lay between the bordering Caledonian and Cobequid positive axes. It is dominated by two units of coarse facies which reflect two periods of accelerated uplift, the first of which was the more pronounced.

A large number of features point unmistakably to the Cobequid positive axis as a source of sediment. The Caledonian positive axis cannot be so definitely fixed as a source area from direct evidence in Cumberland strata but several facts point toward a strong probability that it was: (1) Cumberland strata has not been recognized along the southern margin of the Caledonian Upland. (2) Pebbles within the conglomerate lenses, contained in the finer, non-coal-bearing facies in the shore section near Ragged Point and Two Rivers, are made up largely of vari-coloured vein quartz, for which no correlatives have been recognized in the Cobequid Upland. (3) At the southwestern extremity of the Caledonian Upland, at a point about 20 miles east of St. John (G.S.C. Map 477A) conglomerate of the Lancaster formation, which is correlated with the

Cumberland group (Bell, 1944, Fig. 11), lies unconformably on the pre-Carboniferous rocks of the upland and has apparently overlapped earlier Carboniferous formations which are exposed farther west. (4) The Caledonian positive axis was an area undergoing erosion in late Riversdale time, as attested by overlap of late Riversdale sediments onto the pre-Carboniferous rocks along the southern margin of the Caledonian Upland. (5) Non-marine strata, mapped as the Peticodiac group in New Brunswick, include in places, rocks belonging to the Cumberland group though no definite division has been made. In many places north of the Caledonian Upland the Peticodiac group lies unconformably on strata correlated with the Hopewell group and also, with a similar unconformable relationship, on rocks of Mississippian age and older.

The most important facies from an economic standpoint is the coal-bearing facies which was deposited during the deceleration of uplift that resulted in the recession of the lower coarse facies from the basin area. During this period sedimentation was able to keep pace with subsidence and the basin floor was maintained close to level, a condition that promoted sluggish drainage and widespread peat bogs. The major controls on the areas of peat deposition were the bordering positive axes but there is also evidence that considerable local control was exerted by folded structures within the basin area, notably in the area of Springhill and northward. Thinning and thickening over the crests and troughs of these folds are noted and in general the best quality of coal lies in the troughs.

It cannot be known for certain whether or not sedimentation was continuous across the apical zone of the Cumberland basin at any point during Cumberland time and it cannot be said at this point whether or not there was a basin of thick sedimentation during Carboniferous time in the area occupied at present by the Bay of Fundy. However, in view of the structural makeup of the region it is entirely probable that the Minas basin of deposition extended through the Bay of Fundy area. In middle and late Cumberland time, during the periods in which the uplands were most subdued, it seems highly probable that the upland was breached and for short periods sedimentation was continuous across their lower parts which in the Cobequid Upland would appear to have been near its western extremity.

Pictou Group:

General Statement:

Strata belonging to the Pictou group have not been recognized anywhere within the author's area of field study but lie close by on both the west and north. The Pictou strata is, however, highly significant in so far as they indicate the final fate of the Cumberland basin as a site of deposition.

What is known of the Pictou group has already been effectively summarized by Bell (1944 pp. 21-23, 29,30). However, to make this report more or less complete, a general survey will be made to indicate its place in relation to the Cumberland basin of deposition.

The type section, as designated by Bell (1926, p. 1716), is exposed on the West Branch River John downstream from a point near Mine Brook. Here the Pictou group lies in the southern limb of the Tatamagouche syncline where it includes about 7,400 feet of non-marine sediments. As described by Bell, the sediments include "brownish-red to brick red, soft, micaceous, impure quartz sandstone and arkosic grits, thinly bedded or shaly to massive, alternating with zones of red shales or mudstones, and with minor amounts of red and grey mottled sandstones, grey sandstone, grey arkosic grits, and red or grey intraformational limestone-conglomerate. (Bell 1944 p. 21). A basal conglomerate, 5 feet thick, lies with marked angular unconformity, on Boss Point strata of Riversdale age. Similar strata extends eastward across the northern margin of the Pictou Coalfield and thence to Northumberland Strait. Westward, strata of the Pictou group occupy the Tatamagouche syncline as far as Thomson, which lies approximately 14 miles east of Springhill. In the southern limb of the syncline, near Central New Annam, the Pictou strata overlap the metamorphic rocks at the Cobequid Upland. Farther west strata of the Riversdale group appear unconformably beneath the Pictou group and, near Wallace River, strata of the Cumberland group appear beneath the Pictou unconformity. (Bell 1944, p. 15). In the northern limb of the Tatamagouche syncline (southern limb of the Claremont anticline) Pictou strata lie disconformably on the Boss Point strata from Malagash to a point near Wallace River where Cumberland strata (G.S.C. Map 409A) appears beneath the disconformity.

A small syncline lies near Oxford and extends westward almost to Salt Springs at the eastern border of author's map-area. On Black River, strata similar to the Pictou group lie on Cumberland strata with marked angular unconformity. A basal conglomerate is exposed at the contact. Eastward from this locality the Pictou strata lie unconformably, or with fault contact, on strata belonging to the Windsor group.

North of the Claremont and Minudie anticlines Pictou strata are known to occur extensively from Wallace Harbor on the east across the Isthmus of Chignecto and into New Brunswick where it forms a thin, generally flat-lying blanket of sediments that extends northwestward to overlap older rocks along the margin of the Central Highlands of New Brunswick. From Bathurst, southward for a distance of 72 miles, it lies directly on the pre-Carboniferous rock of the Central Highlands. Northward across Northumberland Strait, Pictou strata underlie the entire expanse of Prince Edward Island.

Immediately north of the eastern extremity of the Minudie anticline a thickness in excess of 7,000 feet is indicated for the Pictou group. (G.S.C. Map 842A). In Hillsborough Bay, near the mouth of Charlottetown Harbor, the borehole referred to earlier penetrated about 12,300 feet of almost flat-lying non-marine sediments before reaching beds of anhydrite, gypsum and limestone. Lack of fossil evidence together with the absence of significant lithologic contrasts, has inhibited division of the non-marine section in terms used on the mainland. It is generally assumed that the marine beds are Windsor

in age, but only upon extended extrapolation, and the overlying non-marine section is usually apportioned arbitrarily. A thick series of Pictou strata is expected at the borehole locality because it occupies a position in the subsiding basin similar to that of the Northport area, at the mouth of the Shinimikas river on the mainland, where over 7,000 of Pictou strata is indicated.

At the eastern extremity of the Minudie Anticline the Pictou strata are in fault contact with the Windsor group but farther westward it lies unconformably on Windsor, Canso and Riversdale strata. On Maringouin Peninsula a series of gently dipping, brownish-red and grey, much crossbedded sandstones, grits, and pebbly grits interbedded with red shales lie on more steeply dipping beds of the Boss Point formation. The fossil content of these strata indicate a very late Pictou age (Bell, 1944, p.22).

Summary and Significance:

The thick deposits of Pictou sediments in areas such as in the Tatamagouche syncline at West Branch River John and in the Shinimikas area in Northumberland Strait together with pronounced thinning over anticlinal structures, e.g. Minudie and Claremont anticlines indicate a definite structural control of deposition in Pictou time.

Angular unconformity and disconformity are much in evidence. In the north limb of the Minudie anticline the angular unconformity between late Pictou strata and the underlying Boss Point strata of Riversdale age indicate a pre-late-Pictou age for the birth of the

Minudie Anticline. In addition, the conformity of basal Cumberland strata with Boss Point strata in the south limb of the anticline brackets the birth of the Minudie Anticline between post-Cumberland and late Pictou ages and the Minudie anticline appears therefore to have been a controlling factor on Pictou sedimentation.

The absence of Cumberland strata between the Pictou and Riversdale strata at the eastern extremity of the Claremont anticline together with unconformable relations noted east of Oxford indicate a recurrent folding on the Claremont anticline during Cumberland and early Pictou times. Folding of Pictou strata in the latter anticline indicate a continuation of folding activity along the same axis in post-Pictou time.

The absence of a recognizable depositional break in the section cut in the Hillsborough Bay borehole seems to indicate continuous sedimentation in that area during the Pennsylvanian period.

It is inferred that the configuration of the Cumberland Basin was largely maintained in Pictou time but that, in the southern and southwestern regions of the basin, two major folds, (Claremont and Minudie anticlines) warped the basin floor and, in the case of the Tatamagouche syncline, set up a smaller area of thick sedimentation within the boundaries of the major basin area.

