Petroleum Geology of the Sydney Area
Cape Breton Island, Nova Scotia

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A report prepared for the Sydney Petroleum Company,

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Kirtley F. Mather

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SUMMARY OF REPORT

The Sydney Area comprises about 430 square miles on the eastern part of Cape Breton Island and the adjacent sea floor. It includes an irregularly bounded lowland, underlain by Carboniferous sedimentary rocks, and peripheral highlands, formed of Pre-Cambrian and early Paleozoic igneous and metamorphic rocks. The Carboniferous strata include the coal seams, extensively mined in the Sydney coalfield. They are grouped in six divisions as follows:

Pennsylvanian	Upper Morien series; 900 to 1300 feet thick; non-marine shale and sandstone with many highly productive coal seams.
	Middle Morien series; about 2300 feet thick; non-marine shale and sandstone with some productive coal seams.
	Lower Morien series; about 3000 feet thick; non-marine shales and sandstones with occasional thin coal seams.
	- - - - unconformity - - - -
	Canso series, Point Edward formation; 0 to 1250 feet thick; non-marine (with possibly some marine) shales, sandstones and limestones.
	- ? - ? - disconformity - ? - ? -
Mississippian	Upper Windsor series; 1000 to 3000 feet thick; marine shale, limestone, sandstone and conglomerate.
	Lower Windsor series, including Grantmire member; 1000 to 2500 feet thick; marine (possibly in part non-marine) conglomerate, sandstone, shale and limestone.

These strata were deposited in a repeatedly down-warped basin, the central and lowest portion of which appears to be beneath the sea at some point off-shore, north or northeast of the map area.

They therefore display a general regional dip toward the northeast and north. Several broad flexures trend in northeast to east directions, more or less radial to the basin as a whole. On the summit of one of these major anticlines, the Cape Percy anticline, there is an elongated dome, the Birch Grove dome, displaying a closure of at least 200 feet and probably more than 400 feet.

The area of this dome is apparently underlain by adequate source beds and reservoir rocks for petroleum. Dynamic and static metamorphism have not been so excessive as to make it unlikely that oil is present in this structure which appears to be an ideal locus for an oil pool. Its large drainage area suggests the probability that a very considerable volume of petroleum may be recovered from it. Depths to the prospective oil sands--4500 to 7500 feet--are well within the range of modern drilling operations.

It is therefore recommended that steps should be taken as promptly as possible with a view to the drilling of a test well on the apex of the Birch Grove dome near the northeast corner of the "mining tract" in the southwest corner of License Map 11-J-4-C. Consideration is given to the nature of these steps, with special reference to the question of additional geological or geophysical surveys prior to the commencement of drilling operations.

INTRODUCTION

Location of area. The Sydney Area comprises about 432 square miles of the earth's surface bounded by the parallels of latitude 46°00' and 46°15' north of the equator and the meridians of longitude 59°45' and 60°15' west of Greenwich. It covers "License Map" sheets of the Nova Scotia Department of Mines designated as 11-J-4-B (southeast quarter of the area), 11-J-4-C (northeast quarter of the area), 11-K-1-A (southwest quarter of the area) and 11-K-1-D (northwest quarter of the area). The quadrangular plot thus delineated is in the eastern part of Cape Breton Island, extending from Sydney Harbour on the west to Morien Bay on the east. The city of Sydney is well within its west boundary, and the city of Glace Bay is 4 miles south of its north boundary and roughly midway between its east and west sides.

Previous geological studies. Within the Sydney Area and adjacent to it on the north and northwest, there is one of the most valuable and most extensively developed coal fields of North America. Consequently this region has been intensively studied by geologists for three quarters of a century. Their work has involved the detailed mapping of all surface exposures of the various formations as well as the identification and correlation of the coal seams encountered in the underground workings. Numerous shallow bore holes have been sunk at many places to determine the presence or absence of workable coal seams.

Many of the data thus secured are assembled on Maps 361A and 362A, published in 1938 by the Canadian Geological Survey. These excellent maps show the topography and areal geology on a scale of 1 inch to 1 mile, with a topographic contour interval of 50 feet. The geological work for these maps was done by A. O. Hayes, W. A. Bell and E. A. Goranson between 1917 and 1931. At every point where we checked the geology shown on these maps, we found them thoroughly accurate and trustworthy.

Dr. Walter A. Bell, geologist and paleobotanist of the Canadian Geological Survey, has devoted many years of careful study to the problems involved in the identification and correlation of the coal seams. The series of memoirs and other papers, written by him and listed in the bibliography included in this report, provide a fund of valuable information from which we have derived many significant data bearing upon the structural details of interest to the petroleum geologist.

Dr. F. W. Gray, Assistant General Manager of the Dominion Steel and Coal Corporation, Limited, and his son, Dr. R. Heath Gray, have also done much geological work in the region and their published reports (see bibliography) have been very helpful. Although they have been especially concerned with the submarine extension of the coal field, their conclusions about the geological history of the entire area have a direct bearing upon its petroleum possibilities. We are particularly grateful to Dr. F. W. Gray for suggestions gleaned from our conferences with him in Sydney in August and September, 1944.

Similarly, we are under obligation to Mr. W. M. Macdonald of Sydney, N. S., for information given us in the course of several conversations while we were in that city. Mr. Macdonald had been responsible many years ago for the drilling of several bore holes intended to secure data concerning the coal seams at points remote from the major mines. The records of such bore holes are often of great help in deciphering the structure of a region such as this.

The Sydney Area was at least cursorily examined by H. E. Boyd and J. A. Hendricks in 1926 when they were appraising the petroleum possibilities of a large part of Cape Breton Island. Their report, published in 1928 by the Nova Scotia Department of Public Works and Mines, was unfavorable concerning the petroleum prospects.

