CANADA
DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

MEMOIR 129

No. 110, GEOLOGICAL SERIES

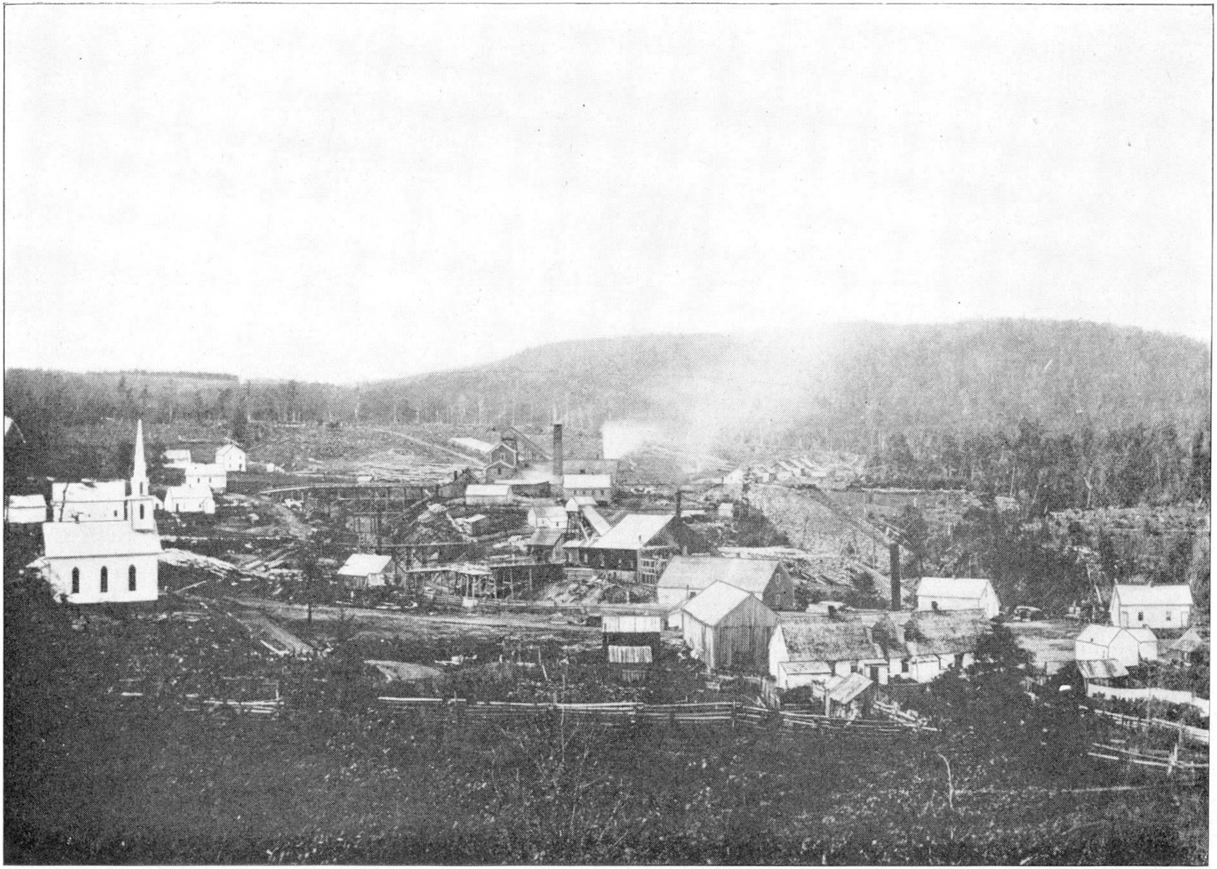
Geology of the Moncton Map-area

BY

W. J. Wright

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1922

No. 1866



Albert Mines at the time of the mining of the albertite vein. Looking from near the manager's house. (From a photograph loaned by Mrs. Jas. Robertson.) (Page 45.)

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INTRODUCTION

The Moncton map-area lies in the southeast part of New Brunswick and includes parts of the counties of Westmorland and Albert.

The geology of this area is primarily the geology of the Carboniferous rocks, which are of special importance because they contain economic deposits of oil and gas, oil-shale, salt, and coal. These deposits are associated with definite horizons of the Carboniferous, and the estimation of their extent necessitates the correct interpretation of the structure and extent of the various horizons.

In 1911, G. A. Young[1] recognized that the detailed geology of the Lower Carboniferous in southern New Brunswick had not always been correctly interpreted in the earlier reports and selected the Moncton map-area as "a favourable place in which to fix some of the revolutionary periods of Carboniferous time." The progress of the work from year to year may be found in the Summary Reports of the Geological Survey, Canada, 1911 to 1915. The field work in the area has been carried out in considerable detail; but before publishing a final geological report and map it will be necessary to study the geology of the adjacent areas to obtain more information as to the unsettled problems in the Moncton map-area; and to examine the core samples from the wells drilled by the New Brunswick Oil and Gas Company.

It is the object of this report to state briefly the information obtained to date, and specify the unsettled problems.

GENERAL GEOLOGY

The rocks of the Moncton map-area are tentatively divided as shown in the following table of formations. There are still some rocks that have not been classified, but they belong to some of the series mentioned; and it is possible that the Weldon and Boyd series are the same.

[1] Geol. Surv., Can., Guide Book No. 1, Excursion in eastern Quebec and the Maritime Provinces, pt. II, p. 355.

Table of Formations

Name of series	Zone	Thickness in feet (approximate)	Age
Tidal deposits			Recent.
Sands and gravel			Pleistocene?
Boulder clay			Pleistocene.
Petitcodiac series	No. 3 No. 2 No. 1	500 400 0–600	Carboniferous. Pennsylvanian.
Unconformity.			
Hillsborough series	No. 4 No. 3 No. 2 No. 1	500 200 20 0–2400	Carboniferous. Mississippian (Windsor)
Unconformity.			
Weldon series	No. 3 No. 2 No. 1	350+ 1,200 600	Carboniferous. Mississippian?
Unconformity?			
Boyd series	No. 5 No. 4 No. 3 No. 2 No. 1	500 25 100 25 450	Carboniferous. Mississippian?
Albert series	No. 3 No. 2 No. 1	4,300 500+ 500	Carboniferous. Mississippian (Horton)?
Unconformity.			
Pre-Carboniferous group	Div. 4 Div. 3 Div. 2 Div. 1	5,000	Pre-Carboniferous.

PRE-CARBONIFEROUS GROUP

The pre-Carboniferous group includes the metamorphic and igneous rocks which unconformably underlie the known Carboniferous rocks. Outcrops of this series in the Moncton map-area are confined to the Caledonia mountains which form a continuous range along the north shore of the bay of Fundy between St. John and Petitcodiac river. Pre-Carboniferous rocks were struck in well No. 52, New Brunswick Oil and Gas Company, at a depth of approximately 550 feet. Very little attention was given to these rocks aside from mapping the boundaries, and the information gained can be stated in a few words.

SUMMARY DESCRIPTION

Following is a summary description of the larger divisions, in the order of age, beginning with the youngest:

Division 4. Batholith of granite, chloritic, gneissoid in part.
Division 3. Basic dykes, several varieties, probably of different ages.
Division 2. Bedded volcanics, dark and greenish, bedding distinct, not schistose, jointing prominent. Thickness on Peck creek........Approximately 5,000 feet.
Division 1. Dark felsites, in thick beds with indistinct bedding planes, not schistose, jointing pronounced, probably volcanic in origin. Thickness unknown.

AGE

The rocks of the pre-Carboniferous group unconformably underlie the Carboniferous system. They were folded and metamorphosed to about their present condition before the deposition of the lowest known Carboniferous sediments, and yielded most of the pebbles and boulders found in the conglomerates and sandstones of the Carboniferous system. On the earlier geological maps they are shown as Precambrian, or pre-Silurian. It is possible that the bedded volcanics are as young as Devonian. The dark felsites have suffered more regional metamorphism than the bedded volcanics, and are probably much older. The granite is intruded into the bedded volcanics, and is, therefore, younger. The basic dykes are younger than the bedded volcanics, and it is inferred that they are older than the granite because none were seen cutting the granite.

CARBONIFEROUS SYSTEM

The Carboniferous sedimentary rocks of the area were laid down near the source of the materials composing them as continental or shallow-water deposits, in the form of alluvial fans and deltas, and as sediments deposited in the shallow waters of enclosed basins and arms of the sea which were at times cut off from the main ocean. The result is a great mass of highly crossbedded, lenticular beds, which cannot be followed for any great distance along the strike. The only exception to this is the Lower Carboniferous limestone (Hillsborough No. 2), which is a true marine horizon that can be followed all the way from Hillsborough to Titusville. Even this bed is destitute of marine fossils over large areas, and locally shows evidence of a chemical origin. But there are groups of beds which maintain their general characteristics over large areas; for example, Albert No. 2, and Petitcodiac No. 2 persist all the way across the Moncton map-area; and there are several other zones which can be distinguished lithologically, though they are not widely exposed at the present surface; for example, Hillsborough No. 4 and Weldon No. 3. These zones serve as keys to the structure and the proper stratigraphic position of the remaining sediments can be determined by finding their relation to one of the key zones.

ALBERT SERIES

The Albert series contains beds of rich oil-shale and is the source of the gas and oil in Albert county. The beds have been folded and eroded and covered by later sediments, which in turn were folded and partly eroded. As a result, the series outcrops in detached basins which are separated from each other on the surface by younger rocks. The folding of the beds is considerable, and locally intense, with severe crumpling and minor faulting.

Lithologically the Albert series is divided into three zones which grade into each other. Beginning with the highest measures exposed, the zones are:

No. 3. Interbedded sandstones and shales, slightly bituminous in part; sandstones, micaceous and frequently ripple-marked, fragments of plants common; some thin beds of bituminous limestone. Thickness (Dover area) approximately........................ 4,300 feet

No. 2.	Beds of rich oil-shale, interbedded with low grade and barren shale. Complete section nowhere exposed. Thickness, more than	500 feet
No. 1.	Basal conglomerate, greenish to black, rounded pebbles, slightly bituminous in part, grading upward into bituminous sandstones and shales, and at Rosevale containing a bed of white, siliceous sandstone. Thickness (at Rosevale) approximately..........	500 feet

Well records indicate that, north of the Stony Creek oil and gas field, the lower members of the Albert series may be red in colour, like those at the base of the series at Elgin.

DISTRIBUTION, STRUCTURE, AND LITHOLOGY

In the Moncton map-area, the Albert series outcrops in three localities, separated on the surface by younger rocks; and as the structure differs in each locality, the areas are described separately.

Dover-Stony Creek Area

The Dover-Stony Creek area spreads over several square miles east of Petitcodiac river, and extends west, under the river, to the Stony Creek gas field. The typical members of the Albert series are not exposed south of Boyd creek; but, in the fault zone on the east bank of the river, are badly contorted dark shales which probably belong to the Albert series.

Structure. On the east side of Petitcodiac river, along Downing and Boyd creeks, the measures dip regularly to the south and southwest at angles of less than 45 degrees. The rocks form part of the north limb of an undulating syncline cut off on the south by the Hillsborough fault. Except for small local crumples, the regular south dip prevails on the east side of Petitcodiac river. But the measures are severely crumpled in the shore section near Dover wharf and Stony creek and the crumple structure appears to extend west at least to where the measures are covered by Zone No. 1 of the Petitcodiac series in the Stony Creek gas field.

In the early development of the Stony Creek gas field the crumpled zone from Dover wharf to Stony creek was supposed to be the crest of an east and west anticline whose northern limb was concealed beneath the almost flat-lying conglomerate of Petitcodiac series No. 1. But the development of the field has not supported this supposition. Last summer, Dr. J. A. L. Henderson, manager of the New Brunswick Gas and Oil Fields, Ltd., expressed the opinion that the gas and oil came from a terrace on the limb of a fold, and not from the crest of an anticline. If this be so, it is quite possible that the south dip continues to the north where it brings up the base of the Albert series under the younger rocks. This possibility is supported by the presence of igneous rocks 500 feet below the surface in well No. 52, about 2 miles north of the Stony Creek gas field. The occurrence of igneous rocks at this point suggests the presence of a partly buried ridge of pre-Carboniferous rocks running northeast and southwest, parallel with the numerous ridges of pre-Carboniferous rocks in southeastern New Brunswick.

Lithology. The measures exposed in the Dover-Stony Creek area belong almost entirely to Zone No. 3 of the Albert series, and the sections along Downing and Boyd creeks afford the best opportunity for studying these measures. In Boyd creek the measures are chiefly dark shales and sandstones, the latter usually having an oily smell when struck with the hammer. No oil-shales were observed in this locality. In Downing creek the measures are chiefly bituminous and carbonaceous shales, with occasional beds of sandstone. In the upper part of this creek, where it approaches the Dover-Memramcook road in a right angle bend there is at least one bed of good oil-shale. It is possible that this is the upper part of Zone No. 2. In the shore sections at Dover wharf, and Stony creek, the measures are all interbedded dark shales and petroliferous sandstones, which belong to Zone No. 3. None of the oil wells in the Stony Creek field have reached the oil-shale of Zone No. 2. The basal conglomerate (Zone No. 1) is not exposed in the Dover-Stony Creek area; but there is evidence which suggests that the base of the Albert series in this area is made up of red beds (*See* page 12).

Albert Mines Area

At Albert Mines, the Albert series is exposed over an area of about 1 square mile.

Structure. On the west, the measures are buckled around a spur of the Caledonia group, and the basal beds dip steeply to the west. It is probable that the two are separated by a fault. To the east the measures are concealed over a large area, but are exposed in the valleys of small tributaries of Frederick brook. The outcrops along these streams show that the measures lie in a northeast and southwest anticline that plunges to the west, and is complicated by intense local crumpling. The underground work of the albertite vein, which followed along the crest of one of the minor crumples, revealed the presence of small faults.

Lithology. At Albert Mines all three zones of the Albert series are represented. The basal conglomerate (Zone No. 1) lies to the west against Caledonia mountain; but lack of outcrops makes it impo sible to determine the relation of these beds to the overlying zones in this area. Zone No. 2 is best exposed along Frederick brook, below the Albert Mines-Shenstone road, where at least five beds of rich oil-shale are exposed in about 500 feet (vertical thickness) of strata. The four lower beds have a peculiar, crumpled structure and are called "curly" shale; the upper bed is the extremely thinly-bedded variety known as "paper" shale. The intervening beds are covered for the most part, and it is probable that they are in part low-grade or barren shale. Borings have proved that there are other beds of rich oil-shale below the lowest bed exposed along this brook. Above the bed of paper shale, after an interval of about 500 feet where the measures are poorly exposed, the interbedded sandstone and shale of Zone No. 3 is well exposed on the main branch of Frederick brook from the south. In sinking the east shaft, thin sandstone dykes were found cutting the Albert shale.

Rosevale Area

In the Rosevale area, the Albert series outcrops in an east and west belt about one-quarter mile wide and 4 miles long. The western extremity is beyond the boundary of the map-area.

Structure. The beds dip regularly to the north at angles of less than 45 degrees and there are no surface indications of faults or local crumples.

Lithology. This is the best locality in the map-area in which to study the lower members of the Albert series. About 1,000 feet (vertical thickness) of the measures are exposed, including Zone No. 1 and at least part of Zone No. 2. To the south, along the foot of Caledonia mountain, the basal conglomerate (Zone No. 1) lies unconformably on the pre-Carboniferous rocks. The conglomerate and interbedded lenses of sandstone are slightly bituminous almost everywhere and grade upward into bituminous sandstones and shales with thin beds of oil-shale, and finally into Zone No. 2, which contains thick beds of rich oil-shale with interbedded low-grade and barren shale. All the measures of Zone No. 2 are bituminous, but there are at least three groups of beds, 20 to 30 feet thick, more bituminous than the others and standing out as low ridges which can be followed on the surface from the most easterly branch of Turtle creek to the headwaters of the west branch. The ridges have not been traced in the basin of the west branch, but beds of rich oil-shale outcrop at intervals all the way to the western extremity of the area, and it is possible that they are continuations of the three groups mentioned. In the bank of the creek, behind the core-house at Rosevale, the shale is cut by a dyke of sandstone.

Summary of Structure

The Albert series lies in northeast and southwest folds which are complicated by minor folds and crumples, and broken by faults. One major anticline and one major syncline are partly exposed in the Moncton map-area.

The crest of the major anticline is exposed at Albert Mines. The north-dipping beds are assumed to continue west under cover of the younger rocks and join the north-dipping measures in the Rosevale area. East of Albert Mines the anticline is covered by unconformably younger rocks as far as Petitcodiac river; but the presence of albertite veins and other bituminous material indicates that the Albert series lies below. The north-dipping measures of the Albert series, on the east side of Petitcodiac river opposite Big cape, are assumed to be the north side of the Albert Mines anticline.

The syncline, well-defined east of the Petitcodiac, is open and plunges to the west. The trough is occupied by the Boyd series, and the Albert series of the Dover-Stony Creek area is on the north limb.

The syncline is broken by the Hillsborough fault, in which the south side moved downward relative to the north side, approximately 3,000 feet. The result of this movement is that the Albert series in the shore section east of the Petitcodiac outcrops nearly 2½ miles south of where it would normally occur if there were no fault, and the Weldon series outcrops between the Boyd and Albert series.

RELATION TO OTHER ROCKS

Pre-Carboniferous Group

At Rosevale, the conglomerate of the Albert series rests on the eroded edges of the bedded volcanics, and contains pebbles of all varieties of rocks found in the pre-Carboniferous group. At Albert Mines, the relation between the Albert series and the pre-Carboniferous is not definitely settled, because of lack of critical exposures. Along part of the contact the beds of the Albert series dip steeply towards the pre-Carboniferous, and it is possible that the two are separated in this locality by a fault.

Boyd Series

The relation between the Albert series and the Boyd series is not clearly shown in the map-area. The structural relations indicate that the two are conformable, and it is probable that one series grades into the other.

Weldon Series

The actual contact between the Albert series and the Weldon series is not exposed in the map-area. The relative distribution and the structure of the two series indicate that the Albert series was folded and partly eroded before the deposition of the basal members of the Weldon series. The evidence of an angular unconformity between the two series is briefly as follows:

In the northwest corner of the Albert Mines area, the Albert series strikes north and south, and dips steeply to the east, whereas the greenish conglomerate of the Weldon, which lies higher up on the hill, dips to the north at angles of less than 10 degrees. Farther east, the dip and strike of the Albert series vary considerably, whereas the structure of the Weldon conglomerate is regular.

On the north side of the Albert Mines anticline, most of Zone No. 3, Albert series, and all of the Boyd series are missing. The absence of these measures is best explained by the supposition that they were eroded before the deposition of the Weldon series.

Hillsborough Series

The basal measures of the Hillsborough series lie on the upturned and eroded edges of the Albert series. This angular unconformity has been recognized by almost all the earlier writers. The evidence is clearly shown in the Rosevale area, where the Albert series, dipping to the north at angles of 35 degrees, is overlain on the north by red and greenish, coarse conglomerate (Hillsborough No. 1) which dips to the north at an angle of less than 15 degrees. East of the Rosevale area, the Hillsborough series overlaps the Albert series and rests directly on the pre-Carboniferous rocks.

Unclassified Rocks

On the east and south sides of the Albert series at Albert Mines there are steeply dipping red rocks, of which the stratigraphical position is not known. The relation of the Albert series to these rocks is discussed in detail on pages 12–13.

AGE

The Lower Carboniferous age of the Albert series is accepted by all the previous writers except R. W. Ells, who in his last written report[1] states that the Albert series is Devonian (Hillsborough No. 2). But all palæontologists agree that the fauna and flora of the Albert series are Car-

[1] Ells, R. W., "Bituminous oil-shales of New Brunswick and Nova Scotia," Dept. of Mines, 1910.

boniferous. The best evidence of the age is given by Lawrence M. Lambe[1] in his report on the Palæoniscid fishes from the Albert shales of New Brunswick. Lambe states that "All the Palæoniscidæ found in the Albert shales of New Brunswick belong to the same genera as, although differing specifically from, those of the Carboniferous sandstone series (Calciferous sandstone series), of Mid and West Lothian and other localities in Scotland...... The great similarity of the fish fauna of the shales in the two countries can lead to no other conclusion than that they are synchronous deposits." Sir William Dawson[2] places the Albert shales in the Lower Carboniferous chiefly on the basis of two fossils, *Cyclopteris Acadica* and *Lepidodendron corrugatum*, and correlates the series with the Horton series, near Wolfville.