Chapter III

Structure

General Statement

Several basins of Carboniferous deposition have been recognized in the maritime region and, in many instances, the original bordering masses have been defined. The basins are usually referred to as the Sydney or Morien Basin, Minas Basin, Cumberland Basin, Monoton Basin, and the Fredericton Shelf.

Relatively gentle deformation has affected the maritime region since Late Pennsylvanian time and as a result the basins of thick Carboniferous deposition have been left more or less intact and the present distribution of Carboniferous sediments broadly define the original basins. Abundant evidence of overlap, unconformity, relative coarseness in grain size, etc., indicate the position of the source areas, the remnants of which are represented by the pre-Carboniferous areas (See Fig. 4). The non-conformity of the long axes of these bordering masses with the Appalachian trend, together with a discordance between the various masses, themselves, has largely confounded attempts to explain the mechanics of basin development in this region.

However, there appears to be a fairly well defined system in the distribution of the basin and bordering masses which may possibly have been determined by a shear pattern developed during the Acadian orogeny. A theory requiring a pattern of shears which would block out the crust in this manner should demand, as a prime criterion, the presence

of bounding faults and in some cases these faults are in evidence. The differential movement between the basin and upland blocks also demand explanation regarding the energy which activated them. A theory covering these mechanisms will be presented in brief.

Within the basin areas the folding and faulting was largely under local control in that the deformation appears to have been dependent upon the relative movement between the bounding pre-Carboniferous masses.

Several major folds dominate the structure of the Cumberland basin. Some anticlines are overturned and in places thrust faulted in a direction normal to the fold axes. At least one and possibly other major anticlines were initiated in late Mississippian or Canso time and re-activated several times in Pennsylvanian time. As a result older strata involved in these folds are deformed more intensely than the younger strata. This is evidenced by several unconformities in the limbs of these folds. In general, deformation was intense in the marginal areas of the basin while in the axial region the strata were practically undisturbed until late in Pennsylvanian time. The folds along both margins of the basin parallel the adjacent positive axes. One major fold, the Minudie anticline, is isolated in the axial region of the basin and it is not related to the marginal folds in a simple manner. It was initiated by stresses which seemingly were transmitted through the basement rocks which were also involved in the fold.

Structure of the Cumberland Basin of Deposition:

The gross form of the Cumberland basin is revealed in the accompanying gravity anomaly map (Fig. 5). The map was compiled by the author from gravity data measured by the staff of the Dominion Observatory.

The most striking features of the gravity map are the pronounced gravity "highs" over the pre-Carboniferous areas in contrast to the bordering areas, underlain by Carboniferous and later rocks. The northeastward continuation of the broad "high" over the Caledonian Upland across the Northumberland Strait and into north western Prince Edward Island strongly suggest a continuation of the pre-Carboniferous ridge under a rather thin cover of Carboniferous sediments. Miller (1946) has pointed out that, in a magnetic traverse conducted along the road bordering the west shore of Northumberland Strait, a magnetic "high" was indicated which coincided roughly with the gravity "high". Because the pre-Carboniferous rocks of the Caledonian Upland are known to be somewhat more magnetic than the Carboniferous sediments (Miller, 1946). The magnetic "high" noted above lends strong support to the probability of a northeastward continuance of the ridge, or in terms used earlier, the "Caledonian positive axis".

A pronounced gravity "high" is aligned along the Cobequid positive axis and also along the MacLellan-Brown positive axis. Several less pronounced "highs" are indicated within the basin margins, the most pronounced of which are: (1) immediately northwest of Pictou harbour and aligned approximately along the axis of the Pictou anticline, (2) a northwest trending high at the southeastern tip of Prince Edward Island, (3) a broad "high" in south-central Prince Edward Island and (4) immediately south and paralleling the Minudie anticline.

Areas of relatively large negative anomalies occur: (1) over the Claremont Anticline, (2) over a northeast trending anticline immediately

northwest of the N.S.-N.B. border and (3) in northeast Prince Edward Island.

In the region of the Cumberland Basin two major factors control the nature and distribution of the gravity anomalies. They are: (1) the relatively high density pre-Carboniferous rocks and (2) the relatively low density Carboniferous rocks within which the low density, thick, Windsor evaporite sequence would be a strong controlling factor. In general it is assumed that the gravity anomalies depend on the distribution of these rocks. This assumption is, quite obviously justified in so far as the major components of the basin is concerned and in the case of some of the lesser features it seems to be, at least, a partially satisfactory basis for interpretation.

It was noted that low gravity anomalies occur over two large anticlines (Claremont anticline and one near the provincial border) while relatively positive anomalies are situated over two other major anticlines (Minudie anticline and Pictou anticline). In the axis of the Claremont anticline the Windsor group is brought to the surface along most of its length and thus provides a ready explanation for the observed negative anomaly. Similarly the northeast trending anticline at the provincial border brings the Windsor group close to the surface though it is not exposed along the anticlinal axis. The highly pronounced negative anomaly over this latter anticline may also indicate piling up on a grand scale of the incompetent evaporite sequence in the axial part of the anticline.

The relatively high anomaly over the Minudie anticline poses a problem since it is known, through drilling, that about 6,000 feet, of

evaporites were piled up in the axial region of the anticline. The only reasonable explanation appears to be that the basement rock was involved in the fold and offset the effect of the lighter strata.

The positive anomaly over the Pictou anticline is more to be expected since the Windsor and Canso groups are apparently absent in this area. Direct evidence of the absence of these groups was noted in the Scotsburn-West Brunch River John district where the Millsville conglomerate of Riversdale age lies unconformably on the River John group of probable upper Horton age. It is thought that a subordinate positive axis existed in this area during Carboniferous time which intermittently formed a low upland barrier between region of the Pictou coalfield and the main part of the Cumberland basin on the west.

That part of the Cumberland lying within the scope of the author's field investigation is dominated by three areas of distinctive structural development. They may be called, for the sake of reference, the Athol synclinal area, the Springhill Salt Springs area, and the Albert county area.

The Athol Synclinal Area:

The structure of the map-area (See Map No. 3) is dominated by a broad southwesterly trending syncline that pitches southwestward from a point near Springhill Junction and northeastward from a point near Apple River. Its southern limb dips gently, for the most part, from the northern margin of the Cobequid upland. Near Springhill where the southern limb flanks the southwesterly pitching nose of the Claremont anticline the inclination ranges up to 45°. The northern limb of the

structure is distorted by a broad northwesterly trending embayment located where the northern limb transects the shore of Chignecto Bay. From Styles Brook westward to the Joggins' area its northern limb coincides with the southern limb of the Minudie anticline along which the inclination ranges from 30 to 70 degrees. Farther westward the northern limb of the Athol syncline swings around the broad embayment and maintains a southwesterly course that approximately parallels the shores of Chignecto and also the structural trend of the Albert county area. In general the syncline is not a clearcut individual structure but appears to have been controlled by the better defined trends of the bordering structures. The axial region of the syncline is broad and marked by gentle rolls which preclude drawing a line to represent the axis.

Springhill-Salt Springs Area:

This area is characterized by structural complexity which arises from the fact that it was undergoing deformation during deposition. Also the deformed strata includes the Windsor evaporite sequence which at times reacts to stresses in a highly unpredictable manner. Much of the evidence for the structural relations to be described has already been presented earlier in the discussion of the stratigraphy.

The dominating structure is the Claremont anticline which crosses the eastern margin of the map-area and pitches southwesterly to intersect the northern margin of the Cobequid Upland near Mapleton. The fold dies out against the pre-Carboniferous rocks in a series of low amplitude rolls.

Immediately north of Leamington the nose of the anticline is cut by a normal fault, downthrown about 100 feet on the north and trending almost due east-west. The pitching nose of the anticline is beautifully outlined by the outcrops of the coal seams (See Map Nos. 3 and 4) in the Cumberland group.

Northeastward along the axis of the Claremont anticline older rocks of the Riversdale and Windsor group appear. The strata of the Riversdale group are more highly folded than the strata of the Cumberland group and underlie the latter with marked angular discordance. The Windsor group appears even more deformed and underlies both the Riversdale and Cumberland groups with marked angular unconformity. The thrust fault indicated along the axis of the anticline immediately northeast of Springhill is nowhere exposed but it appears to satisfy the distribution of the Claremont formation. The plane of the fault is considered to be contained largely in the less competent Windsor strata. The small thrust fault indicated east of Miller's Corner and cutting the coal seams approximately in the antioclinal axis may be a continuation of the larger thrust but such a connection cannot be definitely ascertained.