Purpose of investigations in 1944. For more than fifty years, the petroleum possibilities of Cape Breton Island have been of interest to geologists and petroleum producers. (Norman, bibliography item18). There are oil seeps along the shore of Lake Ainslee, 46 miles west of Sydney, and in Meat Cove, near Cape North, 63 miles northwest of Sydney. Petroliferous rocks in many parts of the island have stimulated much geological exploration and some drilling operations. During the spring and summer of 1944, two wells were drilled near Mabou, 58 miles west of Sydney, to depths of approximately 5600 and 6900 feet, respectively. These wells were favorably located with respect to geologic structure, one on the crest and the other on the flank of a fairly large anticlinal fold. Both encountered unexpectedly great thicknesses of salt in the midst of the Windsor formations and neither reached the desired objective, the underlying Ainslee sandstone.

It has long been known that the Sydney Area is underlain by a great thickness of Carboniferous sedimentary rocks, including marine beds of Mississippian age as well as non-marine Pennsylvanian coal measures. Although this area is included in the large part of Cape

Breton Island concerning which Boyd and Hendricks reported adversely in 1928 (Bibliography item 4) it is obvious that under present conditions it deserves careful examination as a possible locus of one or more oil pools. There has been much extension of scientific knowledge concerning the occurrence of petroleum since 1930; new methods of search for oil have been developed; and techniques of drilling have been greatly improved. The necessity of discovering new oil fields in North America has now become imperative. The purpose of the field studies upon which this report is based was therefore to ascertain, as accurately as time and geological methods would permit, the probabilities concerning the presence of oil in commercial amounts in this area and the localities, if any, in which further work should be concentrated.

Field studies in 1944. Carl W. Beck, Teaching Fellow in Geology in Harvard University, began field studies on Cape Breton Island on July 5, 1944. Edward L. Tullis, Professor of Geology in the South Dakota School of Mines, and Kirtley F. Mather, Professor of Geology in Harvard University, joined him there on July 12, 1944. After several days of reconnaissance field work covering the Sydney Area and other parts of Cape Breton Island, Dr. Tullis and Mr. Beck devoted a month to more intensive work in the vicinity of the Strait of Canso. On August 19 they established headquarters in Sydney Mines and from that date until September 15 they gave their entire attention to the Sydney Area. Dr. Mather was in the field with them from September 8 to 15.

Special attention was paid to the stratigraphy of the Windsor series, the conditions under which its beds had been deposited, and the potentialities of those beds as source and reservoir rocks for petroleum. Detailed sections were measured with plane table, telescopic alidade and stadia rod. It was soon apparent that no adequate structural traps for oil were present in the area of outcrop of the Mississippian strata near the western border of the licensed area, and consequently our structural studies were directed toward the search for such traps in the area of outcrop of the overlying Pennsylvanian strata. Attention was soon concentrated upon an anticlinal structure near the center of the licensed area, and that locality was carefully examined for data additional to those recorded on the maps published in 1938 by the Canadian Geological Survey.

A preliminary report on the area was submitted to the Sydney Petroleum Company on July 28, 1944, and this more complete report was prepared in Cambridge, Massachusetts, during the fall of 1944.

GEOGRAPHY

Topographic features. The greater part of the Sydney Area is essentially an undulating plain, sloping northeastward to an irregular, island-fringed shoreline of submergence. It is one of the most extensive of the many lowland basins, separated from each other by steep-sided hills and elongated table-lands that characterize the topographic pattern of Cape Breton Island. (J. W. Goldthwait, 1924, and D. W. Johnson, 1925, Bibliography items 8 and 15). Its surface features are accurately portrayed in great detail on the Sydney and Glace Bay sheets of the "National Topographic Series" of maps, published by the Geographical Section of the

Department of National Defence, on the scale of 1 inch to 1 mile, with a contour interval of 25 feet. Copies of these maps may be secured from the Surveyor General, Department of the Interior, Ottawa, Canada, at 25 cents each.

Within the Sydney Area, as defined on page 4 of this report, the highest elevation is 400 feet above sea level, an altitude attained in the far southwest corner of the area. A few miles to the west of its western margin, however, the Coxheath and Boisdale Hills rise to altitudes slightly in excess of 600 feet. These elongated uplands delimit the Sydney basin on the west. Somewhat farther to the northwest of the Sydney Area, the Sydney basin is bordered by Kelly Mountain, whereas on the south its margin is denoted by an unnamed "upland", much lower in elevation, the northern outposts of which encroach just within the southern border of the licensed area along the south shore of Mira Bay and on Scatari Island.

Throughout the greater part of the Sydney Area, the irregularly scattered, rounded hills and low divides average around 200 feet in altitude, generally higher toward the southwest corner and lower toward the coast on the north and east. The existing topographic features are in large measure a result of the deposition of a thin veneer of glacial drift, spread irregularly, over the bedrock surface during Pleistocene time.

The deeply indented coastline is a result of late glacial and post-glacial submergence. Sydney Harbour is a drowned valley reaching far back into the basin, and Mira, Morien, Glace and Indian bays are similarly submerged portions of shorter, broader valleys.

Recent erosion by waves and currents is responsible for the numerous low cliffs of the rocky headlands. Many baymouth bars, beaches and spits have been constructed of sand and gravel derived from nearby cliffs and swept into the more sheltered indentations during this process of marine erosion.

Drainage. As a result of glaciation, the Sydney Area is dotted with swamps, ponds and small lakes. Its rivers are comparatively small and flow in circuitous courses. Only a few of them have succeeded in lowering their channels through the glacial drift to expose the bedrock, and these have done so only for short distances along their paths.

The fairly heavy precipitation combined with the poor drainage keeps the water table close to the surface throughout all seasons of the year. No problem should therefore be encountered in getting abundant water for drilling operations, but cross-country movement of wheeled vehicles is by no means facilitated.