Fossil plants collected by the writer from the Albert series were examined by the late W. J. Wilson of the Geological Survey who classified them as follows:

Locality		Remarks
Loc. No.417[3]	424 Downing creek near Dover.	Branching fern stem? indeterminate.
421	"	Branching fern stem.
422	"	Good pinnule of *Aneimites* (*Cyclopteris*) *acadicus* Dawson. This species is typical of Dawson's Horton series, Lower Carboniferous.
423	"	Well preserved specimen of *Cordaites borassifolia* Sternberg. This species has a wide range. Dawson says, "This species is very characteristic of the Millstone Grit and Middle Coal formation in all parts of Nova Scotia and New Brunswick."
419	Boyd creek.	*Lepidodendron?* Species not determinable.
420	Albert Mines.	Indeterminable fragments.
425	Boyd creek.	*Lepidodendron corrugatum* Dawson?
426	Frederick brook.	*Lepidodendron corrugatum?* resembles Dawson's variety *Cyclostigmoides*.

Of the above list No. 422 points to the same age for the Albert shales and the Horton series in Nova Scotia, as Sir William Dawson showed many years ago, and the Lepidodendron, Nos. 419, 425, and 426, go to confirm this view.

Dawson[4] correlates the Albert series with the dark (and grey bituminous) shales near Norton, and with the dark and slightly bituminous shales in Horton bluff, Nova Scotia. Bailey and Matthew[5] consider the Albert series to be the equivalent of dark shales associated with conglomerate limestone and gypsum south of Sussex. R. W. Ells[6] correlates the Albert

[1] Geol. Surv., Can., Mem. No. 3.
[2] Dawson, Sir William, "Acadian geology," 3rd Edition, p. 244.
[3] The specimen from Loc. No. 418 is a fossil bivalve, probably *Naidites*.
[4] Dawson, Sir William, "Acadian geology," 3rd edition, p. 244.
[5] Bailey, L. W., and Matthew, G. F., Geol. Surv., Can., Ann. Rept., 1870-1871, p. 205.
[6] Ells. R. W., "Bituminous or oil-shale of New Brunswick and Nova Scotia," Dept. of Mines, 1910.

series with the rocks of Kennebecasis island which he believes to belong to the Perry group (Devonian). Lambe[1] supports Dawson in correlating the Albert series with the Horton series, on the evidence of the fishes. Wilson[2] found *Lepidodendron corrugatum* and *Aneimites Acadica* in the Albert series on Robertson brook, near Elgin, and in the dark Carboniferous shales on Kennebecasis island, and on Moosehorn brook, near Norton. On the basis of these fossils he correlates the rocks of all these localities with the Horton at Horton bluff.

Hayes[3] calls the Carboniferous rocks on Kennebecasis island the "Kennebecasis series," and believes that this series includes most of the Lower Carboniferous rocks in Kings county, between the Canadian National railway on the north and Caledonian mountain on the south. The term "Kennebecasis series" is adopted in this report to include the Lower Carboniferous rocks in Kings county, N.B., as suggested by Hayes.

CORRELATION

The Albert series has been correlated with the Horton series at Horton bluff and the Kennebecasis series in Kings county, N.B. The correlation is based on the presence of two fossils, *Lepidodendron corrugatum* and *Cyclopteris Acadica*. These fossils have been found in the following series of rocks and localities: Horton series in Nova Scotia, Albert series in the Moncton map-area and at Elgin, and Kennebecasis series on Kennebecasis island and Moosehorn brook.

The writer hesitates to disagree with some of the correlations mentioned above, especially when his difference of opinion is based mainly on structural evidence obtained during a reconnaissance trip along roads. But the correct correlation of the Albert series is so vital to the petroleum industry of New Brunswick, and the reasons for disagreeing with the present correlations seem so well founded that it seems advisable to draw attention to a possible mistake in correlation, even though the conclusions now arrived at may later be proved to be incorrect.

Bailey and Matthew[4] make the following statement:

"Near Sussex, in the eastern portion of Kings county, this formation (Lower Carboniferous) consists of the following members, in descending order:

8. Reddish-brown arenaceous shales and red sandstone.
7. Upper conglomerate; hard and massive beds.
6. Bright red sandstones and brownish-red shales and sandstones. (Brine-springs rise from these beds.)
5. Grey sandstones, flags, and dark grey bituminous shales, with *Cyclopteris Acadica* and *Lepidodendron corrugatum*.
4. Conglomerate, limestone, gypsum, and dark grey bituminous shales with *Terebratula sufflata*, etc., *Cyclopteris Acadica*, and *Lepidodendron corrugatum*.
3. Lower conglomerate, hard and massive beds.
2. Break in section (probably shales).
1. Basal conglomerate."

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[1] Lambe, L. M., "Report on the Palæoniscid fishes from the Albert shales of New Brunswick," Geol. Surv., Can., Mem. No. 3.
[2] Wilson, W. J., Geol. Surv., Can., Sum. Rept., 1912, p. 497.
[3] Hayes, A. O., "Report on the geology of the St. John map-area, Geol. Surv., Can. (Unpublished).
[4] Bailey, L. W., and Matthew, G. W., Geol. Surv., Can., Rept. of Prog., 1870–71, p. 205.

The significant point in the above statement is the presence of dark and bituminous shales both overlying and associated with the limestone and gypsum (Windsor series). However, the authors do not consider that the dark shales belong to the Windsor but imply that they are of the same horizon as the Albert series at Albert Mines. Nowhere in previous reports is there a statement to show that any attempt was made to determine the structural relation of these dark shales to the Albert series at Albert Mines and Elgin.

On a reconnaissance trip made in company with A. O. Hayes in 1919, structural evidence was found to indicate that in Kings county, between the Canadian National railway on the north, and Caledonia mountain on the south, nearly all of the rocks previously mapped as Lower Carboniferous are conformably above the Lower Carboniferous (Windsor) limestone and gypsum. They belong to the same series as the Carboniferous rocks on Kennebecasis island, which are now called the "Kennebecasis series." Owing to the presence of the fossiliferous limestone, and the gypsum, this series is now correlated with the Hillsborough series at Elgin and in the Moncton map-area, and with the Windsor series at Windsor, Nova Scotia. The Hillsborough series unconformably overlies the Albert series, and the dark shales which contain *Cyclopteris Acadica* and *Lepidodendron corrugatum* are among the highest members of the Kennebecasis series. It follows (1) that the dark shales in Kings county are not Albert series, and (2) the plants, *Cyclopteris Acadica* and *Lepidodendron*, are not diagnostic of the Albert series.

Bearing on Oil Industry. These conclusions if correct have a very important bearing on the oil industry. The dark shales on Paticake brook, Moosehorn brook, and at Ratters Corner, are not Albert series brought up in an anticline, but Kennebecasis series in the trough of a syncline. The Albert series was folded and eroded before the deposition of the Kennebecasis series. So that the structure of the Kennebecasis series is not a true guide to the structure of the Albert series.

Extent

The distribution and structure of the Albert series as shown on Ells' map (Map 35A) strongly favours the conclusion of Bailey and Ells[1], that, in Westmorland county, the series outcrops along two sides of a broad geosynclinal basin. The areas at Rosevale, Albert Mines, Belliveau, and Taylor village, are on the south limb, and the Dover-Stony Creek area and the shales at St. Joseph college are on the north limb of the syncline. The north and south limbs probably continue to approach each other east of Memramcook river and unite under the cover of younger rocks to form the west end of a canoe-shaped geosyncline which plunges to the west. Bailey and Ells suggest that the northern limb of this syncline continues west and joins the Albert series at Elgin. But on the assumption that a submerged pre-Carboniferous ridge extends from Calhoun, through well 52, to the pre-Carboniferous spur at Prosser brook, it follows that the north limb approaches the south limb towards the west and that the

[1] Bailey, L. W. and Ells, R. W., Geol. Surv., Can., Rept. of Prog., 1876-77, p. 369.

two unite in the vicinity of Prosser brook, forming the west end of a canoe-shaped fold which plunges to the east; and that the Albert series at Elgin belongs to the north limb of a succeeding anticline to the north.

Whether or not the Albert series underlies the whole of this geo-synclinal basin is a question which cannot be settled by surface indications alone. The series was exposed to erosion before the deposition of the Weldon and Hillsborough series, and in some places the beds may have been entirely removed. But from the west side of Petitcodiac river to the eastern boundary of the Moncton map-area, the presence of the Boyd series, which conformably overlies the Albert series, shows that the latter is below. However, the continuity of the Albert series in this part of the basin is broken by the Hillsborough fault, in which the north side was raised relatively about 3,000 feet.

Ells[1] believed that all of the dark shales in Kings county belong to the Albert series, and on this ground states that the Albert shales appear at intervals all the way from Memramcook river on the east to within a short distance of the village of Hampton on the west, and continue on Kennebecasis island. This conclusion needs further investigation. There is no doubt that the Albert series outcrops over a large area at Mapleton and Elgin, and that a small, isolated area outcrops on Cedar Camp brook, about 4 miles east of Waterford; and careful search may reveal the presence of other areas west of this point. But it has been shown in a previous paragraph that most of the dark and slightly bituminous shales in Kings county, including those on Kennebecasis island, probably lie unconformably above the Albert series, and belong to the upper part of the Windsor series (Hillsborough series).

The lithology of the Albert series at Mapleton and Elgin is quite different from that at Albert Mines and Rosevale. At Mapleton, there are two zones of conglomerate near the base, and the thick beds of oil-shale are absent or concealed by the unconformably overlying conglomerates to the north, whereas on Pollet river, and on Robertson brook near Elgin, the base consists of a great thickness of red conglomerate, sandstone, and shale, which grade upward into dark and grey sandstone and shale, and finally into red sandstone and shale. These rocks are so different from the typical Albert series at Rosevale and Albert Mines that Bailey and Ells in their earlier report[2] placed most of the red measures in Division No. 3, which they considered to be younger than the Albert series. On his later map (Map 35A) Ells corrected this error, and placed all these rocks in the Albert series.

Extent of Areas Concealed. Of the many unsettled problems in the geology of the Albert series, the most important is the location and extent of the Albert series beneath the overlying rocks. The geology of the Lower Carboniferous is so complicated that the interpretation is difficult even where the rocks are exposed, and the interpretation of the structure under the overlying rocks is a matter of speculation which can be settled only by drilling. To date, four wells which did not strike the Albert series have been drilled in the Moncton map-area, and the results seem to

[1] Ells, R. W., "Report on the bituminous or oil-shales of New Brunswick and Nova Scotia," Dept. of Mines, Can., pt. II, p. 11.
[2] Bailey, L. W., and Ells, R. W., Geol. Surv., Can., Rept. of Prog. 1876-77, p. 371.

have complicated rather than simplified the problem. However, field observations and a hasty examination of the well records suggest the following simple solution of the puzzle. The accuracy of this solution should be tested by a detailed study of the geology in the Memramcook valley, and of all the available well records. East of Petitcodiac river, the north and south limbs of the syncline approach each other, and probably come together under the cover of the younger rocks east of Memramcook river. The junction of the two limbs is probably severed by the continuation of the Hillsborough fault.

West of the Petitcodiac, in the Stony Creek gas and oil field, the known facts are somewhat as follows: In the area bounded by Stony creek on the north, Petitcodiac river on the east, the Weldon-Dawson Settlement road on the south, and the Dawson Settlement-Coverdale road on the west, all the wells shown on the map have found the Albert series. On the crest of the main hill the Albert series is covered only by the Petitcodiac series; but along the southern and western sides of the hill red sandstones and shales occur between the bottom of the Petitcodiac series and the top of the Albert series. The depth of the red sediments is shown in the following wells: No. 28—350 feet; No. 25—1,000 feet; No. 24—900 feet; No. 26—1,000 feet. Well No. 27 at Baltimore siding did not reach the Albert series, but found red sandstones and shales below the Petitcodiac series to a depth of over 2,600 feet.

The simplest explanation of the occurrence of the red series in these wells is that they belong to the Boyd series, which dips to the south about 35 degrees, and conformably overlies the Albert series. The Boyd and Albert series were both eroded before the deposition of the Petitcodiac series, and wells Nos. 28, 24, 25, and 26 struck the Boyd near the underlying Albert series, whereas well No. 27 was too far south and did not reach the base of the Boyd series. In this case the logical place to drill for the Albert series is along a line running north from Baltimore siding.

Three wells north of the Dover-Stony Creek area did not strike the Albert series, beneath the Petitcodiac series. Well No. 2 east of Dover found red sandstone and shale with some dark shale to a depth of 2,300 feet (copy of well record). East of the Petitcodiac, well No. 51, three-quarters of a mile north of the mouth of Stony creek, found red sedimentary rocks to a depth of 2,000 feet, but well No. 52, $2\frac{3}{4}$ miles north of the mouth of Stony creek, found pre-Carboniferous igneous rocks at a depth of about 550 feet.

East of the Moncton map-area, in the Memramcook valley, red sandstones and shales are exposed north of the Albert series, and farther north, at Calhoun Mills, there is a small area of pre-Carboniferous granite.

The phenomena mentioned above show that the Dover-Stony Creek area of Albert series is succeeded on the north by a series of red sediments, and finally by a partly submerged ridge of pre-Carboniferous rocks. The structure suggests that the red sediments underlie the Albert series, and rest on the pre-Carboniferous. In this case the red sediments are not exposed elsewhere in the map-area.

The simplest explanation of the occurrence of the red beds, which appear to underlie the Albert series of the Dover-Stony Creek area, is suggested by the lithology of the Albert series near Elgin, along Pollet river and Robertson brook, where the base of the series is of red conglomerate, sandstone, and shale. These red rocks are probably a different phase of the bituminous conglomerate and sandstone that form the base of the Albert series at Rosevale, and indicate that conditions of sedimentation varied in different places just as they do in alluvial and shallow water deposits of the present time. Thus it is possible that the red measures north of the Albert series in the Dover-Stony Creek area are the basal beds of the Albert series which rest on the pre-Carboniferous farther north, and correspond with the basal red beds at Elgin which rest on the pre-Carboniferous to the south.

Following is a summary of the suggested solution. The bituminous measures of the Dover-Stony Creek area (Albert series) are conformably underlain by a series of red beds not exposed elsewhere in the map-area, and conformably overlain by other red rocks (Boyd series). The basal red beds rest on a submerged ridge of pre-Carboniferous to the north, and the whole series dips to the south at angles of not more than 45 degrees. These measures were eroded so that they were exposed in parallel east and west belts, which were afterwards covered by the flat-lying Petitcodiac series. The productive wells in the Stony Creek field struck the belt of bituminous Albert series. Wells Nos. 28, 25, 24, and 26 were far enough south to pass through varying amounts of the Boyd series to the underlying Albert series. Well No. 27 was so far south that it did not reach the base of the Boyd series. Wells Nos. 2 and 51 struck the basal red beds, and well 52 struck the unconformably underlying pre-Carboniferous. The continuation of the bituminous zone in the Albert series west of the Stony Creek field should be found by boring along a line north from Baltimore station.

But the solution of the problem may be complicated in some of the following ways. (1) North of the Stony Creek field there may be an anticline in the Albert and Boyd series, along the line of the submerged pre-Carboniferous ridge. If this anticline plunges to the west, the boundary between the two series will curve to the north, and finally to the east along the north side of the ridge mentioned. This change in direction should be detected by a detailed study of the well records, and a plot of the sub-surface contours of the boundary between the Albert series and the overlying red rocks. (2) The red rocks in the wells mentioned, particularly in well No. 27, may belong to the Weldon or Hillsborough series which overlie the Albert series unconformably. In this case, the Albert series may be entirely eroded east of the Stony Creek field, or may be buried to such a depth that it cannot be reached by drilling.

BOYD SERIES

The Boyd series is made up chiefly of red conglomerate, sandstone, and shale, with two beds of tuff. The beds of tuff are the "Key zones" of the Boyd series; the remaining rocks cannot be distinguished lithologically from the red sediments of the Weldon series. Previous writers did not recognize the beds of tuff and grouped this series with the other red sediments of the area. Bailey and Ells[1] placed the beds in Division

[1] Bailey, L. W., and Ells, R. W., Geol. Surv., Can., Ann. Rept., 1876-77, and accompanying map.

IV, and mapped them as "conglomerates and marls." Young[1] placed them provisionally in the Intermediate group. Ells[2] mapped them as Lower Carboniferous.

SUMMARY DESCRIPTION (*descending order*)

		Feet
Zone No. 5.	Coarse and fine, red, arkosic sandstones and red shale, with red conglomerate near the base. Approximate thickness on Boyd creek	500
Zone No. 4.	Purplish volcanic ash (tuff). Approximate thickness on Boyd creek	25
Zone No. 3.	Red and greenish shale, near the base one bed of greyish sandstone with nodules of jasper. Approximate thickness on Boyd creek....	100
Zone No. 2.	Purplish volcanic ash, like No. 4. Approximate thickness on Boyd creek..	25
Zone No. 1.	Poorly exposed, appears to consist chiefly of red shale, and red arkosic sandstone. Approximate thickness on Boyd creek...............	450

DISTRIBUTION

The type locality of the Boyd series is the lower basin of Boyd creek, on the east side of Petitcodiac river. The rocks are not exposed along the bank of Petitcodiac river, except for a short distance near the southern boundary of the belt. At this point there is an outcrop of the grey sandstone with jasper nodules, which occurs in Zone No. 3, and an abundance of angular fragments of the tuff. But the bed of tuff is not exposed. South of this point there are dark shales which probably belong to the Albert series.

West of Petitcodiac river one bed of tuff shows on the river bank, but it could be traced for only a short distance. Jasper concretions like those in the sandstone of Zone 3 are abundant in the soil between the main road and the river, north of Weldon village, and for this reason the underlying rocks are mapped Boyd series.

STRUCTURE

East of the Petitcodiac the measures lie in an open syncline which plunges to the west and is cut off on the south by the Hillsborough-Belliveau fault. On the bank of Petitcodiac river the measures are badly contorted in the fault zone and west of the river the structure is not known.

RELATION TO OTHER ROCKS

Albert Series

On Boyd creek, the Boyd series appears to grade downward into the Albert series, and it is assumed that the two series are conformable.

Weldon Series

The relation of the Boyd series to the Weldon series is not clearly shown in the area. On the east side of the Petitcodiac the two series are separated by the Hillsborough fault. West of Petitcodiac river, both

[1] Young, G. A., Geol. Surv., Can., Guide Book No. 1, pt. II.
[2] Geological map, New Brunswick, Sheet No. 4 N.W.

series are exposed in the lower valley of Weldon creek, and a brief study of this locality alone would lead to the conclusion that the two series are one. The chief reason for separating them is that near the base the Boyd series in the type locality contains two beds of tuff which are readily distinguished lithologically, and no such rocks have been found in the Weldon series. The Boyd series appears to be conformably above the Albert series, and the Weldon series is unconformably above the Albert series; and it is inferred that the Weldon is younger than the Boyd and that possibly the two are separated by an unconformity. This problem, however, needs further investigation.

Hillsborough Series

The Boyd series does not come in contact with the Hillsborough series in the map-area, but since the Hillsborough series is unconformably above the Weldon, it is inferred that it is unconformably above the Boyd.

Petitcodiac Series

The Boyd series is unconformably below the Petitcodiac series. This is clearly shown on the east side of Petitcodiac river, where the almost flat-lying conglomerate of the Petitcodiac No. 1 spreads over the south and east border of the syncline in the Boyd series.

AGE

The Boyd series is placed in the Lower Carboniferous because it unconformably underlies the Petitcodiac series, and seems to be conformably above the Albert series. No fossils were found in the type locality, but careful search may yet reveal the presence of organic remains, particularly in the greenish shales of Zone No. 3, on the east branch of Boyd creek.

WELDON SERIES

The rocks making up the Weldon series were formerly considered to conformably underlie the Hillsborough series. Bailey and Ells[1] placed them in Division IV, and mapped tham as "conglomerates and marls." Ells[2] mapped them as Lower Carboniferous. Young[3] placed them in the Intermediate group.

The best exposures of the series in the area are found along Peck and Weldon creeks and on the east bank of Petitcodiac river at Belliveau village. In both places, the rocks are made up of three zones which grade into each other. Zone No. 3 is the key zone in the series.

SUMMARY DESCRIPTION (*descending order*)

		Feet
Zone No. 3.	Dark red, hackly shales, severely jointed and slickensided, bedding planes very difficult to distinguish, greenish stains along joint planes. Thickness..	300

[1] Bailey, L. W., and Ells, R. W., Geol. Surv., Can., Ann. Rept., 1876-77, and accompanying map.
[2] Geological map, New Brunswick, Sheet 4, N.W.
[3] Young, G. A., Geol. Surv., Can., Guide Book No. 1, pt. II.