The area lying between the nose of the Claremont anticline and the Cobequid upland is occupied by a shallow syncline that is marked by several minor rolls and normal faults of minor displacement.

Northwest of the Claremont anticline an irregular syncline trends roughly parallel to the Claremont antioclinal axis. The syncline is succeeded on the northwest by another anticline the existence of which is based largely on stratigraphic evidence. The absence of the basal conglomerates of both

Riversdale and Cumberland groups and apparent thinning in strata higher in the Cumberland group points toward the existence of a recurrent positive axis in this direction. The assumption is bolstered by the presence of Windsor strata at the surface along the axis of the supposed anticline. A small syncline lies along Little Forks River and is seemingly cut off sharply by exposures of Windsor strata. It is assumed that this hypothetical anticline is similar to the Claremont anticline and that the small syncline is cut off by a fault which may represent further movement along the plane of a thrust fault that was initiated before the deposition of Cumberland sediments.

The sequence of folds and faults outlined above is transected by a northwesterly trending anticlinal axis that intersects the Claremont anticlinal axis where the Black River crosses the Springhill-Oxford highway. The limbs of this fold are clearly defined for only short distances. This is particularly true of its southwestern limb which is broken by a fault located immediately north of Springhill. Unconformities are known in the limbs but these may be associated with the Claremont axis and are therefore not a necessary indication of movement along the northwesterly trending axis during deposition. A pronounced angular unconformity between Riversdale and Cumberland strata is observable on Black River in the northeastern limb of the anticline. The nearness of this locality to the Claremont axis makes it entirely probable that the unconformity had formerly lain in the northern limb of Claremont anticline and had been folded into the limb of the northwesterly trending anticline later. The same could

be true of the unconformity in its southwestern limb where the lower coarse facies of the Cumberland group wedges out.

The role of the Windsor evaporite sequence in the structural development of the area is not clear. Nowhere could upturned strata, such as is typical of salt dome structure, be definitely recognized along the borders of the Windsor areas and only in one locality was such a structure suggested. About one mile north of the Springhill railway station, where both railroad and highway curve to the northeast, Cumberland strata are observed to lie directly on strata of the Windsor group. Exposures of limestone and gypsum are known at the locality and the outcrop of No. 2 coal seam bends around it in a graceful curve. No outcrops of Cumberland strata have been found close by but workings in No. 2 seam have been carried around the curve and northward thus providing excellent structural data. The coal seam dips steeply, at inclinations up to 60 degrees, near its outcrop but the dip decreases rapidly with increasing depth and, in a horizontal distance of about 1,500 feet, the dip decreases to about 25°. This type of profile is evident around the curve but north and south of it steep dips do not occur. Several tension faults of small displacement radiate from the centre of the curve and the whole structure strongly suggests doming action. It must be noted also that the fold cannot be associated with an anticlinal axis in any direction.

Albert County Area:

The following description of this area is based on the observations made by the author in a traverse along the shoreline and from information on the geological map of Norman and Flaherty (G.S.C. Map 648A).

The area is located on the western shore of Chignecto Bay on the narrow strip of lowland that borders the Caledonian Upland (See Map No. 2). The Carboniferous rocks are highly folded and faulted along a well marked trend that parallels the Caledonian positive axis. The folds and faults reach their greatest development in the area where the shore of Salisbury Bay transects the trend. Northward the folds die out and merge, near the northern margin of the map-area, into a monoclinial structure that bends eastward and is continuous with the southern limb of the Minudie anticline (northern limb of the Athol syncline).

The anticlinal fold of greatest amplitude lies farthest from the pre-Carboniferous contact. Toward the contact the amplitude of the folds decreases notably. This feature is thought to be related to the decreasing thickness of sedimentary strata consequent upon overlap on the competent rocks of the upland. The fault planes are not exposed but the stratigraphic relationships definitely indicate thrust-faulting. In most cases the traces of the fault planes appear to be straight and they are considered to be high angle thrusts. The sinuous trend of the fault that extends from Owl Head to the village of Albert suggests that it is a low angle fault but the cursory examination afforded the author was not sufficient to ascertain its exact nature.

The age of the deformation in this area cannot be closely fixed. The youngest strata exposed is correlated with the Boss Point formation and the latter is involved in the deformation. Strata of Cumberland age outcrop in Chignecto Bay but it is not known whether it is involved there

in the intense folding that effected the pre-Cumberland sediments in Albert county. On the shore near Cape Enrage strata ranging from Canso to late Riversdale age are exposed and appear to represent an unbroken sequence of deposition during that period. This would place the age of the deformation as post-Riversdale at least. It is highly probable that part of the deformation was effected in early Cumberland time since evidence of considerable deformation at this point is abundant in the areas near Springhill. It is more than probable that folding and faulting were renewed along similar lines in the early Pictou deformation that initiated the Minudie antioline and renewed already established folds such as the Claremont antioline.

Mechanics of Structural Development:

The most characteristic structural feature of the Cumberland basin is the parallelism exhibited between near-margin folds and the positive axis on both sides of the basin. The bordering masses acted as solid buttresses against which the softer sediments buckled, folded and faulted. It is fairly obvious that compressive stresses acting in a direction normal or near normal to the margin of the bordering pre-Carboniferous mass would result in structures that would be aligned with margin. Strong regional stresses forced the bordering masses to close in a scissor-like movement on the intervening basin. The strata bordering the margins were first effected because of their inability to pass on stress that exceeded their elastic limit. Thus folding could proceed along the margins while the axial region of the basin was left virtually unaffected through the greater part of Carboniferous time.

The position of the Minudie anticline in the axial region of the basin would seem to be anomalous in view of the argument stated above. The axis of the Minudie anticline lies immediately north of the northern margin of the map-area and trends almost due east-west. Its trend intersects the well defined trend of the marginal structures of the Albert county area at a high angle. On the south it is separated from the Cobequid positive axis by a wide area of practically undeformed sediments. On the north the overlapping Pictou strata obscure pre-Pictou deformation. It seems essential that the Minudie anticline, was folded by stresses that were transmitted through the basement rock. It can be demonstrated by application of the strain ellipsoid in a horizontal plane that a force couple, initiated by relative movement of the two bordering masses, and acting through the basement rock, could have formed the Minudie anticline. The force system would require a southwesterly movement of the Caledonian mass relative to the Cobequid mass. The fact that a gravity high is located along the Minudie anticline indicates a strong probability that the basement rock is actually involved in the fold.

Tectonic framework of Carboniferous deposition:

If lines are drawn through the longest dimension of the pre-Carboniferous areas in the Maritime region a fairly regular system evolves (See Figure 4.), which is strongly suggestive of a major overall control on the forms and distribution of the Carboniferous basins in the Maritimes. Two sets of lineaments are discernible: (1) a set trending roughly north-easterly and ranging between North 35 degrees east and north 50 degrees east;

(2) a set trending approximately north 80 degrees east. The acute angle between these sets averages about 40° but considerable shortening has taken place across the basins since they were initiated and this angle therefore, does not represent the original angular relationship. In the Cumberland basin, shortening in the late Mississippian and early Pennsylvanian strata was in the order of magnitude of 25 per cent, which would account for an original angle of about 50 degrees, or greater, between the bordering positive axes. Assuming that these approximations hold for the entire system, the angular relationship is suggestive of conjugate sets of shears.