Roads and settlements. The Sydney Area is readily accessible by rail, highway, sea and air. Sydney is a city with a pre-war population of about 25,000, the terminus of a main line of the Canadian National Railways and an important port for transatlantic as well as coastal commerce. From Sydney, the Sydney and Louisberg Railway runs to Glace Bay and thence southward to the shore of Mira Bay and on to Louisberg, seven miles south of the south boundary of the Sydney Area. Spurs and branches from this railroad serve the many scattered mining communities along the way.

An excellent, hard-surfaced automobile road crosses the Strait of Canso from the mainland of Nova Scotia to Cape Breton Island by means of a vehicular ferry between Mulgrave and Hawkesbury and thence continues east of Bras D'Or Lake to Sydney and Glace Bay. Other all-season highways connect the several mining towns. There are, however, considerable areas of uninhabited land or sparsely populated farm land wherein the roads are few and poor.

The site at which drilling operations are recommended in a later portion of this report happens to be some distance from an improved highway. It is only a mile due west from the Glace Bay-Birch Grove road, but that is only a gravel road and McAskill Brook intervenes between it and the drilling site. The "Hines Road", shown on the topographic map as crossing the drilling location and joining the Glace Bay-Birch Grove road north of the McAskill Brook bridge, is only an overgrown woods road that would require much work before it could be of much use. There is, however, an ancient railroad embankment, apparently never completed with rails and ties, that leads southward from the Sydney-Glace Bay highway to the immediate vicinity of the recommended drilling location. The wooden culverts at the points where it crosses several small brooks have long since collapsed, but only a little work would be required to put it into condition for year-round use.

The Sydney airport is situated on the south side of the Sydney-Glace Bay highway, seven miles east of Sydney and only four miles away from the recommended drilling location, "as the crow flies."

There are excellent harbor facilities at Glace Bay as well as at Sydney. They are ice-bound for only two or three months each year.

Climate. Because of its proximity to the sea, the climate of the Sydney Area is far milder than one would infer from its northern latitude. Ordinarily there is sufficient snow to interfere with traffic only during January, February and March. The average annual temperature is about 42° Fahr. and the average annual precipitation is about 49 inches.

	Average temperature in degrees Fahrenheit	Average precipitation in inches
January	24.3	5.0
February	23.6	4.6
March	29.7	4.6
April	35.4	3.9
May	46.2	3.2
June	55.4	2.9
July	63.9	3.5
August	63.7	3.6
September	55.2	3.4
October	47.8	4.3
November	46.4	5.3
December	31.5	4.9

Rock exposures. The many marshes and considerable areas of dense scrubby forest growth combine with the generally widespread glacial drift to conceal effectively the bedrock throughout a large part of the Sydney Area. There are several districts, covering several square miles each, in which no outcrops can be found. In some of them, fortunately, there are coal prospect pits and shallow bore holes, drilled to secure information about the coal seams, that partially compensate for the absence of rock exposures. Wherever coal has been mined on a large scale, the underground workings give, of course, an abundance of valuable information concerning both stratigraphy and structure.

The best outcrops are those in the low, wave-cut cliffs along the shore, and the great irregularity of the deeply indented shoreline makes them available at many places. At some places along certain streams there are rock ledges and at a few places the more resistant sandstones are exposed in the inter-stream areas. Were it not, however, for the detailed geologic work done by earlier geologists concerned with the coal resources, it would have been quite impossible to have prepared in so short a time the structure contour map accompanying this report.

STRATIGRAPHY

General statement. It would be impossible to improve upon the concise description of the rocks of the Sydney Area, published by Bell in 1938 (Bibliography item 1) and that statement is therefore quoted here.

The uplands bordering the Sydney basin on the north, west and south are composed of Precambrian and early Paleozoic rocks. "The oldest rocks of these uplands, the George River series, are essentially sediments and are divided into two groups, a quartzite-schist-gneiss member and a presumably younger carbonate member. The former consists mainly of quartzite, schist, phyllite, gneiss, meta-argillite, and some amphibolite. The carbonate member is chiefly crystalline limestone and dolomite, with or without secondary silicates. Volcanic rocks, for example pyroclastics, rhyolite, quartz latite, dacite, and andesite, apparently overlie the George River series and are considerably less metamorphosed. They in turn are overlain, with slight angular unconformity on Long Island, by Middle Cambrian sediments. Finely banded, rhyolitic flows of the volcanic group, interbedded with some cherty sediments and a little conglomerate, are well exposed on the south shore of Mira Bay and on the shores of Scatari Island. The kind and variety of rocks in the volcanic group suggest vulcanism from one or more vents rather than from fissures.

"Plutonic rocks comprising four main petrographic types--quartz diorite, granodiorite, quartz monzonite, and red granite--intrude both the George River series and the volcanic group. They were intruded in the order named and are believed to be closely related in age. As there is no evidence of their cutting any Cambrian strata their age is inferred to be late Precambrian or early Cambrian, more probably the former.

"A variety of dyke rocks, including pegmatite, granophyre, lamprophyre, bostonite, and diabase, cut the plutonic and older rocks. The dykes that intrude the plutonics generally parallel a strong fracture system in the latter, and those cutting the George River series conform commonly in strike and dip to the sediments.

"Cambrian and Ordovician strata are present in the Boisdale Hills and in the so-called upland south of the coalfield. They consist of arenaceous and argillaceous marine sediments that carry fossil faunas of Middle Cambrian, Upper Cambrian, and early Ordovician ages. The Middle Cambrian sediments are mainly sandstones, grits, and sandy shales. The Upper Cambrian and early Ordovician rocks are mainly black and grey shales. These early Palaeozoic sediments are tightly folded and strike northeast.