Zone No. 2.	Dark red shales and sandstones, relative amount of the latter increasing towards the base. At least one zone of dark and greenish argillaceous sandstones containing plant fragments. Sandstones poorly sorted, arkosic, crossbedded, ripple-marked, sometimes mud-cracked. Thickness on Peck creek........................	1,200
Zone No. 1.	Coarse, poorly sorted conglomerate, subangular pebbles, greenish, weathering to red. Thickness on Peck creek....................	600

STRUCTURE

Along the south side of Weldon creek, from the headwaters to Round hill, the Weldon series dips regularly to the north at angles of 20 to 30 degrees, and passes under the red conglomerates of Hillsborough series, Zone No. 1, to the north. Along the lower part of Peck creek, the folding becomes more complex, and the structure is complicated by local crumples and small faults. Along Weldon creek from the mouth of Peck creek to the mouth of Frederick brook, the rocks are red shales of Zone No. 3, in which the bedding is so poorly defined that it is impossible to make out the structure. In places the shale has a slaty cleavage, and there are other evidences of excessive deformation. For this reason it is inferred that the Hillsborough-Belliveau fault passes through this area.

The red shale of Zone No. 3 can be followed along Weldon creek for over one mile below Salem. Beyond that point the structure has not been worked out, and the relation between the Weldon series and the Boyd series in the vicinity of Weldon village is not known.

The basal conglomerate, Zone No. 1, can be followed from the valley of Peck creek east over the divide into the basin of Frederick brook, and across the Albert Mines-Shenstone road, but east of that point the measures are concealed. The Weldon in this locality overlies the Albert unconformably, but it has not been possible to determine the relation between the Weldon and the "unclassified" rocks at Albert Mines.

On the east bank of Petitcodiac river near Belliveau the Weldon conglomerate, Zone No. 1, comes in contact with the Albert series which lies to the south, about 1,000 feet outside the east boundary of the map-area. At that point the two series are separated either by a fault or by an unconformity, and, to the north, along the bank of the river, the beds dip to the northwest, gradually swinging around to the north, and finally dip to the south, forming a syncline in which the measures of Zone No. 3 are preserved. A detailed description of this section is given by Bailey and Ells.[1] Zones Nos. 1 and 2, cut off by the Hillsborough fault, are not exposed on the north limb of this syncline.

The green argillaceous sandstones of Zone No. 2 which contain undeterminable fragments of plants, may be seen at the following points: (1) east bank of Petitcodiac river, 1,000 feet southeast of the boundary of the map-area; (2) Peck creek, 200 feet below letter "k" in the word "creek" (*See* Moncton map-area); (3) Weldon creek, due south from the Shenstone schoolhouse. It is possible that some of these measures contain a flora which will serve to determine the age of the measures. The most likely place for the occurrence of fossils is the locality mentioned above, on the east bank of Petitcodiac river.

[1] Bailey, L. W., and Ells, R. W , Geol. Surv., Can., Ann. Rept., 1876-77.

RELATIONS TO OTHER ROCKS

Pre-Carboniferous Group

The Weldon series lies unconformably on the pre-Carboniferous rocks.

Albert Series

The relation of the series to the Albert series is exhibited on the divide between Peck creek and the headwaters of Frederick brook. At that point the Weldon conglomerate, dipping to the north at an angle of about 10 degrees, overlaps the Albert shales which strike north-south and dip at steep angles to the west.

Boyd Series

The relation between the Weldon series and the Boyd series is not definitely known. East of the Petitcodiac the two series are separated by a fault. West of the Petitcodiac both series are exposed in the lower valley of Weldon creek, and a brief study of this locality alone would lead to the conclusion that the two series were one. The chief reason for separating the two is that, near the base, the Boyd series in the type locality contains two beds of tuff which are readily distinguished lithologically, and no such rocks have been found in the Weldon series. The Boyd series appears to be conformably above the Albert series, and it is inferred that the Weldon is unconformably above the Boyd.

Hillsborough Series

The relation between the Weldon and the Hillsborough series is best shown along the north side of the upper part of Weldon creek. The Weldon shales along the creek bottom dip to the north at angles of 50 to 60 degrees, and are abruptly succeeded by the coarse conglomerate of Hillsborough No. 1 which dips to the north at angles of about 15 degrees. From this it is inferred that the Hillsborough series lies unconformably on the Weldon. Three thousand feet east of the Shaw Creek road, the two series are separated by a vertical fault in which the downthrow has been to the north. But there is no evidence that this fault is extensive. On the east side of Peck creek, at the mouth of the small tributary from Round hill, the shales and sandstones of the Weldon are severely contorted; but the overlying conglomerate on the east bank dips uniformly to the east. This is taken as additional evidence of an unconformity between the two series. The conclusions drawn from a study of these localities in detail is supported by the relative distribution of the series over the whole map-area.

Petitcodiac Series

The unconformity between the Weldon series and the overlying conglomerate of Petitcodiac No. 1 is best shown on the east side of Petitcodiac river near Belliveau village, where the conglomerate lies almost flat on the eroded edges of the folded Weldon series.

HILLSBOROUGH SERIES

The Hillsborough series includes the gypsum and anhydrite and the conformably underlying limestone and red sediments. Bailey and Ells[1] believed that these rocks were conformably above Division IV (Weldon and Boyd series), but placed them in a separate division (Division V) because of their economic importance. Young[2] placed these rocks in the Intermediate group.

SUMMARY DESCRIPTION

The rocks of the Hillsborough series fall naturally into four zones. Zones Nos. 1 and 3 cannot be distinguished lithologically from the red sediments of the other series, but Zones Nos. 2 and 4 are two of the key zones in the Carboniferous series. Following is a summary description in descending order:

		Feet
Zone No. 4.	Anhydrite and gypsum. Approximate thickness	500
Zone No. 3.	Red calcareous shales, sandstones, and conglomerates. Approximate thickness	200
Zone No. 2.	Dark limestone, in some places flaggy, in others massive or crumpled. Fossiliferous in part, grading up into red argillaceous limestone, near the Albert series, contains vugs and seams of bitumen. (Not albertite.) Approximate thickness	20
Zone No. 1.	Red and greenish conglomerate and red arkosic sandstone; calcareous conglomerate, poorly sorted pebbles subangular, up to 2 feet in diameter, made up of pre-Carboniferous with some pebbles of Carboniferous sediments. Along Caledonia mountain this zone thins out and frequently the overlying limestone rests on the pre-Carboniferous rocks. Zone becomes thicker away from the old shore-line. Approximate thickness	0–2,400

AGE

The limestone Zone No. 2 is the only horizon in the Petitcodiac series known to be fossiliferous, and even it is barren of fossils over most of the map-area. On the west side of the west branch of Turtle creek, just below where it leaves the map-area, the limestone (Zone No. 2) is full of fossils. A collection from this and other localities was transmitted to the Division of Palæontology. The report furnished by this division which was prepared by Dr. Geo. H. Girty, a specialist in the Carboniferous faunas, follows:

"The collections, six in number, give every indication of belonging to a single fauna, that which Dawson described under the title Lower Carboniferous, and which occurs in the beds now designated as the Windsor limestone. The species that I have identified in these lots are as follows:

[1] Bailey, L. W., and Ells, R. W., Geol. Surv., Can., Rept. of Prog., 1876–77, p. 374.
[2] Young, G. A., Geol. Surv., Can., Sum. Rept., 1912.

Small Brook Entering Shepody Bay, from Shepody Mountain

Productus Dawsoni?
Pugnax aff. *Dawsoni*.
Harttina Anna.
Edmondia ? n. sp.
Aviculipecten simplex.
Liopteria (*Leptodesma*?) *Dawsoni*.
" " *Acadica*?
Platyschisma dubium?
Bulimorpha ? sp. a.
" ? sp. b.
Meekospira ? sp.
Orthoceras ? sp.
Paraparchites aff. *carbonarius*.

Cape Demoiselle, Albert County, N.B.

Beecheria Davidsoni.
Pteronites Gayensis.
Liopteria (*Leptodesma*) *Dawsoni*.
Modiola Poolei.
Zygopleura? n. sp.
Conularia planicostata.

Cedar Camp, Brook County, N.B.

Beecheria Davidsoni.
Pteronites Gayensis.
Liopteria (*Leptodesma*?) *Dawsoni*.
Aviculipecten simplex.
Pleurotomaria sp.
Orthoceras sp.
Conularia planicostata.

North Shore, Malagash, N.S.

Stenopora sp.
Productus Dawsoni.
" *auriculispina*?
Aviculipecten simplex.
" *cora*.
" *Lyelli*.
Liopteria (*Leptodesma*?) *Acadica*.

"Inasmuch as the geologic age of this fauna was at one time called in question I may say that in my opinion it is unequivocally Mississippian rather than Pennsylvanian, and probably also upper Mississippian. It is true that the present collection does not contain many forms that one would call characteristically Mississippian (*Pteronites Gayensis* is perhaps the most significant), but this incomplete presentation of the fauna can be supplemented with other species described by Dawson and more recently by Beede, so that little doubt can exist regarding the evidence of the invertebrate fossils."

RELATION TO OTHER ROCKS

Albert Series

The Albert series was folded and partly eroded before the Hillsborough series was deposited. The angular unconformity between the two is very plain at Rosevale, where the Albert series, dipping to the north at angles of about 35 degrees, is overlapped by the basal conglomerates of the Hillsborough series which dip to the north at angles of about 10 degrees.

Boyd Series

The Hillsborough series does not come in contact with the Boyd series east of the Petitcodiac, and west of the river the structural relations between the two are obscure. Since the Hillsborough series is unconformably younger than the Weldon series which is younger than the Boyd series, it is inferred that the Hillsborough series is separated from the Boyd series by an angular unconformity.

Weldon Series

The Weldon series was folded and partly eroded before the deposition of the Hillsborough series. This is shown by the following phenomena:

(1) On Peck creek the Weldon sandstones and shales are severely contorted, but the overlying Hillsborough series dips at regular angles.

(2) Along Weldon creek west of Round hill the measures of Weldon No. 2 dip about 45 degrees to the north, but the Hillsborough series dips about 15 degrees to the north.

(3) At Rosevale the Hillsborough series rests directly on the Albert series.

(4) Pebbles of hard and argillaceous limestone from the Weldon series occur in the conglomerate of the Hillsborough series.

Petitcodiac Series

The Hillsborough series was folded and eroded before the deposition of the Petitcodiac series. The evidence for this is given more fully on page 26.

STRUCTURE

The structure of the Hillsborough series in the Moncton area is relatively simple, and is readily interpreted from the structure of the limestone (Zone No. 2) which is the key horizon. Near Hillsborough and in the basin of Demoiselle creek, the measures are warped into two irregular basins. The Hillsborough basin is bounded on the north by the Hillsborough fault, in which the south member moved relatively downward. South of the Hillsborough basin there are three small east-west faults which show in the hill immediately west of Surrey. In these faults the south side moved relatively upward, in each case not more than 50 feet. None of these faults cut the Petitcodiac series and it is, therefore, inferred that the movement took place before the deposition of that series. As a result of the Surrey faults, and the ensuing period of erosion, the limestone and gypsum of the Hillsborough basin are not continuous with these zones in the Demoiselle basin to the south.

DISTRIBUTION

One or more zones of the Hillsborough series outcrop west of Petitcodiac river all the way across the map-area. The best exposures of the whole series occur in the vicinity of Hillsborough and in the basins of Demoiselle and Wilson creeks. East of Peck creek, the outcrops belong to Zone No. 1, except outcrops of the limestone on Cat creek and on the west branch of Turtle creek. The best section of the series in the western part of the map-area is exposed along the west branch of Turtle creek, where the basal conglomerate (Zone No. 1) rests on the eroded edges of the Albert series, and is overlain by fossiliferous limestone (Zone No. 2). The limestone outcrops just outside the boundary of the map-area.

On reconnaissance trips west of the Moncton area, with A. O. Hayes and W. A. Bell, the limestone horizon was found outcropping at intervals along the foot of Caledonia mountain from Turtle creek to Titus Mills, Kings county, but no attempt was made to follow the limestone beyond Titus Mills. At Elgin, Markhamville, and Cedar Camp post office, the limestone contains an abundance of invertebrate fossils, which W. A. Bell believed to be of the same age as those in the Windsor limestone at Windsor, N.S.

Throughout the above area the limestone dips to the north. In some places it is underlain by red conglomerate—in others it rests directly on the pre-Carboniferous rocks. The limestone is overlain in many places by coarse red conglomerate, but at Upham by extensive deposits of gypsum and anhydrite.

The following observations and conclusions were made in company with A. O. Hayes. They may not be as accurate as further detailed investigations would have permitted, but they are given in the hope that they may prove of use to the future of the oil industry.

Along the roads from Upham to Apohaqui, through Campbell Settlement and from Titusville to Passekeag, the sedimentary rocks appear to lie conformably above the limestone horizon. The exact sequence is not known but appears to be as follows in ascending order: (1) red arkosic conglomerate and sandstone; (2) fossiliferous limestone (Windsor); (3) anhydrite and gypsum; (4) red conglomerate sandstone and shale; (5) dark carbonaceous and slightly bituminous shales and micaceous sandstones. The measures lie in two southeast-southwest synclines, with the axis of the intervening anticline along the ridge of pre-Carboniferous rocks north of Salt Springs brook. The southern syncline is open, but the northern syncline is closed. The limestone was not seen along either side of the anticline on the Apohaqui-Upham road. The dark shales at Ratters Corner and on Moosehorn brook and Paticake creek are in the trough of the north syncline.

Limestone (Mississippian) near Norton station[1] shows the presence of the basal measures north of the north syncline. A. O. Hayes believes these rocks to be the same as the Lower Carboniferous rocks on Kennebecasis island. The presence of anhydrite west of Sussex, salt springs at Plumweseep, and gypsum and limestone 4 miles northwest of Petitcodiac station, goes to show the wide extent of this series of rocks.

[1] Wilson, W. J., Geol. Surv., Can., Sum. Rept., 1911, p. 350.

UNSETTLED PROBLEMS OF CORRELATION

A hasty but unsuccessful attempt was made to correlate the so-called Lower Carboniferous rocks at cape Demoiselle and Shepody mountain with some of the series in the Moncton map-area. The gypsum indicates the presence of the Hillsborough series, but the relation of the other rocks to the gypsum is not known. However, some interesting information was obtained.

At cape Demoiselle, popularly called "The Rocks," there is a shore section 1,800 feet long. The measures strike about 40 degrees south of east and dip to the northeast at an average angle of about 35 degrees, the total thickness exposed being approximately 1,000 feet. Most of these rocks are coarse, poorly sorted, red-weathering conglomerates with some arkosic sandstone. Near the south end of the section, two zones of grey, calcareous sandstone and shale, with concretionary limestone, are interbedded with the red conglomerate.

The conglomerate above and below the grey beds contains numerous boulders of fossiliferous limestone, and W. A. Bell, who examined them hastily in the field, believed the fossils to indicate the lowest fossiliferous horizon of the Windsor series (Hillsborough No. 2). The grey beds contain a scanty fauna which Bell suggested might indicate a higher zone in the Windsor than the fossils in the boulders. The calcareous sandstone in the grey beds is crowded with peculiar forms which Hayes believed to be algæ. Some of these forms are one or more feet in diameter and 2 feet high. A collection of fossils from the boulders and from the grey beds was sent to the Palæontological Division of the Geological Survey. This fauna was reported to represent the Windsor limestone (*See* page 18).

The presence of boulders of fossiliferous Hillsborough No. 2 in the conglomerate at cape Demoiselle suggests that the conglomerate may belong to the Petitcodiac No. 1. It may be possible to determine the structural relation of these rocks to the gypsum, about one mile west, and to the Millstone Grit (Petitcodiac No. 2), about one mile north.

The gypsum and anhydrite west of Shepody mountain (*See* geological map of New Brunswick, Sheet 4, N.W.) lies in part against the pre-Carboniferous rocks. The relation suggests a northeast-southwest fault in which the south side moved relatively downward. East of the gypsum the nearest outcrops seen are coarse, poorly sorted, subangular conglomerates, which dip southeast, away from the gypsum. This indicates that the conglomerates of Shepody mountain overlie the gypsum, and it is possible that a belt of gypsum extends from Woodworth Settlement, under Shepody mountain, to the area exposed west of cape Demoiselle. The deep, circular lakes north of Demoiselle station resemble sink-holes and are readily explained if the gypsum belt be continuous as suggested above.

GENERAL REMARKS

According to the evidence on page 21 the limestone and gypsum in Kings county are conformably overlain by a great thickness (possibly more than 2,000 feet) of conglomerate, sandstone, and shale, whereas the gypsum is the highest zone of the series in the Moncton area. If the overlying beds were ever deposited there, they were eroded before the deposition of the Petitcodiac series. In that case, the period of erosion which followed the deposition and folding of the Hillsborough series was many times longer than is intimated by the conditions observed in the area.

In some places the rocks of the Mississippian period are severely folded, as for instance in the gypsum area northwest of Petitcodiac station, where the limestone stands so nearly vertical that it is difficult to determine whether it underlies or overlies the gypsum. Most, if not all, of this folding took place before the deposition of the Petitcodiac series. Notwithstanding the extreme folding of the Mississippian rocks, none of them are known to be in the least degree metamorphosed.

GYPSUM

The Hillsborough basin includes two areas of gypsum and anhydrite, separated by a small stream valley. The eastern gypsum is operated by the Wentworth Gypsum Company, and the western by the Albert Manufacturing Company. On the south, each of these areas is overlapped by the unconformably overlying red conglomerate of the Petitcodiac series. The southern extent of the gypsum beneath these rocks is limited, probably by a series of small faults along a line from the wharf at Edgett Landing to the junction of the Albert Mines Railway spur with the main line of the Salisbury and Albert railway. The limits of the gypsum to the west, north, and east, are clearly indicated by the outcrop of the underlying limestone.

The Demoiselle basin includes one large body of gypsum and anhydrite, which is owned by the Wentworth Gypsum Company, the chief operators, and the Albert Manufacturing Company. The northern, western, and part of the southern limits of the gypsum are clearly defined by the outcrops of the underlying limestone. The southern limit along Demoiselle creek and on the east side of the creek is not known, the gypsum dipping under the red beds of the Petitcodiac series, Zone No. 1. Sink-holes through the red beds are common on the west of Demoiselle creek 400 feet above the creek bottom, and one or two unsuccessful attempts have been made to find the underlying gypsum. The depth of the overlying material is probably 300 or 400 feet.

Relation Between Gypsum and Anhydrite

The relation of the gypsum and anhydrite is so intricate that it is impossible to separate the two on the map. Locally, they are interbedded in thin layers, but usually the distribution of the two seems to be entirely independent of the bedding. Beds of gypsum grade abruptly into anhydrite and vice versa, and irregular bosses of gypsum are mined with anhydrite on both walls, and sometimes include lenses of anhydrite. Beds of anhydrite are cut by bifurcating veins of translucent gypsum, and all gradations from anhydrite with a few veins of gypsum to almost pure gypsum with small lenses of anhydrite are found. No attempt has yet been made to determine if there is any rule governing the distribution of the gypsum in the anhydrite. Bodies of gypsum are located by pros-

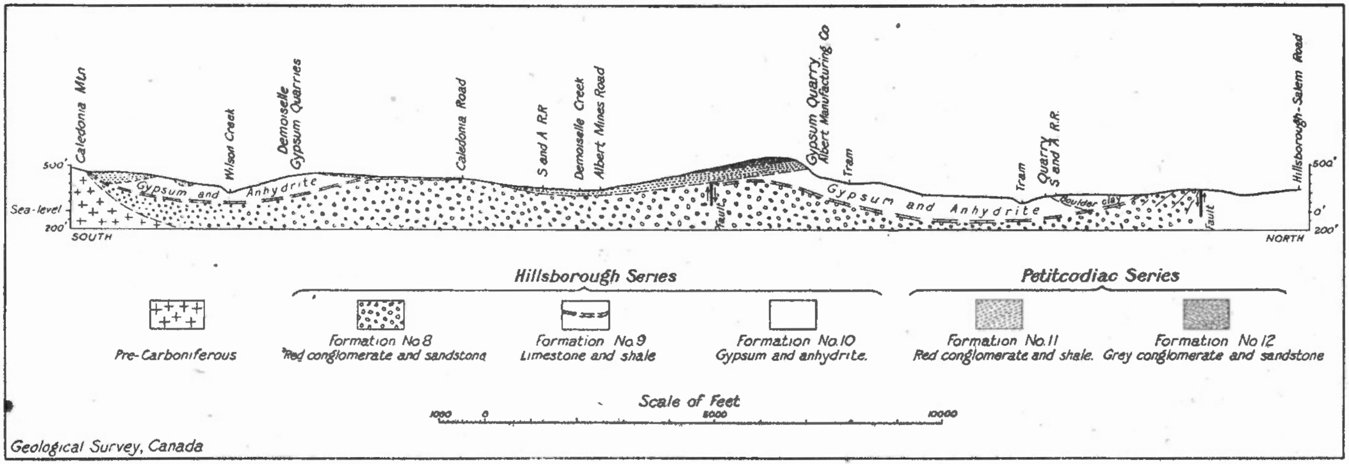

Figure 1. Geological cross-section through Hillsborough and Demoiselle gypsum area, underground structure inferred.

pecting and followed to the edges, and the future supply depends on success in locating new bodies. The situation demands careful investigation to determine, if possible, some general law of distribution that will aid in the location of new bodies.