Besides the regional aspect of these pre-Carboniferous areas, several other factors support a theory of shear control on these basins. Several faults and fault zones with considerable displacement are known which are aligned closely with the positive axes indicated on Plate . Of these the best known are: (1) the Cobequid fault zone which parallels the southern margin of the Cobequid Upland. The location of the fault zone is indicated, in places, by a steep scarp that sharply delineates the metamorphosed rocks and igneous rocks of the upland from the softer Carboniferous rocks of the Minas lowland. This scarp is observable from the contours on Map No. 2. The most recent displacement along the fault zone has been dominantly vertical as indicated by the slickensiding; all vestiges of rifting, if there were such, have apparently been obscured by this latter movement; (2) on the northern margin of the Cobequid upland, near West New Annan, Riversdale strata are in contact with the upland rocks along a fault, of unknown displacement, which parallels the Cobequid

positive axis. Westward within the author's map-area no well defined faults or fault zones of large displacement are known. Three small faults, not exceeding 100 feet in vertical displacement, may represent insipid movement along old faults which have been overlapped by the Pennsylvanian sediments. (3) The Hollow fault extends from the Pictou Coalfield to Malignant Cove and roughly parallels the MacLellan-Brown positive axis. Williams (1914 p. 25) has estimated a vertical displacement of fault in excess of 3,000 feet. The age of the latest large scale movement along is pre-Windsor since Windsor sediments have overlapped it and have suffered little deformation Lower Devonian strata (Knoydart formation) were effected and the calculated displacement refers to the displacement of these strata, (Williams, 1914, p. 93-95). (4) A fault zone extends along the northern margin of the Southern Upland of N.S., near its eastern extremity, from Trafalgar to Chedabucto Bay roughly paralleling West River St. Marys for a considerable distance (See G.S.C. Map 910A). (5) The Coolavee-Aspy fault near Bay St. Lawrence, in Northern Cape Breton Island, roughly parallels axis through the Northern Tableland. (6) The Sydney Coalfield is bounded by two main faults or fault zones named the Bateston and Mountain faults in the south and north respectively. Their trends coincide roughly with the positive axes indicated on Plate . In connection with the Sydney basin it should be noted that a series of folds spread fan-like across the basin with their point of convergence lying to the southwest. At the margins of the basin the folds parallel the positive axes and, in general, the basin structure appears to be a result of a scissor-like

squeeze in a horizontal plane. A somewhat similar structure appears to exist in the Cumberland basin though this type of folding is confined to the marginal areas. (7) In southern New Brunswick a large number of faults parallel the axial trends indicated in that region (See Tectonic Map of Canada and G.S.C. map sheets).

Practically all these faults indicate dominantly vertical displacement through long distances and much of the adjustment between the basins and their bordering uplands must have taken place along these faults. The crux of the problem lies in the manner in which this particular configuration was brought about. The writer suggests that it is actually a shear pattern initiated during a period of intense orogeny in the Devonian period probably the Acadian orogeny of Late Lower or Middle Devonian time. Subsequent deformation throughout the Carboniferous period, and later, has telescoped the entire region and the present angular relation is considered to be different from the original. The average acute angle is about 40 degrees at present and originally was probably closer to 50 or 55 degrees. The resultant compressive stress acted in a horizontal plane and in a direction approximately northwest-southeast. The component stresses may well be explained by differential movement in a horizontal plane between the Precambrian Shield and another large stable mass south of Nova Scotia, possibly the hypothetical Appalachia.

It should be noted that the folding trends in the Palaeozoic rocks that lie across the eastern townships and Gaspé peninsula of southern Quebec are apparently controlled by the configuration of the

underlying basement at the margin of the Shield and the directions of the fold axes do not necessarily indicate a direction normal to the resultant stress for the entire region. This is particularly true of the region near the head of the Gaspé peninsula and at Anticosti Island where the fold axes turn slightly south of east.

Having once evolved the shear pattern suggested above it still remains to explain the source of the energy which brought about the differential movement that distinguished the basin and upland blocks during deposition in the Carboniferous period. It is questionable whether some of the smaller masses would be in sufficiently large isostatic unbalance to move long distances in a vertical direction. It is possible however that the bordering faults provided a freedom of movement not otherwise attainable and adjustment may have been possible for such small isostatic anomalies. The basement rock lying within basin areas is of course hidden by a thick cover of sediments. Up to the present little work of a detailed nature has been undertaken within the pre-Carboniferous areas with the exception of local gold-bearing districts on the Southern Upland of Nova Scotia. In general, however, it may be noted that the pre-Carboniferous areas contain many exposures of granitic rocks that trend approximately parallel to the positive axes. To assume that a similar proportion of granitic rocks does not prevail in the basement underlying the basins would be presumptive but if the granitic rocks are concentrated along the positive axes to their exclusion in the basin areas it would suggest a density contrast which might possibly account for the apparent isostatic adjustment.

A theory which would require folding as the major control meets with several difficulties the most important of which are: (1) folding along two sets of axes that are aligned with the positive axes illustrated on Figure 4 would require a radical shift in the direction of the resultant stress. (2) It does not account for various large scale faults bounding the pre-Carboniferous masses.

Another alternative which may be offered would require a combination of folding and accompanying shearing. If one set of positive axes is assumed to represent fold axes and the other a major set of shears the angular relationship is seen to be in fairly good agreement with theoretical deductions. There remains, however, the fact that major faults trend parallel to both sets of positive axes.

A final answer to the problem of the tectonic origin of the Carboniferous basins may be realized in a more detail study of the pre-Carboniferous areas. The relation of their structural features to the positive axes that define the form of the Carboniferous basins should indicate some association that may lead to a solution.

CHAPTER IV

ECONOMIC GEOLOGY

General Statement:

Prospects of future economic development in the Cumberland Basin rest upon three major products of sedimentary deposition, namely, coal, oil, and salt. To date, in terms of quantity and value, the coal deposits have accounted for the major portion of production, and future possibilities of reserves appear to be extensive. Large quantities of salt are mined at Malagash and at Nappan and the reserves, that are already assured, appear to be capable of satisfying the market for a long time to come. The most elusive, and yet the most important in terms of economic and strategic value, is oil. Upon consideration of its large scale geologic features the Cumberland Basin appears to the author as a most attractive area for future exploration. The significance of large oil reserves to Eastern Canada hardly needs to be emphasized here.

The future possibilities of reserves of coal and oil will be discussed within the framework of the stratigraphic and structural features outlined in the foregoing pages. The purpose will be to indicate the probable description of sediments which are favourable for inclusion of each.

Possible Future Coal Reserves:

The problem of defining the location of a coal deposit is largely a problem of finding a depositional environment favourable to the accumulation of great thicknesses of peat since, unlike oil, natural gas, and other sedimentary products, the coaly material is relatively immobile and

remains encased between the strata with which it was deposited. The coal-forming peat may be deposited in a great variety of topographic environments ranging from relatively narrow, flat-bottomed river valleys to broad flat plains bordering a sea. The prime controlling factors appear to be a lush vegetable growth and sufficient restriction in the drainage to maintain the water level above the accumulation of vegetable debris in order that oxidation is inhibited and the vegetable material thus preserved. The climatic conditions favouring lush growth of the Carboniferous peat forming plants have been generally interpreted as including sub-tropical temperatures, a high humidity, and well distributed rainfall. Although the extensive evaporite deposition of the Windsor period implies arid conditions the apparent contrast with the humid conditions of Pennsylvanian time may have only local significance since great variations in humidity may exist over short distances, depending entirely on the meteorologic elements involved. For example, it may be noted that the topography of the Maritime region during Windsor time was greatly subdued while later the positive axes bordering the Cumberland Basin were re-activated and uplands were formed along their trends. It is conceivable that uplands may have provided a barrier against prevailing east or northeast winds blowing off the ocean. The moisture-laden winds, upon being forced up into higher and cooler levels, would condense and thereby provide a plentiful rain to the lowland lying in front of the uplands. This latter phenomenon is, of course, common over many parts of the world today and is mentioned here only to illustrate one of the possibilities involved in the varying climatic conditions that prevailed in the region under study.

The probabilities of discovering coal seams within a given stratigraphic section are directly proportional to the degree in which it reflects these environmental conditions. The characteristic ensemble of non-marine sedimentary strata associated with coal seams is well illustrated in Fig. 2. The peak of coal deposition is seen to coincide closely with the minimum percentage of red sediments. Also it coincides with the maximum of the finer-grained grey sediments. The colour of the sediments appears to depend entirely on the oxidation state of the iron which, in this area, is largely dependent on the content of the strongly reducing carbonaceous material. Carbonaceous material is abundant in the coal-bearing strata, not only in seams, but also in large quantities of vegetable debris ranging from microscopic spores to large tree trunks (Plate 5), that have been buried with the clastic sediments.



Fossilized tree trunk enclosed by sandstone
in the Joggins section
Plate 5.

Another characteristic feature is the presence of underlays or ancient soils which are recognized chiefly by the presence of stigmaria rootlets that penetrate strata that are usually composed of clay or arenaceous clay. The coal seams, almost without exception, are underlain by such underlays. Underlays on the other hand often appear in the section without overlying coal seams and their significance lies in their testimony of plant life formerly rooted in place. The lack of preservation of the material may be attributed to local drainage conditions which failed to preserve the fallen debris in place. The absence of coal may well be found above the same horizon in other localities. Thus, the presence of underlays is always strongly suggestive of the presence of coal seams.

Within the Cumberland Basin coal seams of workable thickness are restricted to the unit of strata, within the Cumberland group, that has been designated as the "coal-bearing facies". All other rock units within the basin are readily eliminated on the basis of the dominance of coarse sediments, red sediments or marine sediments. Our problem of coal reserves, therefore, develops into a problem of determining the distribution of workable coal seams within this rock unit.