"The upland of the Coxheath Hills merges westward into that of the Boisdale Hills. In the intermediate tract of country occur freshwater arkoses and conglomerates of Middle or Lower Devonian age. Fragments of plants belonging to an Arthrostigma-Psilophyton flora and a species of Estheria are sparingly present in thin shaly bands. These Devonian rocks include at least one bed of volcanic ash. They are overlain unconformably by basal conglomerate of the Windsor series.

"The Windsor series of Upper Mississippian (Visean) age flanks the border uplands of the coalfield. The series consists of extremely variable amounts of conglomerate, limestone, dolomite, gypsum, anhydrite, red shale, and sandstone. They are mainly deposits of a shallow, abnormally saline sea and include local deltaic masses or alluvial fans of conglomerate. Thus Lower Windsor limestone, which lies directly upon older rocks in the Boisdale Hills, becomes sandy towards the Coxheath Hills where it appears as a thin wedge in a thick alluvial fan or deltaic member of conglomerate (the Grantmire member). Similarly, thick Upper Windsor limestones in the district of Boularderie are represented in the Point Edward district fronting the Coxheath Hills by a zone of alternating beds of conglomerate, sandstone, shale, and limestone.

"The earliest Pennsylvanian deposits belong to the Canso series of Namurian (?) age. They occur at the present time only in the upper part of Sydney Harbour and near Cape Dauphin. They apparently once covered a much greater area and were later removed from large tracts during an epoch of erosion that intervened between their deposition and that of the succeeding Morien series. In spite of the erosional intervals represented by their contacts the Canso strata are apparently concordant with the younger Morien series and with the older Windsor series. At Cape Dauphin the

Canso deposits comprise a formation (Cape Dauphin formation) of dark grey, finely arenaceous siltstones and shales, whereas those of the Point Edward formation in Sydney Harbour are mainly chocolate-red shales and sandstones, with a few thin bands of freshwater limestone. A small faunule is furnished by these beds and includes ostracoda, Leaia, Estheria, and Carbonicola. So far as known the deposits are wholly freshwater in origin.

"The Morien series, which rests with erosional unconformity upon strata of the Canso series and of the Windsor series, is the most important coal-bearing group of beds in the Maritimes. Its coal, exploited more than two hundred years ago by the French during construction of the fortress of Louisburg, has been actively mined for more than a century, and at present supplies 75 per cent or more of the provincial production. The series consists of fluvial and fluviolacustrine detritus that was deposited in a progressively subsiding trough of deposition. The sediments, which are mainly grey and red sandstone, grey and red shale, and grey arkosic grit, include some conglomerate in the form of pebbly grits, and also near the base of the series some beds of limestone-conglomerate. Thin bands of freshwater limestone, commonly carrying Spirorbis, are present in addition to numerous coal seams......

"The maximum thickness of the Morien series, probably around 6,450 feet, lies in the vicinity of Glace Bay and perhaps originally farther south in the Morien district, for there is evidence of transgression and overlap towards Kelly Mountain which now forms the northwest boundary of the coalfield."

On their geologic maps, to which reference is made in the introductory portion of this report, Hayes, Bell and Goranson divide the Morien series into three zones which for convenience may be designated as Lower, Middle and Upper Morien. The recognizable formations of the Sydney Area may therefore be presented in tabular form, as follows:

Pennsylvanian

- Upper Morien series 900 to 1300 feet thick
  - non-marine coal measures, highly productive
- Middle Morien series 2300 feet thick
  - non-marine coal measures, few productive seams
- Lower Morien series about 3000 feet thick
  - non-marine coal measures, almost barren of coal
- - - - -unconformity - - - -
- Canso series, Point Edward formation 0 to 1200 feet thick
  - probably non-marine sandstone, shale and limestone
- - - - ?disconformity? - - -

Mississippian

- Upper Windsor series maximum thickness about 3000 feet
  - marine shale, limestone, sandstone and conglomerate
- Lower Windsor series, Grantmire member 1000 to 2500 feet thick
  - marine conglomerate, sandstone and shale
- - - - - great unconformity - - - -

Pre-Mississippian

- Cambrian and Ordovician shale and sandstone
- Precambrian metamorphic and igneous rocks

<u>Upper Windsor series</u>. Any consideration of the petroleum possibilities of the Sydney Area immediately focuses attention upon the Windsor strata as potential source beds for oil. The exposure

of these beds along the shores of the Pt. Edward peninsula between the two arms of Sydney Harbour were therefore studied in detail. The following measured section records their nature and thickness.

Table 1

Rocks of the Upper Windsor series, exposed along northwest side of Pt. Edward peninsula, from Dixon Point southwestward to the mouth of Grantmire Brook and thence up the valley of that stream to a point 1200 feet south of the Route 5 highway bridge.

	Feet
1. Dixon Point limestone, light grey; micro-fossils (?) on weathered surface..	12
2. Limestone, arenaceous; grades into a sandstone with calcite cement. The limestone is massive, but the sandstone weathers into slabs 1" thick......	3
3. Sandstone, grey; calcareous cement; cross-bedded.......	2
4. Concealed..	21
5. Limestone, sandy, or sandstone, calcareous; green......	2
6. Concealed..	7
7. Sandstone, grey; calcareous; fine-grained; weathers tan and forms slabs................................	4
8. Concealed..	322
9. Conglomerate and sandstone, green; feldspathic; average phenoclast, about 1/8". Contains some calcareous beds 1"-2" thick, and some 2" nodules of calcareous, grey sandstone........................	34
10. Limestone, grey; apparently mud-cracked in polygons 2' across; the edges of the plates turn downward..	3
11. Conglomerate and sandstone, green......................	11
12. Sandstone, mottled red and green; calcareous; fine-grained..	1
13. Concealed..	17
14. Limestone, grey; nodular; weathers to a microcellular surface; in places the limestone between the nodules is green........................	5
15. Limestone, mottled red and green; silty................	1
16. Concealed..	23
17. Conglomerate and sandstone, green mottled with red.....	1
18. Limestone, green mottled with a little red; silty......	1
19. Siltstone and fine sandstone, red mottled with a little green..	4
20. Limestone, green; thin-bedded..........................	2
21. Limestone; upper part is black, weathers rusty; petroliferous odor; lower part is medium grey.......	2.5
22. Concealed..	1
23. Limestone, black; weathers brown with a nodular surface; contains galena............................	3

Table 1 (cont.)