This problem involves the origin of the gypsum. The relation between the gypsum and the anhydrite described above suggests that at least part of the gypsum was derived from the anhydrite by the addition of water. This theory was supported by Kramm,[1] but L. H. Cole, of the Mines Branch, who has spent considerable time in the locality, is of the opinion that it does not explain the whole situation.

Regarding the efficiency of water to change anhydrite to gypsum, it is necessary to take into account the action of water during both recent and earlier geological periods. After the beds were deposited and folded they were exposed to atmospheric agencies that removed all of the Hillsborough series (gypsum, limestone, and conglomerate) from large areas before the basal beds of the Petitcodiac series were deposited, and this series was in turn removed by erosion which, over large areas, dissected the gypsum to about its present relief before the advance of the continental ice-sheet. After the retreat of the ice-sheet, the deposits were submerged beneath the sea, and allowance must be made for the action of the salt water. Furthermore, if water caused the alteration of anhydrite to gypsum, the change must have taken place below the surface of the groundwater, where circulation is very slow; because gypsum is more soluble than anhydrite and in the presence of running water would be removed as rapidly as it formed.

PETITCODIAC SERIES

The Petitcodiac series includes the Millstone Grit of previous writers, and the conformably underlying red conglomerate, sandstones, and shales which Bailey and Ells[2] placed in the Lower Carboniferous.

The Petitcodiac series covers the northern two-thirds of the map-area and caps several of the hills in the southern part. The best natural sections of the series are exposed on the east bank of Petitcodiac river north of Stony creek and at Big cape, 3 miles south of Hillsborough.

The measures lie in a broad regional anticline, the axis of which is the continuation of the Caledonia mountain eastward through Hillsborough and Gautreau village. The dip of the beds to the north and south is usually at angles of less than 10 degrees. Over the northern part of the area outcrops are rare, but show that the measures lie almost flat.

The Petitcodiac series is made up of sandstones and shales divided into zones, chiefly on the basis of colour. The following summary description gives an idea of the general sequence beginning at the top:

		Feet
Zone No. 3.	Red sandstone and shale well-bedded. Sometimes ripple-marked. Approximate thickness at least	100
Zone No. 2.	Grey quartzose sandstone and nut conglomerate with abundance of round, white quartz pebbles. Fragmental plant remains common. Crossbedding pronounced. Approximate thickness	200

[1] Kramm, H. E., Geol. Surv., Can., Sum. Rept., 1911.
[2] Bailey, L. W., and Ells, R. W., Geol. Surv., Can., Rept. of Prog., 1876–77.

Zone No. 1. Red shale with greenish nodules and thin beds of platy, micaceous sandstone passing down into red, poorly sorted conglomerate. Local lenses of limestone overlying the conglomerate. At Albert Mines the conglomerate is dark.
Thickness variable.. 0–400

These zones grade into each other, and the only well-defined boundary is that between Zone No. 1 and Zone No. 2. The soft, massive shale capped by the hard, porous sandstone usually forms an escarpment which is readily followed for miles. Furthermore, the dividing line is characterized by the presence of strong springs of fresh water, which are a guide to the boundary even where the rocks are poorly exposed.

No determinable fossil remains have been found in the Petitcodiac series in the Moncton map-area. The age is inferred to be Pennsylvanian for the following reasons: (1) the rocks are unconformably above the Lower Carboniferous limestone and gypsum; (2) all writers agree that Zones No. 2 and No. 3 are the equivalent of the Millstone Grit at Joggins, Nova Scotia, which at that place underlies the productive coal measures. Its Pennsylvanian age is proved by the fossils which it contains.[1]

ZONE NO. I

Bailey and Ells believed that the red conglomerate and shale of Petitcodiac No. 1 were unconformably below the Millstone Grit (Petitcodiac No. 2) and mapped these red rocks as Lower Carboniferous. They mention localities where the red shales of the Lower Carboniferous seem to grade upward into the Millstone Grit; but in the places referred to, the red series is Petitcodiac No. 1.

Young[2] placed Petitcodiac No. 1 provisionally in the Intermediate group, along with the other red sediments in the Moncton map-area. However, he recognized that some of these red rocks were conformably below the Millstone Grit.

Relation to Older Rocks

All the Lower Carboniferous rocks were folded and faulted to about their present extent, and exposed to a long period of erosion before the conglomerates of Petitcodiac No. 1 were deposited. The erosion period lasted so long that the Hillsborough series was entirely worn away in many places, and the Petitcodiac No. 1 is now lying on all of the following rocks: gypsum and anhydrite (Hillsborough No. 4); limestone (Hillsborough No. 2); red conglomerate (Hillsborough No. 1); and all zones of the Weldon, Boyd, and Albert series. The relation to the Hillsborough series is shown in the gypsum quarries south of Hillsborough, and on the south side of Wilson brook. The conglomerate and shale filled up sink-holes in the pre-Petitcodiac land surface and then spread as a sheet over the whole area. South of Blight's gypsum quarry, near Edgett Landing, Petitcodiac No. 1 rests on the limestone and conglomerate of the Hillsborough series, and the same relation may be seen north of the gypsum quarries on Demoiselle creek.

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[1] Bell, W. A., Guide Book No. 1, "Excursion in eastern Quebec and the Maritime Provinces," pt. II, p. 342.
[2] Young, G. A., Geol. Surv., Can., Sum. Rept., 1911, p. 315.

Relation to Younger Rocks

The contact between Petitcodiac No. 1 and No. 2 is exposed in the shore section at Big cape and at Stony creek. The one grades abruptly into the other. But in some instances the nut conglomerate of Zone No. 2 is deposited in old channels which were cut in Zone No. 1. This relation is inferred to be characteristic of the contact over the whole area.

Extent

Zone No. 1 has been traced along the base of the Petitcodiac series on both sides of Petitcodiac river; in the upper basin of Demoiselle creek; and along both sides of the ridge between Petitcodiac and Memramcook rivers. It occurs also at Dorchester cape, but no attempt has been made to follow the zone east of Memramcook river. It may well be correlated with the lower part of the "Boss Point formation"[1] at Joggins, Nova Scotia. At the mouth of Stony creek on the west side of Petitcodiac river, Zone No. 1 dips to the north under Zone No. 2, and it is struck in the wells of the New Brunswick Oil and Gas Company on Stony Creek hill. But from there to the western edge of the map-area the beds seem to be missing, and in the valley of Turtle creek, Zone No. 1 is absent, for the quartz conglomerate of Zone No. 2 rests on the fossiliferous limestone of the Hillsborough series. At Pleasant Vale, 8 miles west of Turtle creek, the quartz conglomerate, Zone No. 2, lies on the eroded edges of the Albert series. No attempt was made to follow Zone No. 1 north of Moncton, but it occurs at the base of the Petitcodiac series between Petitcodiac station and the gypsum area to the north where the older map (Sheet No. 1, N.E.) shows it as Lower Carboniferous. At this point there is a marked angular unconformity between Division No. 3 and the underlying Lower Carboniferous (Hillsborough series).

Economic Bearing

The recognition of a series of red conglomerates and shales younger than the gypsum has an important bearing on the probable extent of the gypsum quarries. At present, the quarrymen believe that there is no gypsum beneath red conglomerate and shale ("marl"). This erroneous belief is due to the fact that they have failed to distinguish between the red conglomerate which overlies the gypsum and the red conglomerate which underlies it. The exposures along the south bank of Wilson creek, and the recent excavations in the quarries of the Albert Manufacturing Company near Hillsborough show plainly that gypsum underlies red conglomerate; and on both sides of Demoiselle creek sink-holes are common with an upper rim of conglomerate indicating the presence of gypsum beneath. It is, therefore, quite possible that in many places the red rocks of Zone No. 1 are underlain by gypsum, whose removal is limited only by the depth to which the mines can be economically operated.

[1] Bell, W. A., Geol. Surv., Can., Sum. Rept., 1912, p. 363.

SUMMARY OF HISTORICAL GEOLOGY

ALBERT EPOCH

Accumulation of fluvial deposits in shallow waters or alluvial fan. Climate humid.

BOYD EPOCH

Accumulation of shallow water deposits with neighbouring volcanic outbursts which furnished the tuffs of Zones Nos. 2 and 4. Climate semi-arid (?).

Folding and Erosion. Intensity of folding not known, probably moderate. Erosion sufficient to locally remove entire Boyd series so that Weldon series rests on Albert series.

WELDON EPOCH

Accumulation of continental and shallow water deposits. Climate probably semi-arid.

Folding and Erosion. Folding moderate. Erosion sufficient to remove entire series locally so that Hillsborough series in many places rests on Albert series.

HILLSBOROUGH EPOCH

Accumulation of coarse, alluvial deposits which were finally overlapped by a transgressing sea with deposition of limestone. Sea finally receding, gypsum deposited in shallow arms more or less completely shut off from the main ocean. Climate semi-arid.

Folding, Faulting, and Erosion. Folding slight in the Moncton map-area, moderate to extreme farther away from the old shoreline. Most of the large faults in the area were formed at the end of this epoch. Erosion sufficient to remove whole series in favourable places.

PETITCODIAC EPOCH

Accumulation of continental deposits (Zone No. 1) in local basins, followed by widespread deposition of shallow water deposits (Zone No. 2). Climate humid. Conditions during deposition of Zone No. 3 not known.

PLEISTOCENE PERIOD

Whole country covered by the ice-sheet which left varying depths of boulder clay. Followed by submergence to a depth of approximately 200 feet, with deposition of sands and gravels.

RECENT PERIOD

Erosion of higher ground, material partly deposited as alluvial fans (for example along upper part of Weldon creek) and partly carried to the ocean. Deposition of marine muds between the levels of high and low tide.

Recent forest trees once grew below the level of the present marsh deposits. Evidence of this is found on the east side of Petitcodiac river, south of Dover wharf, where there are stumps of trees firmly rooted in the underlying soil. These stumps have been recently re-exposed by the removal of marsh mud.

OIL-SHALE

INTRODUCTION

For upwards of fifty years oil has been extracted from oil-shale in Scotland where the industrial situation was such that the product could compete with the petroleum from flowing wells. In America there are enormous deposits of oil-shale which are richer than those retorted by the Scotch companies, but oil from flowing wells has been so abundant and cheap that no successful attempt has been made to establish shale oil industries. But now the production of oil from oil wells in America has reached a maximum, and experts state that the yield may be expected to steadily decline and to approach exhaustion in about twenty-five years. In 1918, the consumption exceeded the production, and the demand for oil is increasing. The use of oil for fuel will advance out of all proportion to the amount consumed in the past, and it is probable that oil will largely take the place of coal as fuel not only for transportation but also for manufacturing and domestic purposes. Producers and consumers, realizing the necessity of finding new sources of oil, are turning their attention to the possibilities of oil-shale.

In the United States, the oil situation has led to great activity in the investigation of oil-shale. The Geological Survey has investigated the deposits, and published approximate figures of oil content, running into billions of barrels. Congress has reserved a large area of the shale as an oil reserve for the navy. As a result of this publicity, approximately one hundred oil-shale companies were organized in 1917, and stock was put on the market. There is danger that this boom in oil-shale properties may lead not only to considerable financial loss, but also to serious delay in the progress of the industry by undermining public confidence. However, several companies are honestly undertaking to develop an oil-shale industry. A number of retorts are being tested, but as yet none is working on a commercial basis. The United States Bureau of Mines is optimistic as to the ultimate future of the industry, and intends to test the practicability of the western oil-shale on a commercial scale.

In Canada, the presence of rich oil-shale in the Maritime Provinces has been known for many years, and considerable money has been spent to determine its value, but no attempt has been made to develop it. The reason for this is apparent. The oil-shale industry is a big manufacturing proposition, involving an initial outlay of millions of dollars, large supplies of oil-shale, and careful preliminary experiments by chemical engineers; and the chief product must compete with oil obtained by established companies from flowing wells. At best, the returns are only a reasonable amount on the sums invested. But the oil situation demands new sources of supply. Already reliable companies are looking over the situation, and some preliminary experiments have been made. It is hoped that operations will be started shortly, and that the experience and confidence gained from a successful industry in the Maritime Provinces will lead to the establishment of similar industries in other parts of Canada.

Deposits of oil-shale occur in the Moncton map-area, at Albert Mines, and at Rosevale. These areas were reported on by the late R. W. Ells[1] for the Department of Mines, and a large number of samples, collected chiefly from Albert Mines and Rosevale (Baltimore), were analysed, with favourable results. One 50-ton sample from Rosevale was shipped to Scotland, and was retorted in a specially designed retort by the Pumpherston Oil Company, Limited. The results from this sample were very encouraging. Several oil-shale experts have reported favourably on these areas, but as yet no company has undertaken to develop the deposits.

In connexion with the present work in the area, considerable attention was given to the structure and extent of the deposits of oil-shale. A map was made of the Albert Mines area, and 20-pound samples of all the accessible beds were sent to the Fuel Testing Plant of the Mines Branch for analysis. The results of the analyses are given in tabular form on pages 46 and 47. The location and number of each sample are shown on the accompanying map (No. 1833) of the Albert Mines area. Time did not permit of detailed work and sampling in the Rosevale area.

ACKNOWLEDGMENTS

Acknowledgments are due to Senator James Domville, for information supplied; to Louis Simpson, I.E., for valuable suggestions and the loan of several reports; and especially to Mr. James Robertson whose knowledge was of the greatest assistance in collecting data for this report.

ALBERT MINES AREA

LOCATION

The Albert Mines area of oil-shale is located on the Salisbury and Albert railway (a branch of the Canadian National railway), about 4 miles southwest of the town of Hillsborough, and 20 miles south of Moncton. Petitcodiac river, navigable at high tide nine months of the year, is 4 miles to the east; Alma, the nearest deep-water harbour, is about 30 miles south on the bay of Fundy.

GENERAL GEOLOGY

Age

The oil-shale occurs near the base of a series of bituminous rocks known as the Albert series.[2] The Albert series is the lowest known horizon of the Carboniferous system. It is correlated with the Calciferous sandstone series which contains the oil-shale of Mid and West Lothian, Scotland.

[1] Ells, R. W., "Joint report on the bituminous or oil-shales of New Brunswick and Nova Scotia," Dept. of Mines, 1910.
[2] See also pages 3-13.

Relation to Surrounding Rocks

On the west the Albert series is underlain by much older metamorphic rocks which are pre-Carboniferous in age, perhaps Precambrian. On all other sides, the rocks of the Albert series are overlain by younger rocks. On the map of the Albert Mines area the younger rocks are shown in one colour, but they are of at least three different ages. For greater details see map of Moncton map-area.

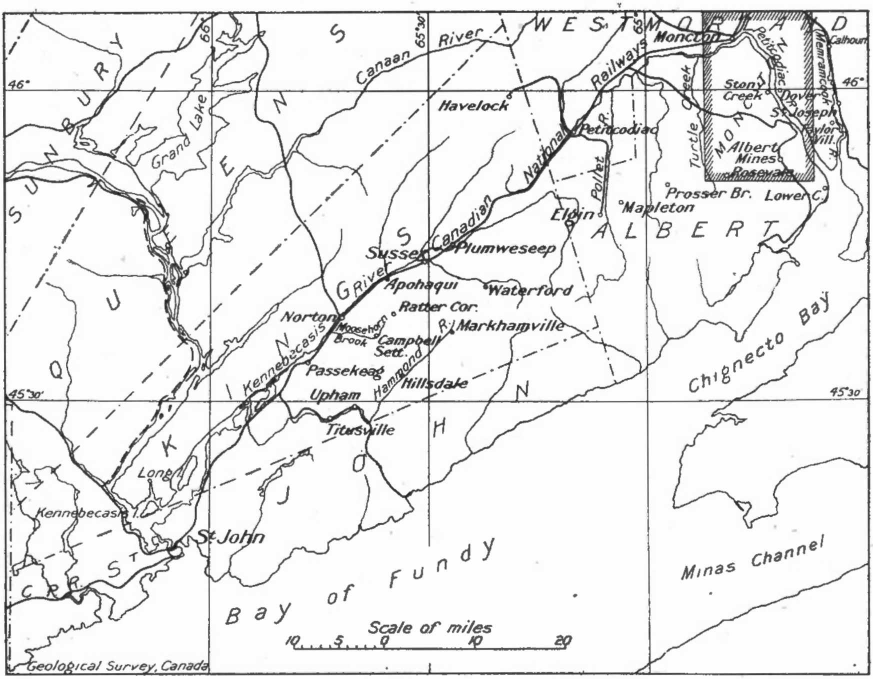

FIGURE 2. Diagram of part of southern New Brunswick, showing localities mentioned in the discussion of the extent of the Albert series and Hillsborough series.

The younger rocks on the north are red conglomerate, sandstone, and shale belonging to the Weldon series. These rocks were laid down on the eroded surface of the Albert series. On the east the Albert series passes under a thick bed of red and greenish conglomerate and calcareous shale which dips about 35 degrees east. This rock formed the upper 20 feet of the east shaft, and underlies a low ridge which can be traced to the north for over 2,000 feet. It is not known whether the conglomerate was deposited on the eroded edges of the folded Albert series or brought in its present position by a north and south fault. In either case these red rocks limit the eastern extent of the shales to a depth of 400 feet and probably to even greater depths.

On the south, from the ridge of conglomerate on the east, to within 200 feet of the main south branch of Frederick brook the younger rocks belong to the base of the Petitcodiac series which dips to the south and east at angles less than 10 degrees. From the brook mentioned to the western boundary of the Albert Mines map, the rocks are chiefly red calcareous shale (known locally as marl) interbedded with dark shales which contain at least one seam of coal about 1 inch thick. These measures are dipping south at angles of 75 degrees or greater, and limit the southern extent of the Albert series. The age of these rocks is not known. They may belong to the Boyd series which conformably overlies the Albert series or to the Weldon series. (In the early days this area was the site of the Princess Alexandra mine, and several shafts and drill holes were put down in search of albertite).

Summary Description

The Albert series is made up of dark and bituminous sedimentary rocks which may be divided lithologically into three zones which grade into each other. Following is a summary description of the zones beginning with the highest:

Zone No. 3.

The rocks of Zone No. 3 are best exposed along the largest southern branch of Frederick brook, south of the main shaft. They consist chiefly of interbedded sandstone and shale with some limestone. Total thickness approximately 1,200 feet.

The bulk of Zone No. 3 is made up of blue-grey, barren, micaceous shales. Only one red bed was noted, and that is near the top of the zone. Thinly-bedded oil-shale is common near the base of the zone, but no beds of economic importance are known.

The sandstones are fine-grained and micaceous, and usually give off the odour of petroleum when struck with a hammer. The greatest development of sandstone occurs south of the public road, between the church and the main shaft. Here there are three beds of very tough, micaceous sandstone containing pyrite and small fragments of plants. These beds can be traced for about 1,000 feet, and afford a key to the local structure. The lowest bed is arbitrarily taken as the base of Zone No. 3.

A bed of brown, sandy, bituminous limestone, containing fragments of plants, is the highest of the bituminous series, and is taken as the top of Zone No. 3.

Zone No. 2.

Zone No. 2 is made up of beds of rich oil-shale interbedded with low-grade and barren shale. The base of the zone is not exposed. Total thickness exposed approximately 800 feet. The measures are best exposed along the main branch of Frederick brook from near Gesner shaft to the eastern boundary of the shale area. Five beds of oil-shale have been recognized and the outcrops mapped. For the purpose of description they are numbered in descending order.

Bed No. 1. Bed No. 1 is made up chiefly of "paper" shale (so-called because the weathered shale splits into very thin, pliable sheets). Total thickness exposed approximately 50 feet. Strictly speaking, this "bed" is a zone made up of distinct beds which vary in their oil content. Interbedded with the shale are 1- to 2-inch beds of hard, tough, bituminous rock (known locally as "ironstone"), which weathers to yellowish tints. This bed is best exposed on the east side of Frederick brook. The outcrop can be followed west along the top of a steep escarpment for 600 feet. At the end of the exposure it is folded into minor anticlines and synclines, and when last seen is dipping west about 65 degrees. Lack of exposures prevent the tracing of the bed east of the brook. It probably forms the low ridge which can be followed to the southeast near the entrance to tunnels Nos. 2 and 3.