Essentially, the coal-bearing unit is a flat wedge of fine, dominantly grey, clastic sediments which is enclosed by coarser barren strata that are partly contemporaneous with it. The wedge has its edge lying along the Cobequid positive axis and thickens northward. Its regularity is broken on the eastern extremity by an area, immediately north of Springhill, that was tectonically positive during deposition.

For a considerable part of early Cumberland time this area was maintained at least slightly above the general level and the sediments did not overlap it until later.

The Joggins-North Springhill group of coal seams overlaps this positive area from the west, whereas the Springhill group of seams overlaps it from the south. It is improbable that any of the seams of either group ever completely covered this positive area.

West of Springhill and away from the positive area, structure sections were drawn across the Athol syncline that separates the Springhill from the Joggins-North Springhill district. The Chignecto seam of the latter district coincided, within a short stratigraphic distance, with the lower workable seams (Nos. 6 and 7) of the Springhill group. A rather low precision in the structure section may be expected across the broad intervening syncline, yet a close relationship is indicated between the two groups of seams. It is believed that the lowest seams of the Joggins group lie stratigraphically below the lowest seams of the Springhill group, a relationship that would conform more closely with the obvious overlap of the Cumberland group southward on to the Cobequid positive axis.

The workable seams of the Springhill District are restricted by the original distribution of the peat-forming bogs, which were bounded on the south by the Cobequid positive axis and on the north by the subordinate tectonically positive axis referred to above. The belt of highest quality coal, which is not more than 6,000 feet wide in most of the seams, trends, with some irregularities, about south 65 degrees west on a centreline through a point near the Springhill railway station.

Barri. unforeseen circumstances this belt of workable coal should be found to spread more widely to the north of Springhill. The lowest workings in No. 2 seam have not yet reached this more favourable area and how far they must be extended to reach it cannot be predicted at the moment.

The number of workable coal seams in the Joggins-North Springhill district decreases from five in the western extremity to one at Chignecto. The latter seam may be traced eastward to beyond Fenwick where it splits into several seams, two of which have been worked at North Springhill. Farther eastward these deteriorate and finally disappear into barren coarser sediments before reaching Little Forks River. The seams display considerable irregularity and may deteriorate locally in any direction; in places, the direction it will take may be predicted reliably over short distances. This is particularly true when the deterioration is associated with a well defined washout such as exists in the Kimberly seam at River Hebert. Over most of the district the seams will probably extend southward along the dip, with similar local irregularities, for a considerable distance. Towards the eastern extremity of the district, the seams will deteriorate steadily in a southerly direction and eventually will terminate against the northern margin of the positive area which separates this district from the Springhill district.

In the Salt Spring district, the Sandrun coal seam averages between 2 and 3 feet in thickness along most of its outcrop length and disappears to the west and northwest. The seam cannot be confidently correlated with any of the seams beyond its restricted area, but the northward extension of No. 2 seam of the Springhill district strongly

suggests that this seam may have overlapped the positive area to that extent. The fact that the thickest part of the Sandrun seam falls roughly on the projection of the centreline of thickest coal in No. 2 seam corroborates such a contention.

In the borehole located about 1 mile north of Neville Lake a section of the coal-bearing facies was cut near the bottom of the hole. Exactly how much coal was cut is not definitely known, but it can be said with assurance that several thin seams do lie in that area. The coal-bearing facies as defined here is undoubtedly to be correlated with the thin edge of the wedge of coal-bearing facies described above and thus it provides an excellent control point for the projection of the area over which this facies is distributed.

On the basis of this assumption it is inferred that the coal seams found there are equivalent to the upper coal horizons in the Springhill district. The implications of this correlation are of tremendous import in so far as the Springhill district is concerned since it seems apparent that there may be an almost unlimited supply of coal in a direction slightly south of west from Springhill. The southern margin of workable coal will be buried at some depth, as will be obvious from a comparison of Fig. 3 with Map No. 3, but very gentle dips persist toward the west and once the coal has been reached there will be little increase in cover over a wide area.

It appears highly probable that the Joggins coal seams lie lower stratigraphically than the Springhill seams. Above the workable seams at Joggins a slight increase in the proportion of coarse sediments is noted together with a similar increase in red sediments. The cause

of this change cannot be ascribed to uplift along the Cobequid positive axis if the assumption that the Springhill coal seams are younger is to be maintained. The change may, instead, reflect an early uplift along the Caledonian axis which did not materially effect sedimentation in the region closer to the Cobequid positive axis.

The existence of workable seams at varying horizons throughout the coal-bearing facies poses the strong probability that workable seams, other than those already known and mined, lie within the basin. The apparent occurrence of progressively younger seams in a southerly direction suggests an "en echelon" arrangement in a vertical plane. In other words workable seams that are older than the Springhill seams and younger than the Joggins seams may be situated in the axial region of the Athol syncline.

It seems apparent that the Minudie anticline, unlike the Claremont anticline and its associated structures, was not initiated until Pictou time and therefore did not form a barrier across the axial region of the basin during Cumberland time. Consequently it is expectable that peat forming bogs persisted northeast of the Joggins area. If the axis of subsidence continued to plunge northeastwardly, as is assumed in Fig. 3, it seems probable that the basin may have been subject to marine incursions. This is, however, highly hypothetical since there is no good evidence of marine Pennsylvanian sediments anywhere in the Maritime Provinces. From a study of the fossil remains in the bituminous shales overlying some of the coal seams in the Joggins district Copeland (1951) has concluded that these shales have been deposited in a brackish water environment. His conclusions are based on the association of marine fish

remains (*Psammodus Ctenoptychius*, etc.) with plentiful invertebrate remains of fresh and brackish water types. He believes that a mingling of these types may have occurred in a lagoonal environment. There is, however, some doubt in the minds of palaeontologists concerning the actual environmental significance of the fish remains noted above and the question still exists without a satisfactory answer.

Future exploration for workable seams north of the Minudie anticline will be inhibited by two major factors: (1) the inferior quality and thickness of the seams in the Joggins-North Springhill district and (2) the thick covering of red sediments belonging to the Pictou group that overlies the Cumberland group in the region north of the Minudie anticline.

East of the map-area it was noted that the fine coal-bearing facies thins rapidly and disappears several miles west of River Wallace. Thin coal seams, possibly of workable thickness, are known to outcrop at Polly Brook and at a point lying about 1 mile southeast of Oxford Junction (G.S.C. Map 410A). These outcrops may be on the same seam but no information is available on the intervening area. Other outcrops of thin coal seams are known near South Victoria and Greenville Station (G.S.C. Map 409A). The flat dipping strata at Polly Brook offer good prospects for a stripping project if the coal seam there proved sufficiently thick.

Summary of Possible Coal Reserves:

The prospects for large reserves of coal in the Cumberland basin depend on two main factors: (1) the continuance of the thick seams of the Springhill district in a southwesterly direction, approximately paralleling the Cobequid positive axis, and (2) the discovery of new workable seams, in the area between the Joggins-North Springhill district and the Springhill district, at stratigraphic horizons lying between the groups of coal seams mined in the latter districts. It should be remembered, in this regard, that the southwestward extent of the influence of the subordinate positive axis lying north of Springhill is not known but it may be expected that it has effected the distribution of these postulated seams in a way similar to the manner in which it effected the known seams of the mining districts.

Recommendations for Exploration:

Further exploration for coal reserves should be directed along the lines suggested above. The best prospects lie southwestward from Springhill along the trend of best quality coal that was established there. The structure in this direction is relatively simple and the prime problem is related to the persistence of high quality coal in that direction. The most effective exploration tool for coal is the core-drill, since it provides the necessary information regarding the thickness and quality of the coal. A program of core-drilling should be planned to begin in the area of well known structure near the present mine workings and thence carried southwestward at suitable intervals.

The possibility of finding new coal seams in the axial part of

the Athol syncline has been emphasized. The depth to the coal-bearing facies in that area prohibits drilling. The seismic reflection method offers the best opportunity to determine the structural relation between the two known groups of seams with greater precision and thereby should indicate whether a sufficiently thick section of strata intervenes which would warrant more direct methods of ascertaining the presence of coal seams.

Possible Future Oil Reserves:

Several attempts have been made in an effort to locate oil reservoirs in the Cumberland basin, but without success, despite the fact that the Cumberland basin seems to offer better possibilities for oil than any basin in the Maritime Provinces. The discouragement attendant upon costly failures have resulted in a stagnation of effort and unless the area is re-examined from a fresh viewpoint it seems probable that further attempts will not be made. In view of this situation the author will outline the various factors that bear on the possible oil reserves of the basin.