		Feet
24.	Limestone, black; weathers bluish-grey; petroliferous odor; algal-like structures	2 ?
25.	Sandstone and siltstone, red with green patches, poorly sorted	10
26.	Concealed	7
27.	Rudderham Point limestone, medium-grey; weathers mottled blue-grey and green; petroliferous odor	6
28.	Concealed	200
29.	Siltstone, red with a few green patches	7
30.	Concealed	28
31.	Shale, siltstone, and fine sandstone; grey and red	2
32.	Shale, grey	5
33.	Sandstone, grey; weathers red; abundant plant fragments	18
34.	Point Edward limestone, black to dark grey; weathers medium grey; calcite cleavage fragments; weathered surface reveals fine-grained oolitic texture	11
35.	Point Edward limestone, black; weathers tan; contains many fossils, part of which are enclosed in banded, limey nodules	12
36.	Sandstone, greenish-grey; plant fragments abundant	5
37.	Concealed	87
38.	Limestone Point limestone, light grey; oolitic; fossiliferous	9
39.	Concealed	18
40.	Siltstone and fine sandstone, red	8
41.	Siltstone and fine sandstone, red and green mottled; nodular; very calcareous	2.5
42.	Sandstone, red mottled with a little green; soft; medium-to fine-grained	5
43.	Limestone, dark grey; petroliferous odor	0.5
44.	Limestone, red and green mottled; sandy	1
45.	Siltstone, red and green mottled; calcareous	3
46.	Concealed	21
47.	Conglomerate and soft sandstone, red and purple with a little green; partly calcareous	14
48.	Concealed	330
49.	Conglomerate, red; soft; largest phenoclasts, about 6"; includes layers of coarse green sandstone	22
50.	Concealed	12
51.	Conglomerate, red	3
52.	Concealed	11
53.	Conglomerate, red; soft	15
54.	Concealed	9
55.	Conglomerate, red with a little green mottling and some green layers; soft	30
56.	Concealed	8
57.	Conglomerate, red with some green; soft	10
58.	Concealed; the thickness of the strata in this interval cannot be ascertained accurately because of the lack of a reliable strike and dip on <u>59</u>; Robb gives 370', and this is as good a figure as any	370

Table 1 (cont.)

		Feet
59.	Conglomerate, red	5
60.	Concealed; the change of strike from exposure 57 to 61 makes it impossible to compute accurately the thickness of the stra in this interval; Robb gives	160
61.	Conglomerate and sandstone, red	26
62.	Conglomerate and sandstone, red; contains a 2' mottled green, nodular, limey layer	20
63.	Limestone, mottled green and grey; weathers pink or greenish-grey; nodules ½" in diameter	4
64.	Limestone, conglomeratic and sandy; grades into #63	2
65.	Conglomerate and sandstone, red with a little green; contains a few thin, green limestone layers	24
66.	Conglomerate and sandstone, red	37
67.	Concealed	82
68.	Sandstone, red	1
69.	Conglomerate and coarse sandstone, grey	33
70.	Siltstone, red	4
71.	Conglomerate and sandstone, red with a little grey	23
72.	Concealed	16
73.	Sandstone and conglomerate, red	3
74.	Sandstone, red; fine-grained	5
75.	Siltstone and fine sandstone, red with green splotches; highly calcareous	12
76.	Concealed	2
77.	Sandstone, red; fine-grained	3
78.	Sandstone, red; medium-grained; highly calcareous; contains patches of sandy, green limestone	2
79.	Concealed	14
80.	Sandstone, red and grey	4
81.	Sandstone, red with green nodules; highly calcareous	5
82.	Siltstone, red; fine-grained; micaceous	6
83.	Siltstone and sandstone, red	10
84.	Sandstone, grey; coarse-grained; feldspathic; poorly consolidated	38
85.	Concealed	11
86.	Sandstone, red; contains greenish-grey calcareous patches 1"-3" in diameter	3
87.	Concealed	340
88.	Conglomerate and sandstone, red	10
89.	Sandstone, green; nodular; calcareous	4
90.	Conglomerate and sandstone, red	4
91.	Concealed	33
92.	Sandstone, red and green mottled; medium-grained; flaggy and massive	9
93.	Concealed	36
94.	Shale, dark grey	2
95.	Sandstone, greyish-green; medium-grained; arkosic; slightly micaceous; contains plant fossils; a few thin beds of coarse sandstone, conglomerate and shale	30
96.	Concealed	80

Table 1 (cont.)