The average oil content of bed No. 1 is not known. Samples from about 5 feet of the bed yielded 36 gallons of crude oil and 39·5 pounds of ammonium sulphate per ton.[1] Samples Nos. 29 and 31 were taken from the outcrop in Frederick brook. Sample No. 29 appeared to be the poorest bed exposed, and No. 31 is assumed to be an average sample of the better grade. A continuous set of samples (fifteen in all) was taken along the north side of tunnel No. 1 (Figure 3). Of these, samples 7 to 15 take in about 50 feet of measures which belong to bed No. 1. Samples 1 to 6 take in about 45 feet of measures which appear to underlie bed No. 1, but the structure is so complicated by small faults that the stratigraphical position of these beds is not definitely known. Although the shale had deteriorated by exposure to the atmosphere the analyses should give a general average of the oil content.

Bed No. 2. Bed No. 2 is exposed on the south side of Frederick brook at the entrance of the small brook near the church. It is made up of tough, brown shale, which weathers into layers 1 to 2 inches thick. Thickness exposed approximately 4 feet. This bed can be followed east up the steep south bank of Frederick brook for 300 feet to where it is exposed in the cutting of an old tram-line. East of this the measures are covered. North of Frederick brook, bed No. 2 is assumed to be continuous with the bed of similar shale exposed in a very small brook from the north. Beyond this point, the bed is covered by superficial deposits.

A 20-pound sample of bed No. 2, taken from the outcrop at the mouth of the very small brook near the church, was tested by the Mines Branch, Ottawa, and found to yield 43 imperial gallons of crude oil and 57 pounds of ammonium sulphate per long ton.[2] Two samples were taken from this bed—No. 32 from the locality mentioned above, and No. 33 from the outcrop on the opposite side of Frederick brook (*See* page 45).

Bed No. 3. Bed No. 3 outcrops in Frederick brook, at the site of an old mill-dam. Total thickness exposed, approximately 2½ feet. The upper part of this bed is massive shale with streaks of black bituminous material that looks like albertite. The internal structure is minutely crumpled, and for this reason is called "curly" shale. The lower 8 inches is hard, brown, and massive with a conchoidal fracture. It contains

[1] Wright, W. J., Geol. Surv., Can., Sum. Rept., 1913, p. 224.
[2] Geol. Surv., Can., Sum. Rept., 1913, p. 224.

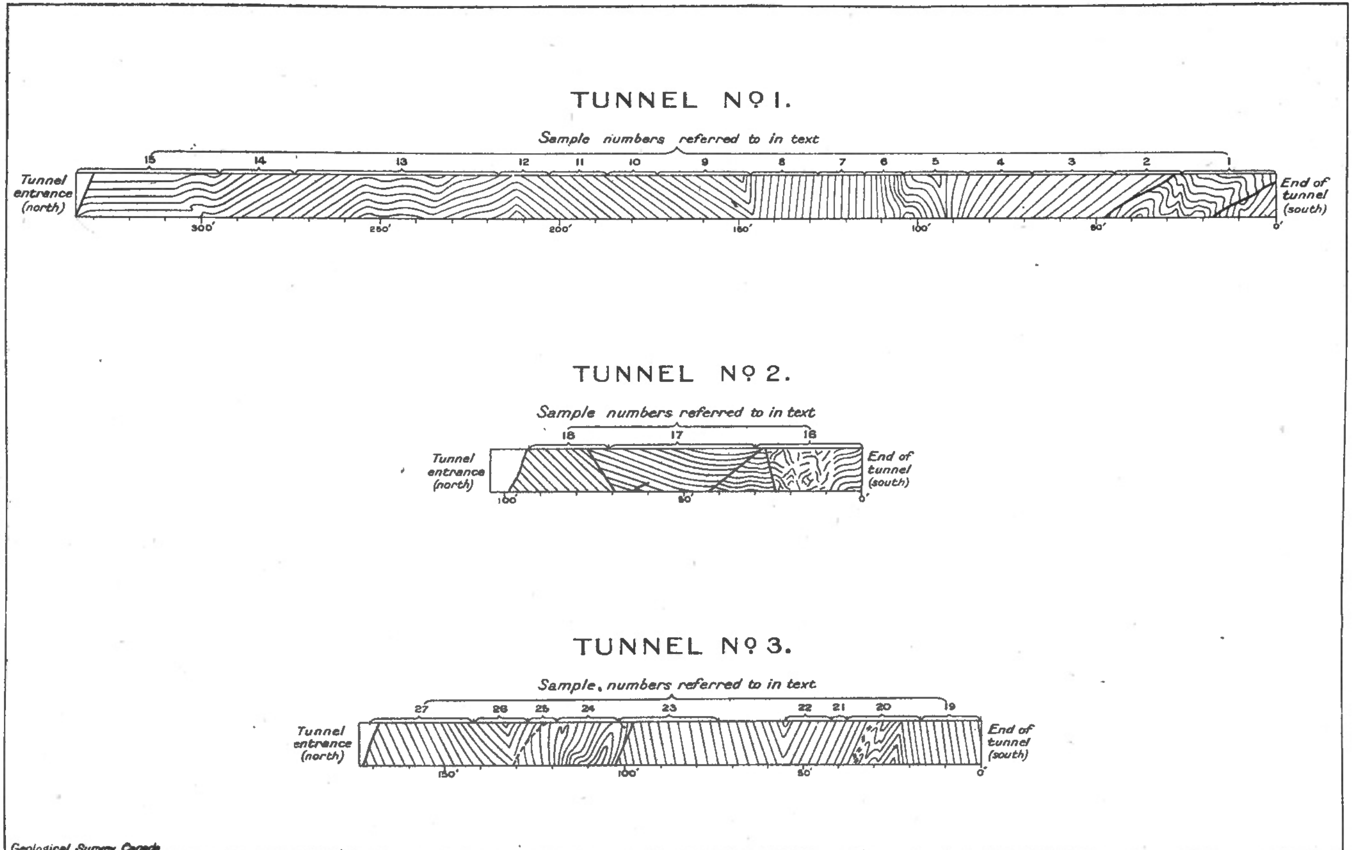

FIGURE 3. Tunnel sections of oil-bearing shales, Albert Mines, New Brunswick, indicating structure and extent of beds represented by Samples Nos. 1 to 27 taken for analysis.

irregular nodules of greenish material with some pyrite (?) and small vuggs of black bituminous material. The immediately overlying and underlying beds are not exposed at this point.

Bed No. 3 cannot be followed by outcrops in either direction from the brook bed. To the east, it is assumed to underlie a low ridge that can be followed for 300 feet. To the northeast the bed is assumed to be continuous, with a bed exposed in the cutting of the old tram-line on the north side of Frederick brook.

A sample from the outcrop of bed No. 3 on Frederick brook was tested by the Mines Branch, Ottawa, and found to yield 45 imperial gallons of crude oil and 48 pounds of ammonium sulphate per long ton. Last season sample No. 34 was taken from the outcrop of the brook, and samples Nos. 37 and 38 are assumed to be from the same bed on the north side of the brook. Sample No. 36 is of 5 feet of hard, platy, brown, sandy, brittle shale, with fragments of plants, immediately overlying No. 37. The immediately underlying measures are covered.

Bed No. 4. Bed No. 4 forms a small fall in Frederick brook about 70 feet (horizontal distance) below No. 3. Total thickness exposed, approximately 5½ feet. It is made up chiefly of curly shale, with some massive plain shale. Fracture conchoidal. Fresh surface brown to black, with thin stringers of black material, resembling albertite, parallel to the bedding. Fragments of plant remains changed to coal are common. In cross-section the coal looks like albertite, and it is possible that much of the material which resembles albertite in the other beds is coal. Weathered surface, blue-grey, with angular, light grey areas. Some muscovite showing along the bedding planes.

Bed No. 4 does not outcrop southeast of the brook. It is assumed to underlie a low ridge which can be traced east for 350 feet, where it curves to the south. To the northeast, the bed outcrops just above water-level for about 50 feet, to where it is covered by the material dumped from the rock cut for an old tramway. It is assumed to be continuous, with a bed that outcrops in the bed of the old tram-line on the north side of the brook about 450 feet east of the falls. Beyond that it forms a low ridge with occasional outcrops that can be followed to the small brook from the north.

A 20-pound sample from the outcrop of the bed in Frederick brook was tested at the Mines Branch, Ottawa, and yielded 52 imperial gallons of crude oil and 73 pounds of ammonium sulphate per long ton. Sample No. 35 was taken from the same locality.

Bed No. 5. Bed No. 5 is the lowest bed exposed in Frederick brook. It is well shown in an open-cut on the south side of the brook, from which upwards of 1,000 tons of shale has been mined for various tests. Thickness approximately 3½ feet.

This bed is typical curly shale. The internal structure is very complicated and varied. In general two varieties go to make up the whole. One is plain brown, massive shale in bands ½ to 1 inch thick, the other is black shale with numerous black stringers of material that looks like albertite. In some instances these varieties end in blunt points, in others they thin out to nothing. Minutely crumpled layers are succeeded by plain, massive layers. The structure of the whole bed is regular except at one point where it is broken by a small fault striking 160 degrees (true), with a relative downthrow of about 4 feet on the east.

Bed No. 5 is exposed for about 50 feet in the open-cut mentioned. East of this, it is assumed to form the low ridge and escarpment which can be followed about 200 feet along the south side of Frederick brook. The outcrop of the bed along the north side of the anticline is partly concealed by the alluvial material in the stream bottom. It is assumed to be continuous with the bed of curly shale exposed at water-level in the mouth of the small brook from the north (*See* sample No. 39).

Immediately overlying bed No. 5 at the open-cut is 1 foot 4 inches of hard, platy, brown shale badly weathered to yellowish brown, accompanied by a yellowish stain. This is overlain by 8 inches of curly shale containing fragments of plants. The next highest bed, 1 foot 7 inches thick, is badly weathered bituminous shale immediately underlying the soil. These three thin beds are probably the same as those on the north side of the brook (samples Nos. 46 and 47).

Below this bed, 1 foot 3 inches of hard, brown, bituminous, sandy shale is exposed in the open-cut. Total thickness unknown. This bed contains fragments of plants and the internal structure is nearly as complicated as the curly shale (sample No. 41).

A 20-pound sample of bed No. 5 at the open-cut, tested by the Mines Branch, Ottawa, yielded 43 imperial gallons of crude oil and 92 pounds of ammonium sulphate per long ton. Sample No. 40 was taken from the same locality.

Measures Above Bed No. 1. The sandstone which forms the base of Zone No. 3 is underlain by about 100 feet of the interbedded barren and bituminous shale exposed in the very small brooks on each side of the church. Some of these beds are rich paper shale; but none appear to be of sufficient thickness to warrant development.

Measures, inferred to lie between the beds just described and the top of bed No. 1, are exposed in Frederick brook between the Gesner shaft and the dump from the main shaft, and in tunnels Nos. 2 and 3. Unfortunately the structure in these places is very complicated and it is impossible to definitely determine the lithology and thickness. The rocks exposed are thinly-bedded oil-shale interbedded with barren shale and thin beds of ironstone. The nature of the soil on the east bank of the valley east of Victoria shaft indicates the presence of thin beds of sandstone. The total thickness of the beds from the base of Zone No. 3 to the top of bed No. 1 is estimated to be 450 feet.

Samples from some of the richest of these beds have been analysed in previous years.[1] Last season samples were taken as follows: Nos. 16 to 18 along tunnel No. 3. The measures in this tunnel are so severely contorted and broken that the total thickness of beds represented is not known. Nos. 19 to 27 from tunnel No. 2 representing about 70 feet of beds. No. 42 representing 3½ feet of a bed on Frederick brook west of the dump from the main shaft. The structure throughout this locality is so complicated that the relative positions of the beds sampled in each of the above-mentioned localities is not known. It is possible that all of the beds are represented in samples 19 to 27.

[1] Wright, W. J., Geol. Surv., Can., Sum. Rept., 1914.

Measures Between Bed No. 1 and Bed No. 2. Between beds Nos. 1 and 2 there are approximately 150 feet of measures. About 10 feet of the beds immediately underlying bed No. 1 are exposed in the bluff west of Frederick brook. They consist of thinly-bedded, brittle bituminous shale with thin bands of ironstone. No sample was taken from these beds. In the back end of tunnel No. 1 there are approximately 45 feet of measures which appear to immediately underlie bed No. 1. Samples Nos. 1 to 6 are taken from these beds. The remaining 105 feet of measures between beds Nos. 1 and 2 are concealed and the only available information concerning them is afforded by the summary description given in the driller's record of bore-hole No. 3 (*See* page 44).

Measures Between Beds Nos. 2 and 3. Between beds Nos. 2 and 3 are approximately 60 feet of measures. About 20 feet of these are barren shale and shaly sandstone exposed on the south bank of Frederick brook. Outcrops on the north side of the brook indicate that the remaining rocks are chiefly hard, sandy, bituminous, shale which contains probably sufficient oil to retort.

Measures Between Beds Nos. 3 and 4. Between beds Nos. 3 and 4 there are approximately 15 feet of measures, about 4 feet of which, 8 feet above bed No. 4, are exposed on the south side of Frederick brook. They are low-grade, sandy, bituminous shale. The outcrop is badly weathered and no sample was taken.

Measures Between Beds Nos. 4 and 5. Between beds Nos. 4 and 5 are approximately 50 feet of measures. Five and one-half feet of these, which appear to immediately overlie bed No. 5, are exposed on the north bank of Frederick brook opposite the open-cut on bed No. 5. The lower $3\frac{1}{2}$ feet is hard, brown, bituminous shale with some pyrite and occasional greenish streaks. Thin layers contain hard, irregular bodies resembling coprolites. For oil content see sample No. 46. Above this is 2 feet of brittle, low-grade, sandy shale containing plant remains. Included in this is a 2-inch bed of rich shale. For analysis see sample No. 47. There are no exposures of the beds between sample 47 and bed No. 4.

Measures Below Bed No. 5. The bed of hard shale, 1·25 feet thick, which underlies bed No. 5 (*See* page 41), is the lowest bed of the Albert series exposed in Frederick brook. The only available information of the immediately underlying beds is obtained from the drillers' records of bore-holes. According to these, bed No. 5 is underlain by at least 135 feet of grey, gritty, oil-shale. The cores of these holes are not accessible, and no information can be given as to the contained oil and ammonium sulphate. The general impression gained from talking with the drillers is that this shale is very rich.

Zone No. 1

Zone No. 1 is made up chiefly of coarse conglomerate, grading upwards into sandstone and shale. Most of these rocks are bituminous, but no beds of oil-shale are known.

Zone No. 1 is poorly exposed in the Albert Mines area. The conglomerates may be seen in the western part of the area where they are in contact with older metamorphic rocks. Among the material on the dump at Manitoba shaft, there is an abundance of sandstone and conglomerate with bituminous shale matrix. These rocks probably belong to Zone No.1.

The relation of Zone No. 1 to the overlying measures cannot be determined in the Albert Mines area. That these measures are the base of the series is inferred from a study of the rocks in the Rosevale area, where the structure is regular, and the beds are well exposed.

Structure

The Albert series has undergone at least two periods of folding, and as a result the measures are severely folded and crumpled. All of the exposed measures seem to belong to one major northeast-southwest anticline, whose main axis is somewhere along the general trend of Frederick brook. South of this, the prevailing dip is to the south, except on the extreme south where the measures are overturned and dip to the north. Evidence of the overturning is afforded by the crossbedding in several beds exposed along the upper part of the main south branch of Frederick brook. North of Frederick brook, the prevailing dip is to the north. In detail the structure is very much complicated by numerous minor folds. No large faults are known, but some may be present which cannot be detected from surface indications. The underground workings reveal the presence of numerous small faults.

Lack of outcrops makes it impossible to work out the detail structure of the whole area, especially west of the main shaft. In the eastern part of the area, outcrops along the small tributaries of Frederick brook, and the sections afforded by tunnels are sufficient to give a general idea of the details. Since this is the locality in which the outcrops of oil-shale occur, the discussion of the structure in the remainder of the area will be omitted. The dips and strikes of all known outcrops are shown on Map 1833 of the Albert Mines oil-shale area, and for details of the whole area the reader is referred to the map.

The outstanding structural units of the oil-shale beds are: (1) the northeast and southwest anticline whose axis follows the general trend of Frederick brook; (2) the large crumple so well defined by the sandstone beds in the vicinity of Albert shaft.

The Frederick Brook anticline can be traced about 1,600 feet. The measures dip to the north and south less than 15 degrees, and plunge to the west about 10 degrees. The northeastern extension of the anticline ends abruptly against the younger beds of conglomerate and sandstone which dip to the east about 50 degrees. From here, the anticline can be followed to the southwest as far as the outcrop of bed No. 1. West of here, the anticline appears to break up into several subsidiary folds, and the measures are intensely crumpled.

North of the Frederick Brook anticline, scattered outcrops indicate that the north dip increases from 10 degrees near the axis, to 50 degrees, at a distance of 500 feet north of the axis. North of this the measures are not exposed.

South of the anticline, the south dip increases from less than 10 degrees to about 20 degrees at a distance of about 200 feet. Beyond this, there are no outcrops. In tunnels Nos. 1, 2, and 3 the measures are intensely folded and broken by small faults (see cross-sections along tunnels). These folds are in thinly-bedded rocks, with no competent strata, and it is possible that the massive beds of curly shale below are not so severely crumpled. The axis of the Albert shaft crumple passes somewhere in the vicinity of tunnel No. 2, and this probably involves all of the beds of oil-shale.

AMOUNT OF OIL-SHALE

Several geologists of note have examined the oil-shale deposits of Albert Mines and estimated the amount of shale and the probable yield of crude oil and ammonium sulphate. The consensus of opinion is briefly as follows: in an area 4,000 to 6,000 feet long and 1,000 to 1,500 feet wide most of the rocks exposed are oil-shale. Furthermore, oil-shale makes the bulk of the rock fragments in the soil. In this area is the gash from which the albertite was removed to a depth of approximately 1,400 feet, and several shafts and tunnels. All of these workings are said to be in oil-shale, and this is supported by the predominance of oil-shale in the dumps from the main and east shafts. The conclusion is that this area is underlain almost entirely by oil-shale to a depth of 1,400 feet. Samples of shale from several points in this area yielded from 32 to 52 imperial gallons of crude oil and 38 to 92 pounds of ammonium sulphate per long ton.[1] On this basis the average yield for the whole body of shale is estimated to be in the vicinity of 40 gallons of oil and 57 pounds of ammonium sulphate per ton. If these conclusions be correct there is here sufficient oil-shale to supply a large oil-shale industry for upwards of 100 years.

The conclusions mentioned above were supported by the author in 1913, but modified in 1914.[2] Since then it has been found: (1) That the above-mentioned area is underlain by shale which varies from rich oil-shale to barren shale, and some sandstone. The richer the shale, the better it withstands weathering. As a result oil-shale forms most of the outcrops and boulders, whereas the barren shale is not exposed, except in the places where the streams are rapidly removing the soil. (2) Erosion has opened about 791 feet of the measures of which about 50 per cent is exposed, and the remainder covered by soil. The richest known beds (about 3 per cent of the whole) have been analysed and found to be excellent oil-shale. (3) The workings of the albertite vein cut the shales where they are dipping at angles of about 75 degrees, and penetrated only about 380 feet of measures. The fact that the shale extends to a depth of 1,400 feet in these workings does not prove the depth of the shale where the measures are lying almost flat, for example along Frederick brook below bed No. 1. In fact it is doubtful if the above workings reached bed No. 1.

The situation is somewhat as follows: the area which contains oil-shale is definitely bounded on the east by the bed of red conglomerate which outcrops near the east shaft; and on the south by the lowest (northern) bed of grey sandstone which runs through the entrance of the main shaft (see Map 1833). North of Frederick brook and west of the Albert Mines-Shenstone road, the measures are concealed. Presumably the beds

[1] Geol. Surv., Can., Sum. Rept., 1913, p. 224.
[2] Wright, W. J., Geol. Surv., Can., Sum. Repts. 1913 and

exposed on the south limb of the Frederick Brook anticline are repeated north of the brook beneath the mantle of soil and drift, and these beds probably extend west and underlie at least part of the swamp west of the Albert Mines-Shenstone road.