Possibly the best method of attack would be to examine the area of the Cumberland on the basis of criteria used by the A.A.P.G. in its latest symposium on possible future petroleum provinces (A.A.P.G., 1951, p.143, pp.146-148). The criteria, as advanced by Ball and Levorsen in that symposium and with one addition by the author, may be summarized as follows: (1) volume and type of sediment:- other factors being unknown, the possibilities of finding oil will depend proportionately on the quantity of sediments. If the sediments are marine and unmetamorphosed the chances increase greatly.

(2) Evidence of oil and gas:- the presence of oil and gas as indicated by seepage leaves no doubt of the existence of source beds, and, if the age of the source beds is determined, it automatically solves the problem relating to the existence of suitable environmental conditions, at least locally, during that particular period.

(3) Unconformities:- Unconformities often hide a new and unknown set of sedimentary and structural conditions. They may seal off oil-bearing structures that have been truncated by erosion and thin down drilling depths that might otherwise be excessive.

(4) Wedge belts of porosity:- Such belts of porosity often originated as near-shore phases of seas that border on tectonically positive axis.

(5) Presence, nature and extent of folding and faulting: The area of accumulation of oil depends on the structural forms that are imposed on the porous media. For example, in a simple anticlinal structure, the oil migrates through the porous media to occupy a position on the crest or flanks of the structure. Again, in any stratigraphic trap the position of the oil is determined by the direction in which the porous wedge is inclined. Sometimes, the area has not been deformed at all and the location of the oil may depend on the original dip of the strata. Faulting may bring a porous, oil-bearing rock in juxtaposition with an impermeable rock and thereby seal it.

(6) Presence of tectonically positive axes within and bordering the area of deposition: To the foregoing five criteria the author would add this latter. A classic example of the control of tectonic elements

upon deposition is the Permian basin of west Texas (King, 1942). The positions of positive axes are considered as offering an excellent opportunity for shallowing of the sea over them and possible emergence of land areas at various times. It is generally conceded that the shallow water environment provided the most favourable conditions for existence of abundant organic life and most oil-bearing strata can be associated with these conditions. The shallow or near-shore conditions associated with positive elements within the area of deposition frequently provide the necessary porous reservoir rocks in the form of widespread sand bodies and in the form of bioherms or organic reefs. In the case of biohermal development, Link (1950) has demonstrated the transgressive and regressive characteristics of bioherms under control of a shifting strand line. He makes a favourable comparison of the growth of bioherms in the Devonian of Alberta with the bioherms of the Permian basin of west Texas. The concentration of massive organic reefs along the edge of the Central Basin Platform of the Permian basin is strongly suggestive of tectonic control.

We shall now examine the Cumberland Basin on the basis of these criteria and thereby attempt to reach a conclusion concerning the most likely position for the accumulation and preservation of oil within its vast volume of sediments.

(1) Volume and type of sediments: It has been indicated that more than 30,000 feet of unmetamorphosed Carboniferous sediments have been deposited in the axial region of the basin. The axis of the basin extends northeastward across the eastern part of Prince Edward Island in the general area of Hillsborough Bay and there is no reason to believe that the thickness

has diminished in this direction and it is more probable that it has increased. In general, the sediments wedge out to the south and northwest over the bordering positive axes of Carboniferous time.

Within the mainland area of the basin the sediments exposed are predominantly continental in origin, but two distinct periods of marine transgression are indicated. These marine transgressions reached their farthest extent in mid-Horton and in lower or mid-Windsor time. It is theoretically possible that marine deposition proceeded continuously in outlying portions of the basin despite the uplift which marked the end of marine deposition near the bordering positive axes in Upper Horton time. The Windsor sea may have been similarly maintained during the uplift which pushed its shores back from the rising positive axes, and therefore it is conceivable that marine sedimentation persisted in the basin beyond Windsor time.

The apparent association of oil with marine, near-shore environments places these transgressive marine phases in a position of predominant importance in our considerations.

(2) Evidence of oil and gas: Within the rocks associated with the Cumberland basin the only definite evidence of oil and gas is in the Stoney Creek oilfield which is located at the northern end of the Caledonian upland. Oil and gas are produced from the Albert formation of Horton age. Production is confined to lenticular sand bodies enclosed by bituminous shales which are generally regarded as lacustrine in origin. Near the top of the Albert formation are thick beds of salt which, in this region, can hardly be attributed to an origin other than marine. The limestones of the

Windsor group are usually bituminous to some degree but oil, as such, has never been definitely associated with them.

It should be noted here that in the Lake Ainslie district of Cape Breton oil seepages from Horton sandstone are known and small quantities of oil were found in holes drilled near McIssaac Point in this district (Norman, 1935, p.70). However, depositional relationships between this district and the Cumberland basin are obscure and it cannot be said with assurance whether the basin was continuous with the western part of the Cape Breton during Carboniferous time. The probable northward extension of the MacLellan-Brown positive axis from Pictou and Antigonish counties may well have formed a barrier to isolate the region of western Cape Breton from the Cumberland basin. However, the seepages there are of value as supporting evidence of a generally favourable climatic environment for organic deposition in Horton time.

(3) Unconformities: Unconformable relations are recognisable at several stages in the Carboniferous sediments. Except in the case of the early Pictou unconformity it is characteristic of the Cumberland basin that the unconformities are located along the margins of the basin while sedimentation proceeded more or less continuously in the axial region. These marginal unconformities (See Fig. 1) are particularly significant in that they indicate intermittent positive movement in the bordering masses and consequently give definite evidence of thinning over the crests. The structures underlying these unconformities may prove worthy of testing if these structures were found to lie along well defined trends of oil bearing sediments.

The early Pictou unconformity is by far the most significant in that it has obscured the pre-Pictou structure of a large proportion of the total area underlain by rocks of the Cumberland basin.

(4) Wedge belts of porosity:

The shores of the advancing seas of Horton and of Windsor time were, presumably, aligned with the basin borders. Along these trends it is expectable that all the features of seashores would be in evidence, including such sedimentary forms as beaches, offshore bars, etc. The excellent sorting that occurs in these types of sedimentary bodies produces a high porosity and consequently they are excellent reservoir rocks. In the case of a transgressing sea these bodies may be overlapped and thereby enclosed by finer grained sediments.

These beaches and bars may be discontinuous along the trend also but in general they form a well defined belt of porous rocks, a factor which lends itself well to exploration because once such a trend is established it serves to narrow down the total area to be tested at a given horizon.

It is unfortunate that the areas, in which the Windsor and Horton are exposed, are located close in to the basin borders and well into the apical zone of the basin where the sediments are those deposited at the furthest transgressions of the sea. The large proportion of evaporites, of red poorly sorted deltaic deposits, etc., noted in the exposures are largely attributable to this circumstance. It is more unfortunate that the outer portions of the basin, where it is expected that more normal marine conditions persisted, is entirely blanketed by the overlapping Pictou sediments.

(5) Presence, nature and extent of folding and faulting:

Deformation in the Cumberland basin was effected in the Carboniferous period at various stages. The latest significant folding occurred before the deposition of the Pictou group, as evidenced by the very gentle folding that effected the latter. The marginal folds, described earlier, in our discussion of the structural geology, are seemingly too intense to warrant any possibility of accumulating large quantities of oil even if they happened to lie within favourable areas from the point of view of sedimentation.

The Minudie anticline offers a broader, less intensely folded structure which would offer better possibilities if it was located in an otherwise favourable area. This structure has already been tested near its crest, as it appears on the surface, and the section out in the hole has been outlined earlier in this report. The significant points demonstrated by this test were: (1) the lower Windsor is not oil-bearing there (2) evaporite deposits belonging to the Windsor group have been squeezed into the axial region of the anticline to form a thickness measuring vertically in excess of 6,000 feet; (3) at least 5,500 feet of continental deposits, dominantly red shale and sandstone and grey sandstone, underlie the marine Windsor and are apparently equivalent to the Weldor and Hillsborough formations of Upper Horton age that are exposed in New Brunswick; (4) marine strata of Horton age were not penetrated and thus leave their existence in that area still hypothetical; (5) the thickness of the section in the axial region of the basin is so thick as to make drilling to lower horizons prohibitive unless very favourable conditions were indicated.