		Feet	
97.	Sandstone, grey-green................................	1	2888.5
98.	Shale, grey................................	4	2892.5
99.	Concealed................................	80	2972.5
100.	Conglomerate, red; poorly consolidated; this is interpreted by us to be the uppermost exposure of the <u>Grantmire Member</u> of the Windsor Series. The contact, therefore, between the Upper and Lower Windsor is in the concealed interval, #<u>99</u>. Bell and Goranson put the contact 125' below #100, and include #100 in the Upper Windsor..	40	3012.5
	Total...........	3012	

In addition to the outcrops along the line of traverse upon which Table 1 is based, there is an exposure of limestone in a very old quarry on Kelly Hill, distant 650 feet to the southeast from the shore of West Arm in a direction at right angles to the traverse along that shore. The strike of the beds is such as to make it highly probable that this limestone belongs in the stratigraphic sequence in a position that would place it in the concealed interval #87. It is about 13 feet thick; medium grey; weathers same color; upper half thin-bedded or laminated, resembling somewhat the "Ribbon limestone," widely exposed near the base of the Windsor series in the Mabou-Lake Ainslee-Richmond districts in the western and southwestern portions of Cape Breton Island; lower half massive, fine-grained and oolitic; both upper and lower beds contain sand grains, some of which are arkosic, and display cross-bedding. No fossils were found, and in their absence it would not be safe to correlate this limestone either with the "Ribbon" or any other limestone member of the Windsor series.

According to the geologic map prepared by Bell and Goranson and published by the Canadian Geological Survey (Map 360A) the contact between the Windsor and the overlying Pt. Edward formation is in the covered interval along the shore northeast from Dixon Point. About 40 or 50 feet of concealed beds above the Dixon Point limestone would be included in the Windsor if there is no significant change in dip and strike. At no place have we found any exposure of this Windsor-Pt. Edward contact, but all relevant observations confirm Bell's deductions concerning its positiom and nature. Adding 40 to 50 feet at the top of our measured section in accordance with those deductions and subtracting the 40 feet of Grantmire conglomerate (#100) from its bottom, gives a total thickness for the Upper Windsor series of about 3000 feet.

In this thickness of about 3000 feet there are included both the "Windsor series", 600 feet thick, and the "Age uncertain, probably Mississippian" beds, 2633 feet thick, of Hyde's 1913 report (Bibliography item 12). Commenting on his section, Hyde wrote that the thickness of 600 feet for his restricted "Windsor series" is "only about half as great as the figure assigned by Robb to the same beds" and that the thickness of 2633 feet for the underlying beds is adopted from Robb, but "is probably much too large." Our measurement of the thickness of that portion of the Windsor above the base of the Limestone Point limestone (the bottom of Hyde's "Windsor series"), including 40 feet of concealed beds above the Dixon Point limestone, is 931 feet. Our traverse, however, includes a concealed interval, #8, computed to represent a thickness of 322 feet, on the assumption that there is no change in structural conditions between the outcropping beds, #7 and #9, at either end of the interval. That assumption seems warranted from all the evidence available in the surrounding region, and the figure is believed to be correct within a possible margin of error of 15% or 20%. It is therefore our conclusion that Hyde's measurement is as much too small as Robb's is too great.

Our measurement of the thickness of that portion of the Upper Windsor series underlying the Limestone Point limestone is 2081 feet. This is 552 feet less than Robb's figure, adopted by Hyde, and is therefore in fairly close agreement with Hyde's ideas. It is not clear, however, whether either Robb or Hyde selected the same horizon as we did for the Grantmire-Upper Windsor contact. Moreover, in our traverse there are three concealed intervals for each of which the computed thickness is more than 300 feet and another one for which the computation is 160 feet. For two of these (#58 and #60) we adopted Robb's figure as being as good a guess as any we could make. For the others the strike and dip of the exposed beds at either end of the concealed interval are much the same, but within those two the strike and dip change appreciably, and the precise nature of the change cannot be discovered. Our total figure, therefore, may be as much as 500 feet in error.

Far more important, however, than any precise knowledge of the thickness of the Upper Windsor strata at the far western border of the Sydney Area is the question of its thickness and composition in the central and northeastern portions of that area, where it is presumably present beneath a thick cover of overlying Pennsylvanian coal measures. All the evidence supports the expectation that it is so present. There are outcrops of Windsor beds along the south shore of Mira Bay, 18 to 20 miles southeast of Point Edward, as well as other outcrops on the shore of Boularderie Island in Saunders Cove, 7 miles to the northwest of Point Edward, and at Cape Dauphin, 7 miles north of Saunders Cove. Farther north along the shore on the north side of St. Ann Bay these same beds are also exposed for several miles on either side of Briton Cove, extending to a distance of at least 24 miles north and a little west of Point Edward. At all of these localities the Windsor strata crop out near the border of the Sydney basin and dip downward toward its center. Although no one could at this time guarantee that equivalent beds are continuous across the basin floor, that is the only reasonable deduction from all available evidence. All that is now known about the character, intensity and localization of the post-Canso, pre-Morien diastrophism is opposed to the theory that it so wrinkled and elevated the central part of the Sydney basin as to cause the removal of the Windsor series by erosion before the deposition of the Lower Morien sediments.

On the other hand, it is unlikely that the Upper Windsor series retains the great thickness displayed in the Pt. Edward Peninsula throughout its entire extent across the floor of the Sydney basin. The Coxheath Hills constituted an upland bordering the Windsor sea in Mississippian time, even as now they form a highland overlooking the Sydney lowland. Proximity to that rugged shore was responsible for the large amount of gravel and sand in the Windsor beds, especially in the lower members of the Upper Windsor, as well as in the dominantly conglomeratic strata of the Lower Windsor, Grantmire beds. At other points along the shore of the Windsor sea in the Sydney Basin where the adjacent land was less hilly, the Windsor beds are finer-grained and thinner, with a much greater percentage of limestone and calcareous shale in the lower members. Presumably, the equivalent beds in the central part of the basin, in the general vicinity of Glace Bay, consist largely of shale and limestone with an even smaller percentage of sandstone and no conglomerate. The total thickness of the Upper Windsor (as here defined) may therefore be only 1200 to 1500 feet beneath the Glace Bay district, instead of the 2500 to 3000 feet displayed in the Pt. Edward peninsula.