Careful structural sections of this area show that there are approximately 791·75 feet of the Albert series between the bed of grey sandstone on the south and the bottom of bed No. 5. Holes put down with a core drill penetrated shale 135 feet below bed No. 5, making a total thickness of at least 926·75 feet. Of these 316·25 feet are exposed; and 25·5 feet of the richest beds exposed have been analysed in previous years.[1] Samples from 192·25 feet including 25·5 feet mentioned above were analysed at the Mines Branch, Ottawa, and the results of the analyses are given in the tables on pages 46 and 47. Of the remaining 124 feet exposed, 100 are interbedded barren shale and oil-shale, with no workable beds; 20 feet are sandstone and sandy shale; and 4 feet are low grade, sandy oil-shale. The table on the following page gives a summary of the known facts.

[1] Geol. Surv., Can., Sum. Rept., 1914.

Summary Description of Zone No. 2, Albert Series, Containing the Oil-Shale at Albert Mines. (Descending Order.)

Summary description	Approximate thickness in feet	Thickness sampled in 1919	No. of sample[1] sent for analyses to Mines Branch	Thickness sampled previous to 1919[2]
Interbedded barren and paper shale. No workable beds known. Exposed in small streams east and west of church	100	....	....	....
Poorly exposed or severely contorted. In part cut by tunnels Nos. 2, 3, and 4. Inferred to be chiefly oil-shale with some barren shale and sandstone. Sequence not definitely known	350	70	16–28; 42	5
Bed No. 1. Chiefly paper shale. Exposed on Frederick brook and in tunnel No. 1	50	50	7–15; 29; 31	5
Thinly-bedded oil-shale with bands of ironstone. Exposed on Frederick brook below bed No. 1, and in back end of tunnel No. 1	45	45	1–6	....
Measures concealed	105	....	....	....
Bed No. 2. Oil-shale. Exposed on Frederick brook	4	4	32; 33?	4
Measures concealed. Contains some sandy oil-shale near base	35	....	....	....
Barren shale and shaly sandstone. Exposed on Frederick brook above bed No. 3	20	....	....	....
Sandy oil-shale. Exposed in cutting for old tramway north of Frederick brook, at bore-hole No. 1	5	5	36	....
Bed No. 3. Curly shale. Exposed at site of old mill-dam on Frederick brook, and in cutting mentioned above	2·5	2·5	34; 37; 38?	2·5
Measures concealed	11	....	....	....
Low-grade, sandy oil-shale, poorly exposed on south side of Frederick brook	4	....	....	....
Bed No. 4. Curly shale. Exposed at small fall in Frederick brook	5·5	5·5	35	5·5
Measures concealed	44·5	....	....	....
Low-grade oil-shale exposed on north bank of Frederick brook opposite open-cut on bed No. 5	2·0	2·0	47	....
Low-grade oil-shale, same locality as above	3·5	3·5	46	....
Bed No. 5, curly shale. Exposed in open-cut on south side of Frederick brook	3·5	3·5	46	3·5
Hard, brown oil-shale, same locality as above	1·25	1·25	41	....
Oil-shale? penetrated by core-drill	135	....	....	....
Total	926·75	192·25	....	25·5

This table shows that there is not sufficient information to prove that all the shale is oil-shale which can be mined by the open-cut method. In fact, there is no available information to show the extent of the five known beds beneath the surface. In the absence of this information any estimates of the total amount of oil-shale are largely speculative.

The only attempt to prove the concealed measures was made under the direction of James Caldwell in 1915. Two holes were put down at the locations shown on the map. No. 1 begins about at the top of bed No. 4 and penetrates to about 135 feet below bed No. 5. No. 3

[1] See tables of analyses, pages 46, 47.
[2] Wright, W. J., Geol. Surv., Can., Sum. Rept., 1914.

begins about 10 feet below bed No. 1 and ends in about the same measures as the bottom of hole No. 1. Unfortunately neither the cores nor Mr. Caldwell's report are available. Copies of the drillers' records of these holes are given below. It is not known how competent the driller was to recognize oil-shale, and the records are not sufficient for the problem in hand.

The simplest way to attack the problem is by core drilling. Analyses of the cores from bore-holes Nos. 1 and 3 would go a long way toward solving the problem. In case these cores are not available, one hole dipping 75 degrees northeast, located on Frederick brook about 50 feet south of the entrance to tunnel No. 1, would prove the shale from the top of bed No. 1 to the bottom of bed No. 5 at a depth of about 340 feet. A second hole, dipping northeast about 80 degrees, located at the open-cut on bed No. 5, would prove the beds underlying No. 5. Another way to test the measures between the top of bed No. 1 and the bottom of bed No. 5, would be to crosscut the outcrop and sample the beds. A crosscut 450 feet long, from the open-cut on bed No. 5, along the south side of Frederick brook to the cutting for the old tram-line, would open up the measures between beds Nos. 2 and 5. A second crosscut 450 feet long from the outcrop of bed No. 2 at the mouth of the small brook near the church to the outcrop of bed No. 1 on the east side of Frederick brook, would open up the shale between beds Nos. 1 and 2. The overburden along this line varies probably from 0 to 10 feet.

The problem of proving the shale which overlies bed No. 1 is not so simple. Wherever these measures are exposed they are intensely crumpled. The extent of the crumpling south of Frederick Brook anticline is shown by the sections along tunnels Nos. 1, 2, and 3. Exactly what happens in this crumpled zone is not definitely known. Careful consideration of all the available evidence leads to the conclusion that the prevailing dip of the beds is to the south, and that the dip increases to 75 degrees south before the workings of the albertite vein are reached. In this case a drill hole located near the Albert shaft and dipping 45 degrees northeast parallel with the line of section (Map 1833) would cut most of the measures overlying bed No. 1 at a depth of about 450 feet. It is possible that the measures at this point are so broken because of the sharp crumble that it would be difficult to work the drill.

If all the shale encountered in the bore-holes be rich enough to retort, a deposit of millions of tons is indicated, and it will be easy to prove an area sufficiently large to warrant development. The same holds true if it be found that only the beds from the top of bed No. 1 to the base of bed No. 5 are sufficiently rich to retort. If the cores indicate that only certain beds are rich enough to retort, it will be necessary to prove their underground extent by further drilling. Before doing this, it is advisable to crosscut the beds north of Frederick brook in order to prove the structure. Presumably the beds which outcrop south of the anticline are repeated on the north, and it may be that the structure is more regular, affording better opportunity for mining.

Drillers' Record of Boring Made at Albert Mines, Albert County, N.B., March and April, 1915[1]

(For exact location of holes see Map 1833)

No. 1 Bore-hole, Angle of Dip 1 in 12, West

Name of rock	Colour, etc.	Thickness bored	Total depth from surface	Remarks
		Ft.	Ft. In.	
Oil-shale..........	Grey, gritty............	....	....	From surface down 3 feet thin-bedded. Shale peeling off in thin flakes, balance of hole solid heavy beds from 1 ft. to 20 in. in thickness.
	Thin-bedded shale........	3	3	
	Heavy-bedded shale......	10	13	In several places struck small pockets of gas.
	Grey with thin bands of brown..................	12	25	
	Grey with thin bands of light brown.............	13	38	
	Grey, gritty, very seamy.	9	47	
	Grey, gritty, heavy-bedded.....................	15	62	
	Light brown.............	3	65	No. 1 bore-hole finished at 243 feet from surface.
	Grey, gritty, heavy bedded.....................	5	70	
	Grey, gritty, heavy bedded.....................	50	120	
	Grey, gritty, heavy bedded.....................	47	167	
	Grey, gritty, etc..........	23	190	
	Grey, gritty, etc..........	26	216	
	Grey, gritty, etc..........	27	243 6	243 ft. 6 in. (Amount of core recovered.)

No. 2 Bore-hole, Angle of Dip 1 in 12, West. Same Location as No. 1

		Ft.	Ft.	
Oil-shale..........	Grey, gritty.............	16	16	
	" " heavy bedded	20	36	
	" "	4	40	
	" "	7	47	
	" "	20	67	
	" "	29	96	96 ft. (Amount of core recovered.)

[1] Obtained from the Commissioner of Lands and Mines, Fredericton, N.B.

No. 3 Bore-hole, Dip West 46 Degrees

Name of rock	Colour, etc.	Thickness bored	Total depth from surface	Remarks
Loose gravel......	....	11	11	The angle of No. 3 bore-hole at start was 46 degrees, at 356 feet from the surface was 32 degrees.
Flaky blaes......	Soft, soapy blue in colour, smells strongly of gas...	92	103	
Oil-shale..........	Grey, gritty.............	11	114	
Flaky blaes......	Blue in colour, soft soapy.	6	120	
Oil-shale..........	Thin with bands of hard feldspar...............	33	153	
Hard blue slate..	With layers of oil-shale from 2 ft. to 8 ft. thick..	133	286	The last 131 ft. good oil-shale showing core in places full of oil.
Hard blue slate...	Very compact with layers of oil-shale 2 to 10 ft. thick..................	25	311	This bore-hole should have been driven down to a depth of 900 ft. or 1,000 ft. as core was showing better as the drill went deeper.
Oil-shale..........	Grey, gritty.............	45	356	
Oil-shale..........	Grey, gritty.............	44	400	
Oil-shale..........	Grey, gritty.............	43	443	

Analyses of Albert Shales

SAMPLES OF SHALE

Summary description of oil-shale samples from Albert Mines. Sent to Fuel Testing Plant, Mines Branch, Ottawa. All samples approximately 20 pounds. All shale bituminous unless otherwise specified. For exact location of samples from tunnels see Figure 3 and for localities of miscellaneous samples see Map 1833, in pocket.

From Tunnel No. 1

This tunnel opens on Frederick brook 900 feet below the main shaft.

Sample	No. 1,	0-26 feet.	Thinly bedded shale, numerous veins of selenite.	One sample.
"	No. 2,	26-45 feet.		
"	No. 3,	45-68 feet.	Platy shale.	
"	No. 4,	68-86 feet.	Thinly bedded shale.	One sample.
"	No. 5,	86-104 feet.	Same as No. 4.	
"	No. 6,	104-115 feet.	Platy shale.	
"	No. 7,	115-128 feet.	Thick-bedded shale.	
"	No. 8,	128-147 feet.	Thinly bedded shale.	
"	No. 9,	147-173 feet.	Thinly bedded.	
"	No. 10,	173-187 feet.	Massive shale.	
"	No. 11,	187-203 feet.	Platy shale.	
"	No. 12,	203-217 feet.	Thinly bedded, rusty rock, comes up in anticline.	
"	No. 13,	217-274 feet.	Thinly bedded shale.	
"	No. 14,	274-295 feet.	Massive shale.	
"	No. 15,	295-335 feet.	Massive rock.	

From Tunnel No. 2

Opening on north side of public road northwest of the manager's house.

Sample No. 16, 0-30 feet. Chiefly thinly bedded shale, with thin, irregular lenses of ironstone, contorted.
" No. 17, 30-71 feet 7 inches. Chiefly thinly bedded oil-shale with some 1-inch to 3-inch lenticular bands of ironstone.
" No. 18, 71-93 feet. Massive shale.

From 0-26 feet the beds are badly crumpled. From 26 feet to the end the structure is regular.

The beds 30-71 feet are probably those which show on the surface in the ditch by the roadside.

The sample is not a fair average of the shale in this tunnel, especially sample No. 1. The walls are very tight and difficult to sample.

From Tunnel No. 3

Between manager's house and the main road to north. Beginning at the back (south end).

Sample No. 19, 0-17 feet. Thinly bedded oil-shale with three bands of ironstone 6 inches thick. Dip 75-80 degrees south.
" No. 20, 17-38 feet. Blue-grey shale, barren, crushed, and slickensided.
" No. 21, 38-42 feet. Hard, tough, brown, massive shale. Dip north 70 degrees.
" No. 22, 42-55 feet. Thinly-bedded shale, thin veins of fibrous gypsum (?)
" No. 23, 74-102 feet. Tough, massive oil-shale. Dip south 80 degrees.
" No. 24, 102-119 feet. Crumpled, barren shale.
" No. 25, 119-127 feet. Hard, massive, brown shale, standing about vertical.
" No. 26, 127-142 feet. Thinly-bedded, brittle shale. Strike 360 (true north), dip south 50-65.
" No. 27, 142-171 feet. Massive shale, probably low grade. At 55 feet syncline. Beds south of this strike 360 degrees. Dip west 60 degrees.
From 55-74 feet beds same as 42-55 feet.

Miscellaneous

Sample No. 28. From 40-foot tunnel, west of road near Gesner shaft. Sample of the back 10 feet. Remainder seems to be the same but badly weathered.
Structure uniform. Strike 45 (true north), dip south 60.
" No. 29. Hard, brittle bituminous shale from the bluff of paper shale on Frederick brook. Bed No. 1. This looks like the poorest shale exposed in this bluff. Fair sample of 2 feet.
" No. 31. Thinly bedded shale from the bed forming the small fall at the bluff of paper shale, Frederick brook. Bed No. 1. Sampled by a shot. Good bed 3½ feet.
" No. 32. Platy shale from Frederick brook, near entrance of small brook from the church. Bed No. 2. Sampled with crowbar, fair sample of 4 feet.
" No. 33. Rather massive shale from the north side of Frederick brook at the entrance of a small brook about north opposite No. 32. Believe this the same bed as No. 32. Bed No. 2.
" No. 34. From old mill-dam site Frederick brook. Curly shale, sample 2 feet across bed. Shot, fair sample, bed No. 3.
" No. 35. Curly shale from fall about 75 feet below No. 34. Sampled across 4 feet of bed. Fair sample, bed No. 4.
" No. 36. Platy, hard, bituminous shale from old railway cutting on the north side of Frederick brook, about 100 feet below No. 35. Sample 4 feet thick, fair sample.
" No. 37. Hard, brown, bituminous shale, immediately underlying No. 36. Sample 3 feet. Fair sample.

Sample No. 38. Curly shale, on the north side of Frederick brook, about 200 feet east of No. 37. Bed No. 3. About 150 feet north of brook. Sample 3 feet. Not very good sample.

" No. 39. Water level in Frederick brook, north side, about 200 feet northeast of crusher, curly shale. Sample of about 2½ feet. Bed No. 5 fair sample.

" No. 40. Curly shale by crusher. Bed No. 5. From this place 500 pounds sent to Fuel Testing Plant, Ottawa. This bed is the one tested by the Albert Coal Co. for fuel in 1919. Sample of 4 feet. Good sample.

" No. 41. Hard, brittle, brownish shale, immediately underlying No. 40. Sample of 1 foot.

" No. 42. Paper shale from Frederick brook, north side, above the dump from the main shaft. About 75 feet west of the fish beds. Sample of 3½ feet. Fair sample. Paper shale.

" No. 46. Hard brown bituminous shale with occasional greenish streaks parallel to the bedding. Shows little or no black streaks. Some pyrite. One bed about ¼ inch thick looks like a bed of coprolites.

This bed immediately overlies that shown in sample 39, and is immediately overlain by sample 47. The sample taken on the north side of Frederick brook opposite the crusher, from the level of the brook up the bank. Sample good. Three and a half feet.

" No. 47. Brittle, sandy shale, with very little bituminous matter. Contains a 2-inch bed of good shale, full of black streaks. Contains fragments of plants. Also dark, irregular blotches parallel to the bedding, which at first seem to resemble plant remains. Closer inspection shows that most of these are due to different colour of the shale. Sample only fair because the beds weather more readily than good oil-shale. Sample of 2 feet.

Analyses

Sample No.	Analysis			Distillation				Oil			Gas	
	Ash %.	C. V.	N_2 %.	Residue.	Distillate.	Gas.	Balance.	Dry oil %.	S. G. oil.	Yield gals. per ton.	Yield cub. ft. per ton.	C. V.
1	68·6	3,240	0·45	84·5	11·5	2·0	2·0	9·3	0·850	21·9	920	620
2	72·0	2,540	0·40	86·5	10·7	1·9	0·9	9·4	0·855	19·8	1,030	550
3	68·4	2,970	0·44	85·6	11·3	2·8	0·3	9·2	0·835	22·0	1,120	560
4	68·2	2,430	0·44	84·2	11·1	2·9	1·8	8·8	0·830	21·2	1,300	560
5	76·0	2,450	0·37	90·7	10·1	1·4	− 2·2	7·8	0·845	18·5	670	610
6	69·5	2,380	0·43	89·4	9·8	2·7	− 1·9	7·0	0·820	17·1	1,160	510
7	79·1	1,370	0·35	90·7	6·4	1·8	1·1	3·6	0·820	8·7	820	530
8	75·5	1,710	0·43	89·4	7·4	2·5	0·7	3·8	0·812	9·1	1,060	460
9	73·9	2,170	0·42	87·6	9·4	1·7	1·3	6·4	0·865	14·7	700	640
10	80·3	1,025	0·32	92·6	5·2	1·0	1·2	2·4	0·870	5·6	430	500
11	71·0	2,790	0·40	85·2	12·5	2·1	0·2	8·9	0·840	21·3	930	600
12	75·0	2,790	0·53	85·5	12·5	2·6	− 0·6	8·2	0·835	19·5	990	470
13	66·8	2,570	0·43	85·2	11·1	2·5	1·2	8·5	0·835	20·3	1,190	620
14	79·3	1,105	0·29	92·2	5·8	1·3	0·7	3·4	0·835	8·1	560	550
15	80·8	1,295	0·50	88·9	7·6	2·5	1·0	3·6	0·830	8·7	950	350
16	67·6	2,000	0·36	90·3	8·9	2·7	− 1·9	7·1	0·855	16·5	980	510
17	66·8	3,450	0·61	82·9	13·3	2·1	1·7	10·0	0·835	23·9	940	650
18	82·5	670	0·33	96·2	4·9	1·2	− 2·3	2·6	0·850	6·0	470	480
19	72·2	2,680	0·44	85·5	12·1	2·1	0·3	8·4	0·850	19·8	870	580
20	88·2	90	0·33	93·5	7·7	neg.	− 1·2	neg.	......	neg.	240	neg.
21	79·1	880	0·26	86·9	5·6	1·0	6·5	3·3	0·853	7·6	380	540
22	68·5	2,930	0·42	83·9	13·0	2·1	1·0	10·2	0·840	24·4	900	640
23	83·3	630	0·47	91·3	5·2	1·6	1·9	2·4	0·845	5·6	550	400
24	86·5	70	0·45	91·0	6·2	1·5	1·3	neg.	......	neg.	440	380

Analyses—Concluded

Sample No.	Analysis: Ash %	Analysis: C. V.	Analysis: N_2 %	Distillation: Residue.	Distillation: Distillate.	Distillation: Gas.	Distillation: Balance.	Oil: Dry oil %	Oil: S. G. oil.	Oil: Yield gals. per ton.	Gas: Yield cub. ft. per ton.	Gas: C. V.
25	78·1	1,025	0·41	89·0	6·6	2·4	2·0	3·9	0·845	9·2	770	280
26	75·1	1,710	0·38	85·6	9·0	1·3	4·1	5·9	0·835	14·2	790	590
27	75·5	1,260	0·41	94·2	6·6	1·6	− 2·4	3·4	0·856	8·8	560	330
28	76·0	1,700	0·31	88·7	7·7	1·7	1·9	5·3	0·855	12·4	640	460
29	73·0	1,560	0·45	93·5	8·3	1·8	3·6	5·4	0·850	12·7	700	440
31	63·0	3,040	0·44	82·3	11·6	1·8	4·3	10·0	0·840	23·8	820	770
32	76·5	1,495	0·58	83·4	8·7	2·5	5·4	7·5	0·865	17·3	900	450
33	75·4	2,720	0·48	90·2	8·6	2·5	− 1·3	7·2	0·860	16·7	930	480
34	73·8	1,655	0·49	90·5	6·3	4·1	− 0·9	5·7	0·860	13·2	1,330	370
35	65·1	4,105	0·60	86·7	9·8	1·9	1·6	6·9	0·830	16·6	1,180	630
36	77·3	1,880	0·50	90·3	6·5	3·0	0·2	5·6	0·880	12·7	1,060	480
37	78·0	1,440	0·25	91·0	5·2	1·5	2·3	4·7	0·862	11·3	470	540
38	69·0	3,460	0·58	81·0	14·2	3·9	0·9	12·2	0·870	28·0	1,485	580
39	68·2	3,545	0·54	85·7	11·3	2·8	0·2	10·8	0·860	25·2	1,060	750
40	65·3	4,210	0·66	84·4	12·0	4·4	− 0·8	11·4	0·860	26·5	1,350	660
41	81·2	820	0·21	86·0	2·7	4·4	6·9	2·1	0·860	4·8	1,180	720
42	68·2	4,090	0·71	80·2	17·8	3·0	− 1·0	13·8	0·855	32·2	1,550	570
46	75·8	2,230	0·41	87·4	7·6	4·5	0·5	7·1	0·850	16·6	1,020	440
47	83·5	1,235	0·30	91·7	4·7	2·1	1·5	3·9	0·855	9·1	900	500

NOTE.—*Analyses* are all given on the samples as received, calorific values are given as B.Th.U's. per lb.