A broad anticlinal fold is indicated, from outcrops, to lie a short distance northwest of the N.S.-N.B. border. Its axial trend parallels the Caledonian positive axis. Gently dipping limbs mark the position of the fold at the surface but a large negative gravity anomaly, located directly over the anticlinal axis (See Fig.5), suggests that the light Windsor strata may lie close to the surface. It is entirely possible that this anticline was folded in late Windsor time, truncated by erosion and subsequently overlapped by the continental Pennsylvanian sediments which were later moderately folded along the same axis.

A broad, gentle fold, trending slightly north of east, effects the Pictou strata in the southeastern part of Prince Edward Island. From the information assembled from sparsely distributed gravimeter stations the fold cannot be associated with a significant anomaly. It is probable that the fold has little or no expression at depth. The deep test made in Hillsborough Bay passed through strata that lay essentially horizontal to a depth of 14,696 feet.

Most of the faulting recognized within the basin area is associated with the intensely folded strata along the margins where thrusting and cross-faulting occur. Normal faulting occurs along the northern margin of the Cobequid Upland, in the region of West New Annam, where Riversdale strata are down-faulted on the north against the pre-Carboniferous rocks of the upland. Similar faulting may be expected elsewhere along the margins of the uplands but its presence cannot be ascertained because of the extensive overlapping of late Pennsylvanian sediments.

(6) Presence of tectonically positive axes within and bordering the area of deposition:

Numerous unconformities, evidence of extensive overlapping, etc., point to the persistence of three tectonically positive axes which partly define the Cumberland basin during Carboniferous time. The remnants of these tectonically positive axes are found in the Cobequid, Caledonian, and MacLellan-Brown uplands. The trend of the Cobequid positive axis coincides roughly with the long axis of the area of exposure of pre-Carboniferous rocks that extends from Chignecto Bay, 100 miles in an eastward direction. The Caledonian axis is best illustrated by the gravity contours (See Fig. 5) which indicate the extension of the pre-Carboniferous ridge under the northwestern part of Prince Edward Island.

The positive gravity anomaly over the Caledonian ridge is seen to be somewhat wider and distinctly more irregular than the Cobequid ridge. A considerable thickness of sediments have been deposited in a subsidiary basin that lies within the margins of the broad ridge. It has been called the Moncton Basin (See Fig. 4) and lies roughly along an axis through Moncton and Sussex. A marked re-entrant is indicated in the ridge, by the gravity contours, near the mouth of the Peticodiac River and it is thought that periodic connections between the Cumberland basin and this subsidiary Moncton basin may have existed there. The position of the Moncton basin also appears to have been the locale of the lake environment in which the bituminous Albert formation was deposited. The salt occurrences in late Albert time may possibly represent flooding of the area by the sea, intermittently overflowing from the Cumberland basin through the opening

suggested by the re-entrant in the gravity contours as noted above.

The MacLellan-Brown positive axes extends northward for an unknown distance from Pictou and Antigonish counties, where it is marked by the pre-Carboniferous rocks of the MacLellan-Brown upland.

Relatively minor positive anomalies are indicated in southcentral P.E.I., in the southeastern extremity of P.E.I., and in the region between West Branch River John and Pictou harbour. Unconformity in the latter region indicate that this positive anomaly represents a subordinate tectonically positive axis but the anomalies indicated on P.E.I. are not accompanied by evidence which would support a similar conclusion.

The possible connection between these tectonically positive elements and suitable environmental factors for the formation and storage of oil is fairly obvious. If the topography of a region is controlled by the tectonic elements within it, the configuration of these elements will control the depth and extent of a sea that transgresses over it. In other words the structural control will define its shores and its areas of deep and shallow water and consequently will control the environmental variations that, in turn exert a strong control on the distribution and the destiny of the organisms that inhabit the sea.

The distribution of organic life is controlled to a large extent by the discharge of sediment into the sea. For example the muddy waters of the mouths of rivers are uninhabitable for most organisms and, in general, marine areas adjacent to rapidly rising land areas are sites of such rapid sedimentation that the existence of abundant organic life is seriously inhibited. Another example of environmental control on organic life,

particularly applicable to the Cumberland basin, is the singular lack of organic remains in most evaporite deposits. In this case the high salinity, in the waters from which the deposits have crystallized, was toxic to organic life. It should be added, however, that in some circumstances the existence of abundant organic life may actually bring about the conditions suitable for the concentration of marine waters and ultimate saline crystallization. A case in point is the isolation of bodies of marine waters behind organic reef barriers. Thus normal marine life might proceed on the seaward side of the reef while in the back-reef area conditions may be toxic to organic life. It is not known whether organic reefs are associated in this way with the evaporite deposits of the Windsor and Horton groups.

Organic reefs as oil reservoirs have come into a position of great importance and it is fitting that the possibilities of oil in the Cumberland basin should be considered with attention to this factor. The development of extensive bioherms (organic reefs) is large controlled by the movement of the strand line. The nature of the control has been discussed by Link (1950) who has pointed out that a moving strand line, moving in either direction and at a rate that will allow the organisms constituting the reefs to extend the existing reef or to begin another, is most conducive to extensive reef development.

The requirements for reef development appear to be best satisfied by the margins of tectonically active platforms or ridges which are covered or intermittently covered by the sea, a condition that is seemingly well satisfied by the northeast extension of the Caledonian positive axis and

possibly by the extension of the MacLellan-Brown positive axis. It is assumed that both positive axes plunge northeastward and in that direction did not erect large areas that were subject to active erosion such as occurred along the Cobequid positive axis and in the southwestern parts of the Caledonian and MacLellan-Brown axes. The rapid influx of sediment resulting from such uplift would have been inhibitive to the development of organic reefs.

Summary of Oil Possibilities:

The presence of all criteria in varying degrees of abundance should promote optimism in regard to the oil possibilities in this basin of deposition. Perhaps the most discouraging factor is the lack of convincing evidence of oil and gas in association with marine strata. But, as was pointed out above, the areas in which the marine strata are exposed are also the areas in which the marine strata had reached their farthest transgression and normal marine conditions did not persist for long periods in these areas.

The more favourable area from the standpoint of persistence of favourably marine conditions would appear to lie farther outward from the apical zone of the basin in the area which has been so effectively blanketed by strata of the Pictou group. Within this latter area the most favourable region for exploration lies along the borders of the tectonically active ridges. This conclusion is supported by several factors: (1) organic reefs, if formed in this basin during marine deposition would almost certainly be localized along the margins of these ridges; (2) wedge belts of porosity,

in the form of sands may also be expected to be aligned with these ridges; (3) if deformation is relatively gentle under the Pictou sediments the pre-Pictou strata may be expected to have a low regional inclination dipping away from the margins of the ridges and thereby favour the upward migration of oil into the porous media bordering the ridges; (4) relative positive movement in the ridges, during deposition, would have the effect of thinning the stratigraphic thicknesses to be penetrated to reach any given horizon.

Recommendations for Exploration:

In view of the factors noted above, the most favourable area for exploration lies along the margins of the tectonically positive ridges. Because the extension of the MacLellan-Brown ridge lies beneath the waters of the Gulf of St. Lawrence, the Caledonian ridge is left as the most feasible site for further investigation. The gravity map, included in this report, illustrates only the broad outlines of the ridge and therefore additional gravitational and seismic exploration will be necessary to define its margins more accurately. These surveys should indicate whether the structural features described above are present and will serve as a much more reliable basis for deciding on the location of exploratory wells.