The probable composition of the Upper Windsor series in the central part of the Sydney Basin is of special importance because of the possibility that these rocks may have been the source of petroleum for an oil pool of economic significance. As moted im the measured section, Table 1, several of the limestones yield a petroliferous odor when freshly broken. This, together with the fossils, indicate an abundance of organisms in the Windsor sea. The calcareous shales and limestones appear at their outcrops to be entirely satisfactory source beds for oil. This characteristic should be even more favorable where the equivalent beds were accumulated in the quieter waters at somewhat greater distances from the shore. It would seem well-nigh certain that beneath the Glace Bay district the Upper Windsor is at least potentially an adequate source for petroleum in commercial quantities.

Finally, the gypsum content of the Upper Windsor series must be considered. It was the presence of unexpectedly large amounts of rock salt in association with the gypsum beds of the Windsor series in the Mabou district that prevented the wells drilled in

1944 at that place from reaching the underlying Ainslee sandstone. Is it likely that gypsum and salt are present in the Sydney Basin to an extent similar to that in the Mabou-Lake Ainslee Basin? In this connection, the complete absence of gypsum from the measured section on the Pt. Edward peninsula is most significant. It is possible, though highly improbable, that gypsum beds occur in one or more of the concealed intervals in that section. If so, there is no suggestion of its presence in the entire peninsula. On the other hand, there are outcrops of gypsum beds near the mouth of Leitches Creek, on the west side of the harbor, 1.7 miles west of the line of traverse for the measured section, and along the shore of Saunders Cove, 7 miles to the northwest. At both of these localities the gypsum bed is probably only 10 or 15 feet in thickness, although in Saunders Cove there may be two such beds. There is also a thicker bed of gypsum, largely covered by glacial drift, in the area west of McInnis Lake, 10 miles southwest of the Point Edward locality, as well as north of St. Ann Bay in the general vicinity of Briton Cove. At all these places the gypsum seems to have much the same stratigraphic position--near the top of the lower third of the Upper Windsor. The only generalization that seems to be justified is therefore that gypsum will probably, though by no means certainly, be encountered by wells drilled in the central part of the Sydney Basin, as for example in the general vicinity of Glace Bay, but that it is extremely unlikely that it is present there in any such great thickness or number of beds as in the Mabou district. The same generalization applies to rock salt, of which there is no suggestion in any of the surface phenomena of the Sydney region, but which is associated with the gypsum in the Mabou region.

Lower Windsor series, Grantmire member. As reported by Bell in the extensive quotation beginning on page 12 of this report, the lower part of the Windsor series, as exposed immediately to the west of the west boundary of the Sydney Area (but shown near the west side of the accompanying map), is a thick body of conglomerate, sandstone and shale to which the name, Grantmire member, is applied. The areas within which it crops out at the surface are shown on Map 360 A, issued in 1938 by the Canadian Geological Survey and covering the quadrangle adjoining the Sydney Area on the west. A complete section of its beds is exposed along the course of Grantmire Brook. According to Fletcher this formation is 2525 feet thick at that place. We did not make an instrumental measurement of its thickness, but this figure is apparently correct within a reasonable margin of error.

The coarse texture of the conglomerates and sandstones, and the absence of limestone in this exposure of the Grantmire member is evidently a local phenomenon, due to the presence of a great alluvial fan or delta constructed at the foot of the Coxheath Hills and close to the shore of the early Windsor sea. Elsewhere in this part of Cape Breton Island the lower Windsor beds are generally of finer texture and include considerable amounts of limestone. Thus in Frenchvale Valley, 5 miles to the southwest between Coxheath Hills and Boisdale Hills, there are thin marine limestones and calcareous sandstones overlying a basal conglomerate and occupying the same stratigraphic position as the conglomerates and gritty sandstones in the midst of the Grantmire Brook sequence. Similarly near Catalogne Gut and Bateston, on the south shore of Mira Bay, 18 to 20 miles eastsoutheast from the mouth of Grantmire Brook, the Windsor beds include dolomite and limestone overlying a basal conglomerate. Fossils from "Dixon siding," near Catalogne Gut, were examined by E. M. Kindle (Bibliography item 16, quoted by Hayes and Bell, Bibliography item 11, p. 13). Bell reports this fauna to be "a typical Lower Windsor assemblage" and it is probably safe to conclude that the limestones containing it are equivalent in age to non-calcareous beds in the midst of the Grantmire member at its type locality.

Bell Revised in accompanying Mem. Map 362A as "all of Upper Windsor age"

The Mira Bay exposures are 8 miles due south of Birch Grove and doubtless represent the nature of the Lower Windsor strata beneath the Birch Grove-Glace Bay region far more faithfully than do the exposures along Grantmire Brook. It may be confidently expected that in the central part of the Sydney basin there are upwards of a thousand feet of Lower Windsor limestones, calcareous shales and sandstones beneath the Upper Windsor beds. These are of course potential source rocks for petroleum. Thus the total thickness of both Lower and Upper Windsor source beds in the general vicinity of Glace Bay may well be as great as 2000 or even 2500 feet.

Canso series, Point Edward formation. In the vicinity of Point Edward there is no conspicuous difference in lithology and attitude between the Upper Windsor strata and the overlying beds that are referred to the Canso series, the lowermost Pennsylvanian strata of Nova Scotia. The separation is based solely upon the fossil content of the two groups--Chester (equals Dinantian) fossils in the Windsor and Namurian (equals Pottsville) fossils in the Point Edward. So far as our observations go, there may be no break in sedimentation to mark the transition from the Mississippian to the Pennsylvanian, although Bell and his colleagues suggest the probability that there is at least a disconformity between the rocks of the two periods. As stated above, we have found no exposure of the actual contact, nor does Bell indicate in any of his reports that he has found one.