The nitrogen is reported as percentage by weight.

Shale with 1 per cent nitrogen theoretically might give a yield of 94 lbs. ammonium sulphate per 2,000 lbs. shale. In practice a yield of 60 per cent of theoretical is the best that can be expected, smaller yields are obtained unless the distillation is carried to high temperatures in the presence of steam.

Distillations. Variations in the method of carrying out the distillation cause marked differences in the relative yields of solid, liquid, and gaseous products. The method chosen gives a relatively high yield of oil and the results are comparable with each other.

The distillations were carried out in a retort immersed in an electrically heated lead bath. In all tests the temperature of the bath was slowly raised to 600-650 degrees C. and kept there until the evolution of gas had practically ceased. The results stated are the percentages by weight (of original shale) of the solid residue left in the retort, the liquid distillate, i.e. water and oil, and the gaseous distillate.

The weight of gas is calculated from its observed volume and its composition as found by analysis, this weight includes that of the water vapour carried off in the gas.

These results are obtained from single tests only, their accuracy is indicated by the weight unaccounted for in each test.

Oil. The results given under the heading oil are for the liquid distillate after the removal of water. The dry oil is expressed as its percentage by weight of the original shale. Specific gravities were determined at 70 degrees F. in terms of water at the same temperature. Yields are expressed in imperial gallons per ton of 2,000 lbs.

Gas. Volumes are in cubic feet of gas measured moist at 60 degrees F. and 30 inches of mercury. Calorific values are in B. Th.U's. per cubic foot measured as above, calculated from the analysis.

NOTES ON ABANDONED WORKINGS

All efforts to secure official records of workings at Albert Mines have failed. The following brief notes are copied from information given from memory by James Robertson, who has lived on the property since the beginning of the development, and who was for many years foreman in the mine.

Main Shaft

Total depth, 1,460 feet. From 800 feet to the bottom a level was driven south to the vein at every 100 feet. At a depth of 1,200 feet a level was driven north about 500 feet.

Rock encountered: one bed of sandstone near the top. Below the bituminous shale.

Note. The oil content of the shale cut by this shaft is unknown. No barren shale shows in the dump. The measures are dipping to the south at angles of about 75 degrees, so that the vertical thickness of the beds penetrated is probably not more than 360 feet.

East Shaft

Total depth, 1,000 feet. Rock encountered: about 20 feet of red conglomerate at the top. Below that, bituminous shale to the bottom. No barren shale shows in the dump. The conglomerate was separated from the underlying shale by about ½-inch of gouge. The strike and dip of the shale is about the same as that of the overlying conglomerate. At a depth of 380 feet a small dyke of calcareous sandstone cuts the shale.

The albertite vein was 75 feet north of the shaft at a depth of 580 feet, and 20 feet north at a depth of 1,000 feet.

Victoria Shaft

Total depth: 1,000 feet. Levels driven south to the "Air Shaft" branch of the albertite vein. Rock encountered: bituminous shale.

Albert Shaft

Total depth: 400 feet on the albertite vein.

Gesner Shaft

Total depth: 400 feet. At the bottom a drift to the north 90 feet. Rock encountered: bituminous shale.

The shaft was sunk on a vein of albertite which was less than 1 foot wide.

Manitoba Shaft

Total depth: 100 feet. At the bottom of the shaft, one drift to the west 300 feet, and another to the east 400 feet. Rock encountered: bituminous shale.

In the material on the dump there are fragments of conglomerate with rounded pebbles up to 2 inches in diameter, with bituminous, sandy shale matrix.

Shaft About 500 Feet West of Gesner Shaft

Total depth: 28 feet. Rock encountered: bituminous shale. Fragments of curly shale occur in the dump. This shaft was sunk on a vein of albertite 2 or 3 inches thick.

Shaft North of Princess Alexandra Shaft

Total depth: 40 feet. Sunk by J. Blight in search of albertite. Rock encountered, flaggy, greenish-grey, micaceous sandstone and blue-grey barren shale. The sandstone is crossbedded and contains an abundance of plant fragments, and some pyrite. Gives off an oily smell when struck with a hammer. A marked flow of gas was encountered at the bottom of the shaft.

Drainage Tunnel, Just East of the Main Shaft

Said to be in oil-shale, but the south end is in barren shale.

BALTIMORE AREA

The details of the oil-shale in the Baltimore area have not been worked out. Following is a summary of the information obtained.

LOCATION

The Baltimore area is at Rosevale, 39 miles southwest of Moncton. It has no railway connexion, but there is a good site for an 8-mile spur to Turtle Creek station on a branch of the Canadian National railway.

GEOLOGY

The Albert series in which the oil-shales occur, outcrops in the Baltimore area in an east and west belt about 3 miles long and $\frac{1}{4}$ of a mile wide. The base and southern limit of the series lies along the foot of Caledonia mountain, and from there the beds dip to the north at regular angles of from 20 to 30 degrees. About 500 feet (vertical thickness) of the measures are exposed, and the remainder is concealed under almost flat-lying younger formations to the north, east, and west.

Most of the beds in this belt are bituminous, but there are three zones, 30 to 50 feet thick, richer than the others, that stand up as low ridges which can be followed along the strike for at least 4,000 feet. Throughout the remaining 2 miles of the belt there are beds of rich shale which are probably continuations of the zones mentioned above, but this has not yet been proved.

At several points along the strike of each of the zones there is at least one very rich bed, 3 to 7 feet thick. One bed in each of the two upper zones has been proved, locally, by slopes and tunnels, to a depth of 100 feet along the dip. A 50-ton sample of the upper bed was sent to Scotland in 1908, and retorted by the Pumpherston Oil Company. Twenty-pound samples from the two upper beds have been tested in the laboratory of the Mines Branch, Ottawa, and by W. A. Hamor of New York. Following are the results of some of the tests:

Analyses of Oil-Shale from Baltimore[1]

——	Oil, imp. gals. per ton	Sp. gr. of oil	Ammonium sulphate, lbs. per ton
50 tons, from upper bed, retorted in Scotland	40·0	0·920	77·0
20 lbs. from upper bed	39·0	0·895	76·0
" " "	49·0	0·892	67·0
" " middle bed	54·0	0·892	110·0
" " "	52·0	0·904	112·2
" " Turtle creek, west branch	56·8	0·891	30·5

AMOUNT OF OIL-SHALE

No information is available as to the extent of the rich beds of oil-shale. It is possible that they pinch out and are succeeded by others along the dip and strike. A series of drill holes was put down between the east and west branches of Turtle creek. The report on these cores which are stored at Rosevale is not available.

Field observations lead one to believe that each of the three zones mentioned above contains a workable deposit of shale rich enough to be retorted; and that each of these is continuous for at least 4,000 feet, presumably farther.

The regular structure is favourable for proving the field by core drilling. In fact it may be that a study of the cores already taken will give the necessary information.

BITUMINOUS SHALE OF CANADA

Following is a summary of available information on the bituminous shale of Canada, based chiefly on reports published by the Geological Survey, Canada, with additional notes by the author.

BRITISH COLUMBIA

No workable deposits of oil-shale have been found in the province of British Columbia. During the past two years some search has been made, but no definite reports of progress have been received.

[1] Ells, R. W., "Joint report on the bituminous or oil-shales of New Brunswick and Nova Scotia," Dept. of Mines, Canada, 1910.

The search is carried on chiefly on Graham island where typical curly shale has been reported in the vicinity of Rennel sound.[1] This shale belongs to a series of black and brown argillites, known as the Maude formation, which is characterized by a strong bituminous odour and films of tar along the joints and bedding planes. The folding of the beds is "considerable and locally intense, with severe minor crumpling and faulting," suggesting that conditions are not favourable for mining shale.

No samples of oil-shale from Graham island have been analysed by the Mines Branch, but one sample of slightly bituminous shale from Saanich in the southern part of Vancouver island yielded 0·9 per cent of crude oil per ton. This yield is far too low to be of commercial importance.

MANITOBA, SASKATCHEWAN, AND ALBERTA

A belt of bituminous shale upwards of 150 feet thick, and lying almost flat, is exposed on Carrot river and at several points on the northern and eastern slopes of Pasquia hills in Manitoba.[2] An analysis of shales taken at random from this belt was made by the Mines Branch, Ottawa,[3] with the following results:

Crude oil, imp. gals. per ton........................	7·0
Ammonium sulphate, lbs. per ton....................	22·5

The bituminous shales are known to occur at intervals throughout a belt at least 60 miles long. Rocks of Niobrara (Cretaceous) age to which these shales belong, floor a narrow belt of country roughly 1,000 miles long, extending across the provinces of Manitoba, Saskatchewan, and Alberta. This belt has never been searched for oil-shale, and it is quite possible that beds of rich shale may be discovered.

ONTARIO

Bituminous shale is widespread over the province of Ontario, but as far as known is all low grade.

The Ohio shale in the western part of the peninsula has been recently examined. Samples, tested by the Mines Branch, Ottawa, gave results far too low grade to be of commercial importance.

The Utica shale is usually considered to be more bituminous than the Ohio. About sixty years ago a 7-foot bed of the Utica shale was mined and retorted at Collingwood, on Georgian bay, but the yield was only 7 to 8 gallons per ton. Other estimated yields of this shale are 10 to 12 gallons per ton. No figures are available as to the amount of ammonium sulphate. It is not improbable that careful search may reveal the presence of beds rich enough to retort.

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[1] MacKenzie, J. D., Geol. Surv., Can., Mem. 88.
[2] McInnes, Wm., Geol. Surv., Can., Mem. 30, p. 133.
[3] McInnes, op. cit.

QUEBEC

Large areas of Utica shale are found in the province of Quebec, but they are low grade, and do not differ materially from the Utica shale in Ontario.

Another variety of bituminous shale is found in Gaspe peninsula, but it has not been examined in recent years. Logan[1] states that there is a belt of this shale extending from Gaspe basin west along York river. It includes beds of oil-shale varying in thickness up to 15 inches, and some of the associated sandstones are impregnated with solid bitumen. Partial analyses of the oil-shale gave the following results:

Sample No.	No. 1	No. 2	No. 3	No. 4	No. 5
Volatile matter, %	32·4	22·8	42·8	30·4	52·4
Carbon, %	8·9	8·1	7·4	8·9	26·3
Residue, %	58·7	69·1	49·8	60·7	21·3

Logan's report also mentions oil-shale at Port Daniel,[2] on Chaleur bay, where some of the shale holds sufficient bituminous matter to burn. In the present year (1919), Mr. R. E. Lenthall has done some prospecting on the oil-shale at Port Daniel, and states that analyses of "grab samples" show from 29 to 35 per cent volatile matter.

The percentage of volatile matter from the Gaspe shales compares favourably with that in rich oil-shale. These shales warrant more detailed examination.

NEW BRUNSWICK

In addition to the deposits at Albert Mines and Rosevale (*See* previous pages), beds of rich oil-shale are reported in the Albert series in many places, more particularly at Mapleton, Prosser Brook, St. Joseph College, and Taylor village. Analyses of shale from these localities show yields of oil and ammonium sulphate as high as those from Rosevale and Albert Mines.[3] These areas have not been studied in detail, and it is impossible at the present time to give even an estimate of the amount available.

Louis Simpson, I.E., of Ottawa, says that there are large deposits of oil-shale in the vicinity of Lutz and Indian mountains, a few miles north of Moncton.

NOVA SCOTIA

The oil-shale of Nova Scotia occurs in rocks of Carboniferous age. The richest known beds are found in Pictou and Antigonish counties.

[1] Logan, W. E., Geol. Surv., Can., Rept. of Prog., 1844; Geology of Canada, 1863, p. 792.

[2] Geology of Canada, 1863, pp. 445 and 785.

[3] Ells, R. W., "Joint report on the bituminous or oil-shales of New Brunswick and Nova Scotia," Dept. of Mines, Canada, 1910.

PICTOU COUNTY

The oil-shale of Pictou county occurs in the Productive Coal Measures which underlie an area of approximately 20 square miles in the vicinity of New Glasgow.

Mr. Spence, who has taken several leases in the more promising areas, has spent considerable time and money on the property, and has paid for expert examinations and analyses of the shale, kindly offered all of the information he had obtained, but time did not permit to take full advantage of the opportunity. ~~No drilling or underground work has been done~~.

The following brief description is based on a short preliminary examination of the beds exposed along McLellan brook.

The shale may be roughly divided into three varieties which grade into each other. (1) Soft, massive, greasy-black shale, with conchoidal fracture. The beds are broken by two pronounced systems of joint planes which are at approximate right angles to each other and to the bedding planes. As a result the beds weather into rectangular blocks. This shale is probably a variety of cannel coal. (2) Thinly-bedded, pliable, brownish, shale containing sufficient bituminous matter to ignite with a match. (3) Thinly-bedded, brittle, slightly bituminous shale, grading into barren shale. In addition to these three varieties is a very highly bituminous variety of cannel coal called "stellarite." This variety was not seen in place.

Variety No. 1, a relatively small amount of the whole, occurs in distinct beds 1 to 4 feet thick. Variety No. 2 occurs in beds up to 20 or more feet thick, and grades into variety No. 3. All three varieties of bituminous shale are interbedded with a much greater thickness of barren, carbonaceous shale and some sandstone. The measures dip at angles up to 35 degrees. The structure is very simple when compared with that of the shales at Albert Mines. The conditions of sedimentation were such that the individual beds are probably extensive along the dip and strike. The best known, and perhaps the only bed, of stellarite immediately underlies the Drummond coal seam. There was no opportunity to see this bed.

Published analyses of the stellarite show yields of 50 to 126 gallons of crude oil per ton. The oil content of the other varieties of shale is not definitely known. Judging from the appearance of hand specimens, variety No. 1 will yield 35 to 40 gallons per ton; and variety No. 2 from 20 to 25 gallons per ton. Variety No. 3 does not contain sufficient oil to warrant development.

Samples of shale collected in the vicinity of New Glasgow by R. W. Ells were analysed by the Mines Branch, Ottawa, but there is no information as to the thickness or relation of the various beds and the analyses, therefore, are of little practical value.[1]

No systematic effort has been made to determine the number, thickness, or extent of the various beds of oil-shale. The probabilities are that the bed of stellarite cannot be mined without disturbing the overlying seam of coal, and that most if not all of the beds of variety No. 1 are too

[1] Ells, R. W., "Joint report on bituminous or oil-shales of New Brunswick and Nova Scotia." Dept. of Mines, Ottawa, 1910.

thin to be mined without also removing some of the adjacent beds. The total thickness of this variety probably amounts to at least 100 feet, and underlies 2 or 3 square miles. The structure is so simple that the extent and average yield of the various beds can readily be proved by careful geological mapping, followed by core drilling and analyses. The deposit is located in the midst of the coal and steel industry and the situation is ideal for developing a new industry.

Samples of Oil-Shale from Vicinity of New Glasgow, N.S., 1919

The following samples from the New Glasgow vicinity were taken to get an idea of the general idea of the shale in that vicinity. All of the samples were taken from the outcrop of the beds, care being taken to break away the weathered surface. The results of the analyses, published below, give a fair idea of the richness of the beds.

No. 201. 4-foot bed of "blocky shale" in bed of very small brook at brick kilns of Stephen Brooks.

No. 202. Flaky shale immediately underlying No. 1. Sample across about 4 feet of beds. Taken from bluff overlying the beds of fire-clay about 100 feet north of the small brook. About 1 foot below this sample comes the beds of fire-clay about 20 feet thick. Sample from near weathered surface.

No. 203. Flaky shale in the small brook bottom immediately overlying the blocky seam, No. 1. Sample across about 4 feet of beds. Measures covered above this to the bottom of next sample.

No. 204. Sample across 8 feet of beds made up chiefly of flaky shale, with an 8-inch seam of blocky shale. From same small brook. Highest measures exposed. About 10 feet of beds between the bottom of this and the top of No. 3. About 5 feet of these beds said to be fire-clay. The bottom of this sample is about 1 foot above the fire-clay.

No. 205. Across 4 feet of flaky shale overlying the coal seam on McLellan brook above the Fulling mill. Greyish-brown with brown powder. Slightly micaceous. Under a match intumesces slightly. Does not burn. Gives smell of oil. Abundance of plant remains. Curls before knife scarcely perceptibly.

Analyses[1]

Sample No.	Analysis			Distillation				Oil			Gas	
	Ash %.	C. V.	N_2 %.	Residue.	Distillate.	Gas.	Balance.	Dry oil, %.	S. G. oil.	Yield, gals. per ton.	Yield, cub. ft. per ton.	C. V.
201	70·2	3,565	0·72	90·4	8·5	2·4	1·3	6·4	0·865	14·7	850	500
202	88·0	630	0·37	88·0	6·5	......	......	1·0	0·865	2·3	......	......
203	84·5	1,135	0·50	87·8	6·6	......	......	1·8	0·860	4·1	......	......
204	78·9	1,980	0·59	88·7	7·6	2·8	0·9	2·6	0·890	5·8	1,080	530
205	84·8	1,080	0·24	90·8	4·9	......	......	1·4	0·880	3·1	......	......

[1] The note on page 47 applies to these analyses also.

ANTIGONISH COUNTY

Henry How[1] states that deposits of oil-shale in Antigonish county are "very favourably spoken of by Mr. Campbell"—probably John Campbell, Inspector of Mines, Nova Scotia. Mr. Campbell reports: "The fact that the centre of the Antigonish basin is occupied by highly bituminous limestone overlying the oil-coal and oil-shale beds may possibly indicate that the whole group is upper Devonian or Lower Carboniferous rocks which are not known in this country to contain coal beds of any value. The bituminous beds appear to be divided into two groups, the lower of which appears to be about 70 or 80 feet in thickness, 20 feet of which may be regarded as good oil-shale including 5 feet of curly cannel rich in oil. The upper band, which lies in immediate contact with the limestone, cannot be much short of 150 feet in vertical thickness of strata containing a large percentage of oil. Of this great bed of oil-batt about 30 feet will in all probability yield from 20 to 25 gallons to the ton. The 5-foot seam of curly cannel will yield at least 40 gallons crude oil to the ton, and the 15 feet of the best section of the oil-batt will yield at least 20 gallons to the ton."

Ells[2] adds that in view of the commercial possibilities of these shales samples were collected from the principal deposits and analysed by the Mines Branch, Ottawa. Eight of these samples gathered from the Hallowell Grant—known usually as the Big Marsh—gave results far below Mr. Campbell's estimate, the average of the eight being less than 9 imperial gallons of crude oil per ton.

CAPE BRETON ISLAND

Cape Breton island has not been prospected for oil-shale, although the geological horizons are such that important deposits might be found. Incidentally several samples of low-grade bituminous shale have been analysed by the Mines Branch, Ottawa.

Old Geological Survey reports state that there are a number of beds of oil-shale and cannel coal near the head of East bay extending for several miles. About thirty years ago, one of these beds was mined to supply a small retort, but the works have long since been abandoned. No figures are available to show the yields of crude oil.

Samples of bituminous shale were collected by A. O. Hayes from the dumps of four coal prospects, and tested by the Mines Branch, Ottawa, but the yields were very low.

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[1] Mineralogy of Nova Scotia, pp. 34, 35.
[2] "Bituminous or oil-shales of New Brunswick and Nova Scotia," pt. II, pp. 22, 23.

APPENDIX

RECENT EXPERIMENTAL WORK IN THE ROSEVALE (BALTIMORE) OIL-SHALE AREA

(*By W. S. McCann*)

Since May, 1921, the D'Arcy Exploration Company, a subsidiary of the Anglo-Persian Oil Company, has been carrying out exhaustive experiments on the oil-shales of the Rosevale area. A small experimental plant has been built on the West Branch of Turtle creek, with apparently satisfactory results.

DESCRIPTION OF EXPERIMENTAL PLANT

The plant, although complete in itself, is a unit of a possible future plant of much greater capacity. It is designed to treat the oil-shales by the Wallace process. By this process the oil-shale, crushed to 1 inch diameter, is fed into the top of a vertical retort, and disposes itself in a layer $2\frac{1}{2}$ to $3\frac{1}{2}$ inches thick between the heated walls of the retort and an inner duct of the same shape as the inner chamber of the retort, but tapering slightly toward the top. The inner duct is perforated with small holes, to permit of the gases being drawn by vacuum from the shale as the process of roasting goes on. The withdrawal of the gases by this method is intended to prevent their secondary decomposition which would increase the amount of unsaturated hydrocarbons and thereby reduce the amount of refined oil per gallon of crude.