Chapter V

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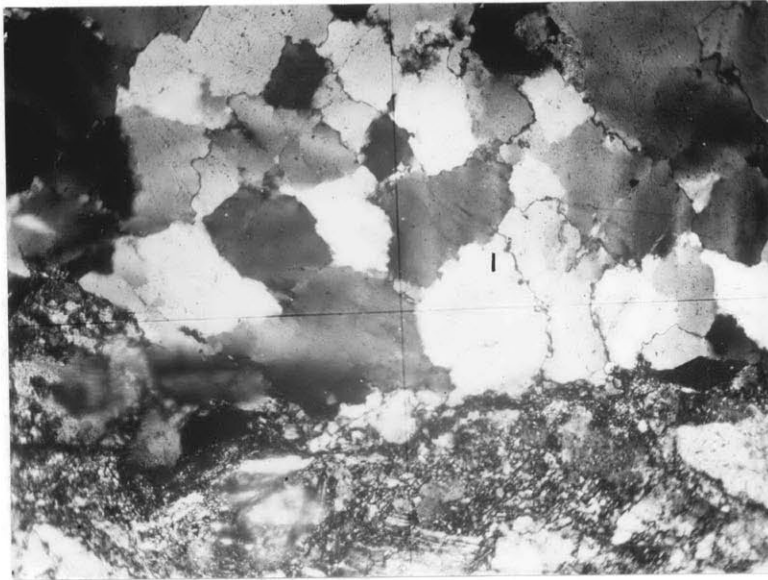
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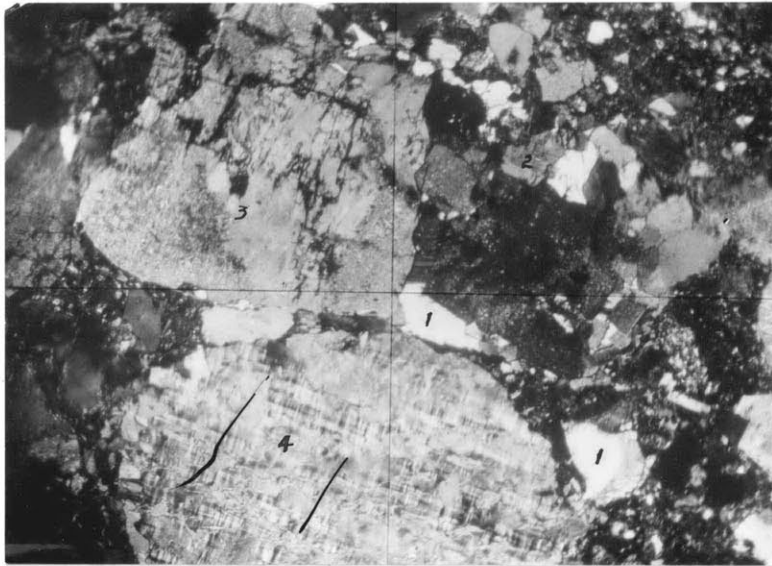
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Photomicrograph of the matrix of the lower coarse facies (Cumberland group)
at Leamington Brook
(crossed nicols, x 60)

1. quartzite - note clear delineation of the sutured grain interfaces.

Plate 6

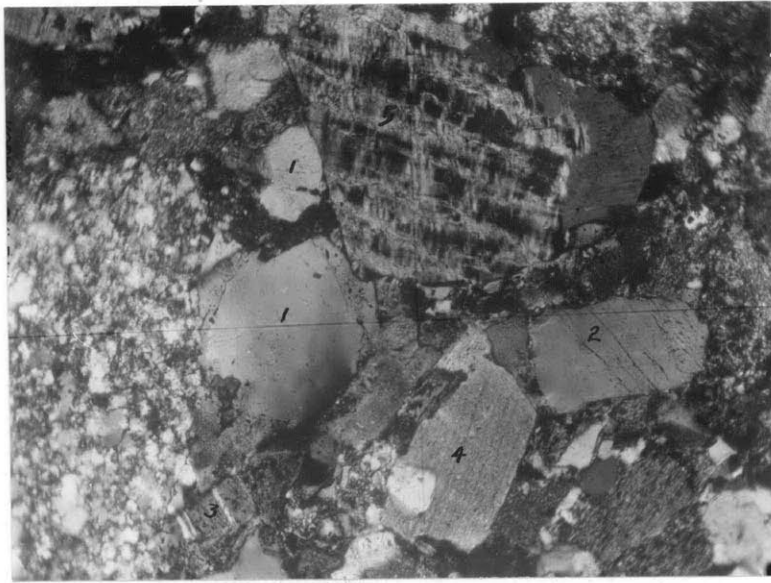


**Photomicrograph of the matrix of the lower coarse facies (Cumberland group)
at Leamington Brook**

(crossed nicols x 60)

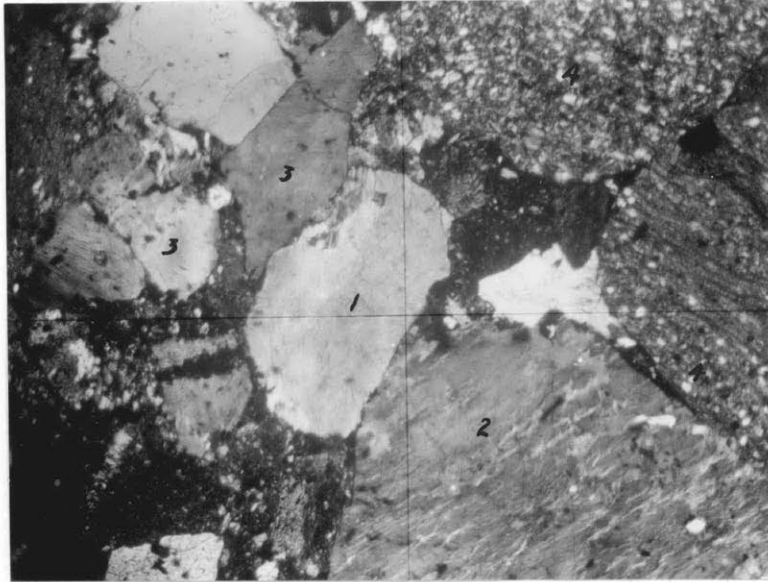
- 1. quartz**
- 2. plagioclase**
- 3. microperthitic orthoclase**
- 4. microperthitic microcline**
- 5. rock fragments**

Plate 7



Photomicrograph of the matrix of the lower coarse facies (Cumberland group)
at Henry Brook

1. quartz
2. quartz with sub-parallel inclusions
3. plagioclase
4. plagioclase, somewhat altered, with
quartz inclusion
5. microcline microperthite



Photomicrograph of the matrix of the lower coarse facies (Cumberland group)
at Reid Brook

(crossed nicols, x 60)

1. quartz
2. microperthite
3. orthoclase, partially decomposed
4. rock fragments, mostly siltstone

Plate 9



**Photomicrograph of the matrix of the lower coarse facies (Cumberland group)
at South Brook**

(crossed nicols, x 60)

- 1. quartz**
- 2. plagioclase**
- 3. micropertthite**

Plate 10



**Photomicrograph of the matrix of the lower coarse facies (Cumberland group)
at South Brook**

(crossed nicols, x 60)

- 1. quartz**
- 2. slate**
- 3. shale**

Plate 11

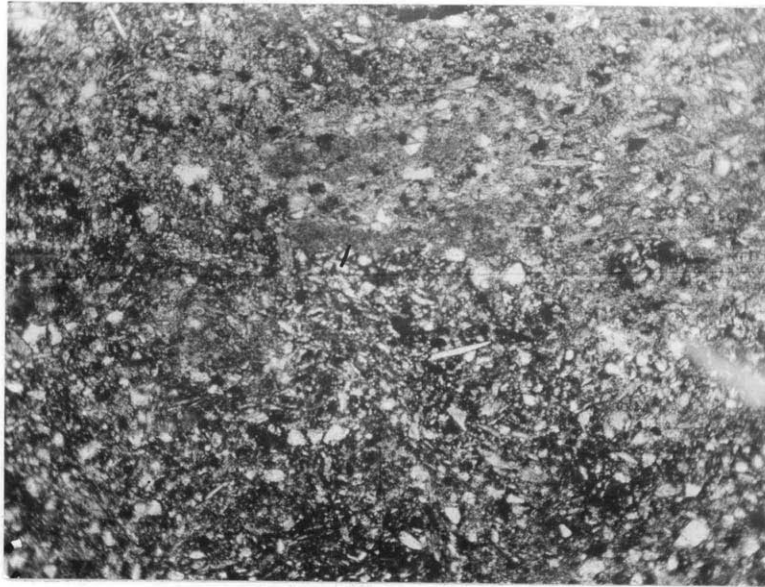


Photomicrograph of the matrix of the lower coarse facies (Cumberland group)
at Lawrence Brook

(crossed nicols x 60)

1. quartzite
2. shale and siltstone - note rounding

Plate 12



Photomicrograph of a fine-grained lens within the lower coarse facies
(Gumberland group)
at Lawrence Brook

(crossed nicols, x 60)

1. siltstone made up mainly of quartz grains and shreds of sericite - heavily stained with hematite.

Plate 13

Photo is
missing.

Photomicrograph of a sandstone bed in the upper part of the lower coarse
facies (Cumberland group)
near mouth of Reid Brook

(crossed nicols x 60)

1. quartz
2. micrographic intergrowth of quartz
and orthoclase
3. schist fragments

Plate 14



Vertical aerial photograph showing well marked strike-ridges formed by massive grey sandstone beds in the fine, non-coal bearing facies of the Cumberland group

Location: one mile west of the mouth of Kelly River.