The charge (about 1,000 pounds of shale) is roasted in the retort for three hours at a temperature of approximately 1350° F., and steam is injected into the retort during the treatment. The volatile constituents are drawn by vacuum from the inner duct to the water-cooled condenser in which the oil is separated from the permanent gas which passes on to the ammonia scrubber plant. This is a large vertical pipe filled with wooden baffles. The permanent gas enters the pipe near its bottom and ascending through the layers of baffles, meets a descending spray of water which absorbs any ammonia to form ammonia water. The ammonia water leaves the scrubber near its bottom and is conducted to storage tanks for later treatment for the saving of the ammonia as sulphate of ammonium. This latter part of the process has not yet been installed in the plant.

Through the kindness of Mr. John Henderson, representative of the D'Arcy Exploration Company, and Mr. George W. Wallace, the inventor of the Wallace process for the treatment of oil-shales, the following information is available. These data are advanced, not as being representative of the quality of the oil-shale of the Rosevale area, but in order to show some of the characteristics of the oil-shales, and the nature of the work which is being done in the experimental plant. The location numbers refer to the workings shown on the map of the Rosevale oil-shale area (No. 1931, in pocket).

DATA FROM EXPERIMENTS CONDUCTED AT OIL-SHALE TESTING PLANT, ROSEVALE

Comparison of Wallace Retort and Scotch Tube Method in Oil Yield

(Shale taken from No. VII Working)

Date, June, 1921	Retort		Scotch tube method	
	Gals. oil per long ton	Specific gravity	Gals. oil per long ton	Specific gravity
5	31·76	0·895	32·4	0·895
6	29·70	0·894	34·5	0·907
7	36·55	0·897	32·7	0·908
8	28·35	0·896	29·4	0·904
9	28·80	0·896	27·8	0·899
10	33·50	0·898	28·2	0·908
11	25·90	0·900	26·7	0·907
12	30·15	0·898	26·5	0·915
13	25·40	0·895	26·5	0·915
14	32·90	0·895	24·3	0·908
15	26·25	0·896	29·0	0·912
16	31·30	0·894	35·2	0·901
17	29·50	0·894	30·4	0·910
18	30·35	0·893	26·2	0·905
19	29·96	0·893	26·2	0·905
20	26·50	0·890	27·4	0·914
21	27·20	0·895	27·9	0·912
22	24·35	0·903	26·4	0·911
23	28·75	0·903	23·4	0·900
24	35·03	0·903	28·7	0·911

NOTE.—Long tons and imperial gallons used.

Capacity Data

(Area of Retort 63·24 Square Feet)

(Shale from No. VII Working)

Date, June, 1921	Long ton shale retorted	Average time (hours)retorted	Gallons oil per ton
1	2·38	3·60	29·75
2	2·37	4·00	31·00
3	2·51	3·60	31·00
4	2·50	3·60	31·30
5	2·86	3·10	31·70
6	2·86	3·10	29·70
7	2·50	3·20	36·55
8	2·86	3·10	28·35
9	2·50	3·55	28·80
10	2·14	3·50	33·50
11	3·34	2·20	25·90
12	2·71	2·50	30·15
13	3·01	2·40	25·43
14	3·62	2·00	32·90
15	3·32	2·18	26·25
16	3·32	2·18	31·30
17	3·62	2·00	29·50

REMARKS.—From June 1 to June 11, inclusive, charges were 4 inches thick. From June 11 to June 17, inclusive, the charges were 2½ inches thick. On June 2, the weight of charge was reduced from 888 lbs. to 800 lbs. to keep raw shale out of zone of oven not heated. Tonnage variation due to overlapping charges from day to day.

Approximate Analyses

(Shale from No. VII Working)

Date, June, 1921	4	7	10	12	14	15	16	17
	%	%	%	%	%	%	%	%
Moisture	1·16	0·95	0·95	0·87	1·12	0·95	0·62	0·72
Volatile matter	19·90	20·10	17·47	13·10	13·10	18·93	17·37	20·77
Fixed carbon	9·54	9·44	7·14	10·05	7·96	8·94	7·94	5·16
Ash	69·40	69·51	74·44	75·98	77·82	71·18	74·07	73·35
			Spent Shale					
Moisture	0·47	1·00	0·14	0·57	0·36	1·23	0·65	1·11
Volatile matter	2·66	2·97	2·05	3·11	1·30	2·96	2·47	5·15
Fixed carbon	2·29	5·18	0·85	3·72	3·01	3·89	3·65	2·37
Ash	94·58	90·85	96·96	92·60	95·13	91·92	93·75	91·37

Gas Data

(Shale from No. VII Working)

A. Gas Analyses

	%	%
CO_2	14·4	13·4
O_2	2·1	1·6
CO	10·4	1·9
CH_4	28·3	31·3
H_2	31·0	37·4
N_2	6·8	8·0
B.T.U	525·0	514·0

B. Gas Yield

Working	Av. cub. ft. per long ton	B.Th.U.
H.1	4430·9	–
H.2	4791·2	442
No. VII	7191·6	525
No. VII dump	5419·0	–
No. X	5632·4	261·2

Ammonia Data

(Shale from H.1 Working)

Date, July, 1921	Hours of steaming	Gallons liquor per ton	Pounds NH_3 produced	Pounds $(NH_4)_2SO_4$ per ton
5	3·0	195·5	8·140	13·90
6	2·0	75·2	3·935	7·84
7	2·0	74·4	4·930	8·40
8	1·0	62·4	6·700	10·05
9	1·25	64·2	6·360	9·30
10	1·25	38·5	7·310	10·20
11	0·75	44·4	6·715	9·18
12	0·75	61·3	7·493	10·48
13	0·75	84·1	9·080	12·72
14	0·75	56·8	6·580	12·27

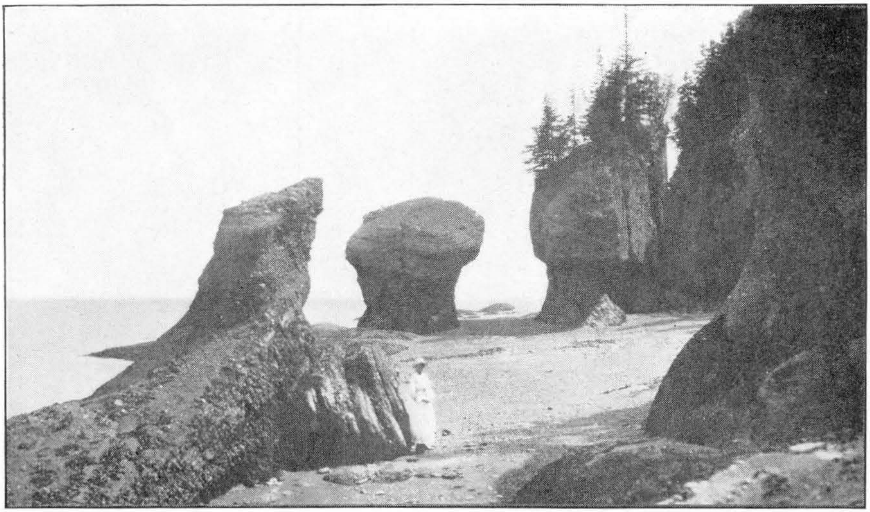
Bomb Analyses of Oil-shale of the Rosevale Area

	Gals. oil per ton		Gals. oil per ton		Gals. oil per ton
1	40	15	19	29	16
2	48	16	12	30	19
3	35–64	17	30–80	31	23
4	23–50	18	35–60	32	15
5	30	19	45–60	33	40
6	23	20	20–69	34	30
7	30	21	67–98	35	23
8	33–70	22	53–80	36	20–52
9	37–70	23	67–75	37	30–50
10	10	24	35	38	34–42
11	18–24	25	52	39	26–34
12	12–15	26	51	40	23
13	25	27	40	41	35
14	20	28	20	42	44

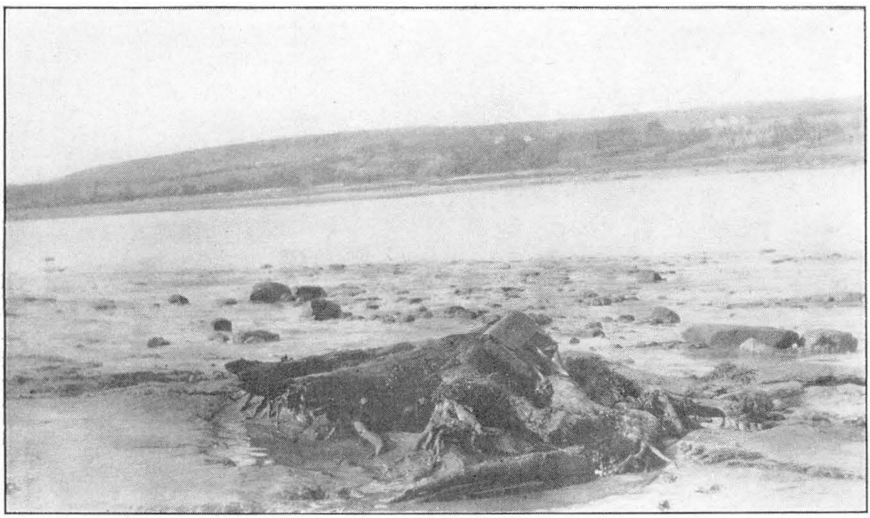
1. Working II, sample from roof.
2. " " crosscut.
3. " " dumps.
4. Working IV (Baltimore brook)
5. " V (8 feet from portal)
6. " 20 "
7. " 40 "
8. " IX, samples from dumps.
9. " X, "
10. New tunnel at plant. Sample at portal.
11. " 1—14 feet from portal.
12. " 15 "
13. " 20 " (roof)
14. " 20 " (floor)
15. " beginning of crosscut.
16. " " " (roof).
17. Swingston tunnel, shale hollow, right crosscut.
18. " left crosscut.
19. " portal.
20. " centre of crosscut.
21. " rich seam at face.

22. Shale hollow. Left working.
23. " Right "
24. Left bank Turtle creek below No. V, 8 feet above water-level.
25 " at water-level.
26. Shale hollow. East tunnel 5 feet from portal.
27. " " 10 "
28. " " 15 "
29. " " 20 "
30. " " 25 "
31. " " 30 "
32. " " 35 "
33. " " 40 "
34. " " at portal.
35. Testing plant, foundations for tanks.
36. " at grizzly.
37. Shale hollow. Side hill tunnel dump.
38. " "
39. Working XV.
40. " H. 3.
41. Mouth of Mill brook.
42. Working H. 6.

PLATE II

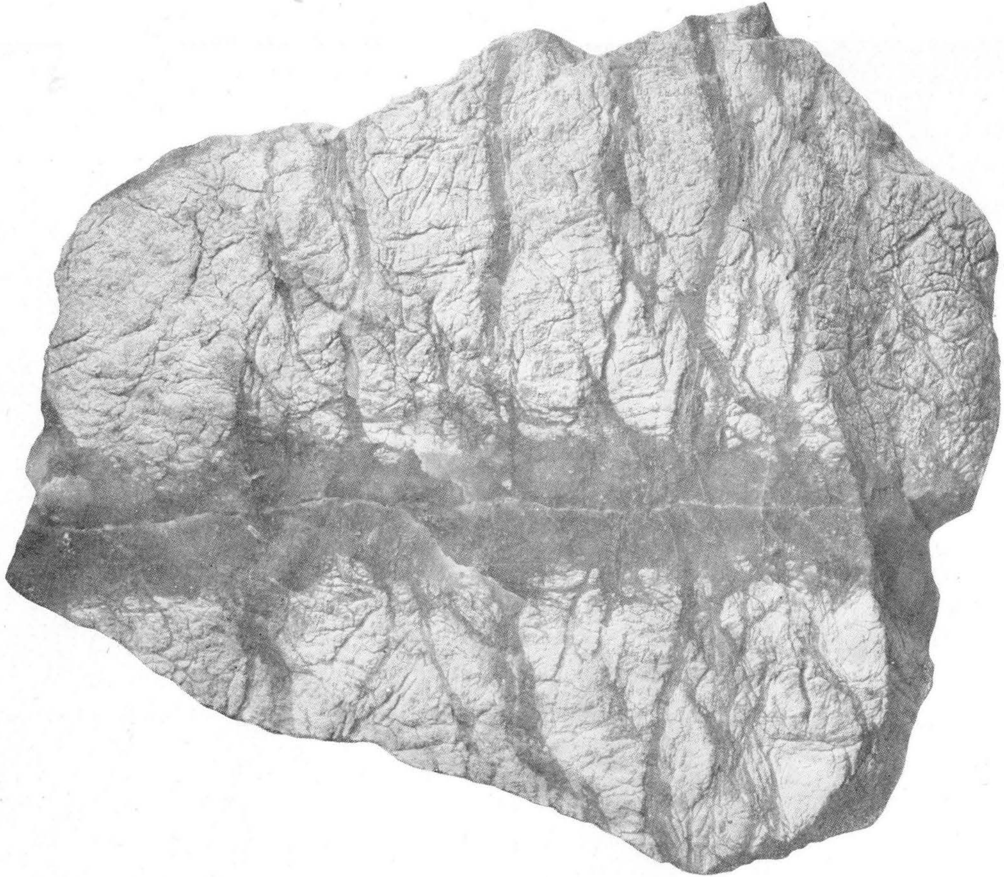


A. Results of marine erosion on red conglomerate, "The Rocks," cape Demoiselle, Albert county, N.B. (Page 22.)



B. Tree stump 20 feet below high tide. Roots embedded in the soil. Exposed by the removal of marine mud. East bank of Petitcodiac river near Dover wharf at low tide. (Page 29.)

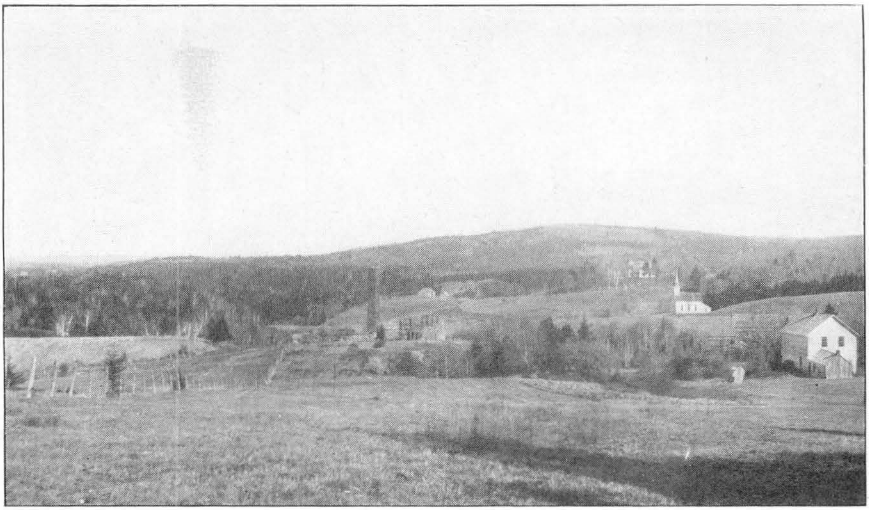
PLATE III



Anhydrite (white), with gypsum (dark) along joint planes. Suggests a preliminary stage in the alteration of anhydrite to gypsum. Specimen $9\frac{1}{2}$ inches wide. From gypsum quarry, Demoiselle creek, Albert county, N.B. (Page 23.)

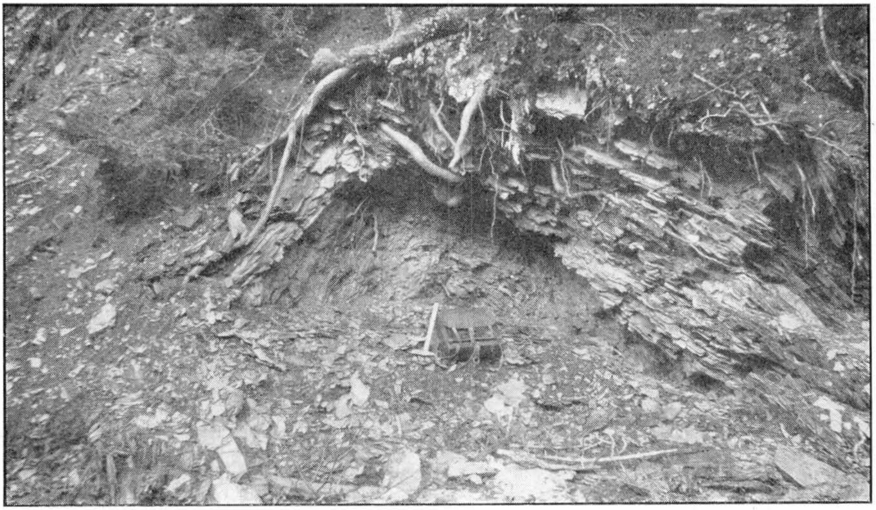
PLATE IV

A. Gypsum (light) surrounding anhydrite (dark). Suggests an advanced stage in the alteration of anhydrite to gypsum. Specimen from gypsum quarry, Demoiselle creek, Albert county, N.B. (Page 23.)



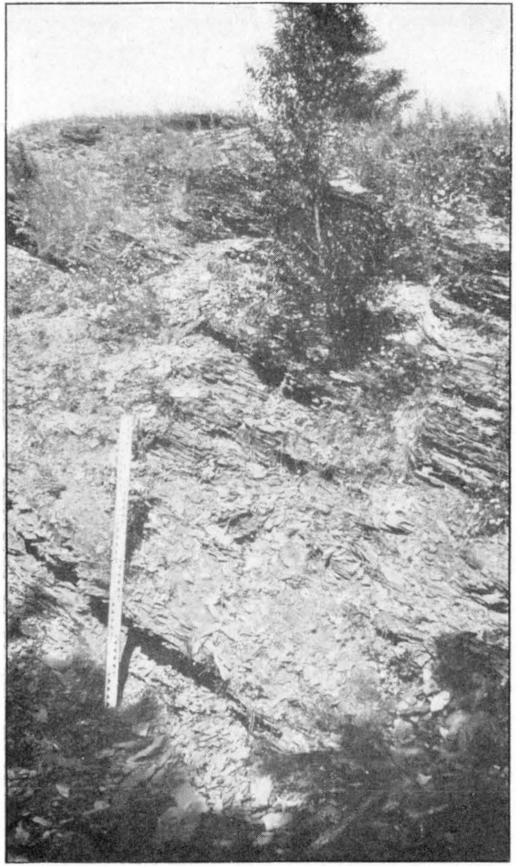
B. Albert Mines, 1919. Looking east. Tall chimney marks the position of the main shaft. (Page 30.)

PLATE V



A. Local crumple in the Albert series, Zone No. 2. Frederick brook, Albert Mines, near dump from the main shaft. (Page 33.)

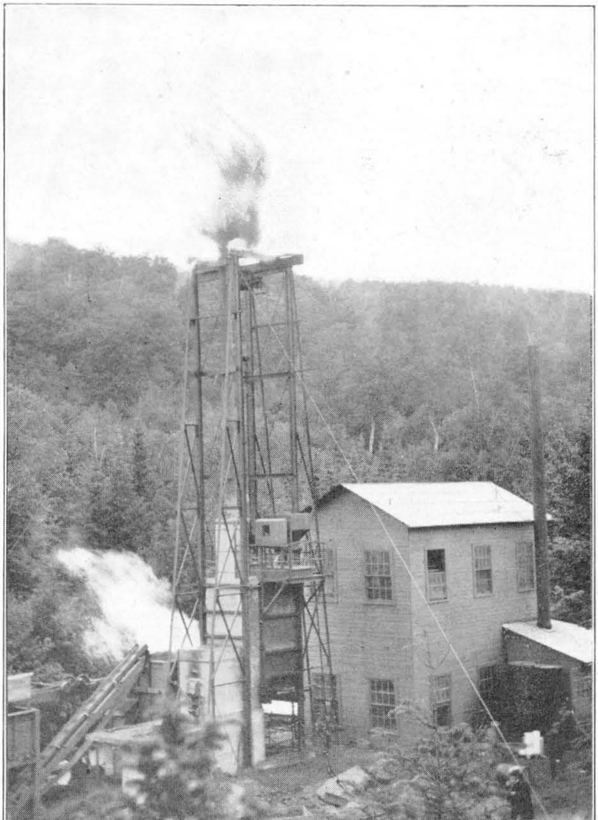
B. "Curly" shale, Bed No. 5, exposed by an open-cut, Albert Mines. (Page 35.)



A. "Paper "shale, Bed No. 1, on Frederick brook, Albert Mines. (Page 33.)

B. Talus from "paper" shale. Bed No. 1, Frederick brook, Albert Mines. (Page 33.)

PLATE VII



Oil-shale testing plant (Wallace process) Rosevale. (Page 56.)

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