No unmistakably marine fossils have been reported from the limestones of the Point Edward formation in the type locality, although the lithologic appearance of several of the limestone members is like that of marine beds. It is altogether possible that the formation consists of alternating marine and non-marine strata deposited near the shore of a shallow oscillating sea covering only a part of the flat floor of the Sydney Basin that had been so built up by sedimentation during Windsor time as nearly to exclude the marine waters. With these thoughts in mind and in view of the petroliferous odor emitted by some of the limestones when freshly broken, it is natural to give consideration to the potentialities of the Point Edward formation as a source of petroleum. The strata exposed along the west side of the Point were therefore measured with plane table and alidade. Table 2 presents the data thus secured. The top of the measured section is the uppermost bed at the extreme tip of the Point.

Table 2.

Rocks of the Point Edward formation exposed along the northwest side of Pt. Edward peninsula from Edward Point southwestward toward Dixon Point.

	Feet
1. Sandstone and siltstone; red; fine-grained, ripple-marked	15
2. Sandstone; grey; fine-grained; contains plant fossils	2
3. Limestone; grey; shaley	2
4. Siltstone, calcareous; and shale, non-calcareous; red and grey-green mottled	7
5. Concealed	17
6. Shale, red and green mottled; soft	16
7. Sandstone, maroon mottled with green; fine-grained, micaceous	5
8. Limestone, black, weathering grey; strong petroliferous odor; black fossil markings appear to be plant fragments	1
9. Concealed	6
10. Shale, red, green, and grey	4
11. Concealed	53
12. Siltstone, red	4
13. Siltstone, red and green; nodular; calcareous	1.5
14. Siltstone, red	1
15. Sandstone, red; fine-grained	3
16. Concealed	17
17. Limestone, grey and red, mottled and banded	6
18. Shale and siltstone, red and green, mottled and banded	7
19. Concealed	12
20. Siltstone, red and green mottled; slightly calcareous	1
21. Siltstone, grey; slightly calcareous	2
22. Concealed	7
23. Siltstone, grey; calcareous	3
24. Concealed	2
25. Limestone, grey	2
26. Concealed	12
27. Limestone, medium to dark grey; weathers light grey	1
28. Concealed	40
29. Silty limestone, grey; nodular	1
30. Siltstone and shale, red; contains numerous 1" nodules of grey calcareous material, weathering green	1
31. Siltstone and shale, red	4
32. Limestone, green; shaley	1
33. Shale (50%), siltstone (35%), and fine sandstone (15%), red; some of the siltstone is calcareous	24
34. Limestone, grey, partly red; 6" below the top of the limestone is a 3" band containing flakes of red and grey shale up to ½" in diameter	4.5

Table 2 (cont.)

	Feet
35. Limestone, grey; thin-bedded; contains red, argillaceous limestone layers	4.5
36. Shale, red with some grey; calcareous	5
37. Limestone, grey	1
38. Limestone, red	0.5
39. Limestone, grey	1.5
40. Siltstone, grey; calcareous	1
Total	298.5

Between the outcrop of bed number 40 in the above table and the outcrop of the Dixon Point limestone, top of Table 1, there are no exposures along or near the line of our traverse. This concealed interval is presumably occupied by poorly resistant sandstone or shale. Robb (Bibliography item) computes the thickness of the concealed beds as 459 feet. The strike of the Dixon Point limestone is, however, sufficiently different from that of bed number 40 to render untrustworthy such apparent precision. The correct figure probably is somewhere between 400 and 500 feet. Bell draws the boundary between the Point Edward and Windsor formations so as to place that contact 40 or 50 feet above the Dixon Point limestone. This puts about 400 feet (between 350 and 450 feet) of the concealed beds in the Point Edward formation. Adding that figure to the approximately 300 feet of the measured section gives a total in close agreement with Bell's statement that "the Point Edward formation.....is 750 feet thick on Point Edward peninsula."

There are additional exposures of Point Edward beds on the east shore of the South Arm of Sydney Harbour, within the Sydney city limits. The section of 118 feet of shale, sandstone and limestone, measured by Hayes and Bell (Bibliography item 11, p. 14) at Battery Point, probably lies within the concealed interval near the base of the formation on Point Edward peninsula. The beds beneath the northern outskirts of the city are doubtless much higher in the stratigraphic sequence than the topmost bed at Edward Point. All told it appears that the total thickness of the Point Edward formation, beneath and near South Arm, is of the order of 1250 feet, as estimated by Bell.

In spite of the fact that at this locality the Point Edward is largely or wholly a non-marine formation, there is a distinct possibility that farther to the east it may serve as a source rock for petroleum. Certain of its limestones, notably bed 8 in Table 2, contain bituminous matter and yield a petroliferous odor when freshly broken. Some of its limestone members that are devoid of identifiable fossils cannot be distinguished lithologically from marine limestones. Its characteristics at points a few miles farther away from the southwestern periphery of the Sydney basin may be quite different from those displayed near the head of Sydney Harbour. The differences are most likely to be such as to improve rather than decrease its potentialities as a source of oil. There is a distinct possibility that if present beneath the Birch Grove-Glace Bay district the Point Edward formation may add a few hundred feet of thickness to the potential source rocks of that locality.

On the other hand there is no certainty that any of the Point Edward beds, either marine or non-marine, will be encountered by the drill in the general vicinity of Glace Bay. The Morien series may rest directly upon the Windsor in that part of the Sydney basin. We agree with Bell et al that an episode of widespread erosion removed the Point Edward formation from a large portion of the Sydney Area before the basal beds of the Morien series were deposited. The change from sedimentation to erosion seems to have been accomplished without any notable folding of the pre-Morien strata, inasmuch as the Point Edward beds wherever they are present are accordant in attitude with the overlying Morien strata as well as with the underlying Windsor. In advance of drilling operations in the central part of the Sydney Basin there is no way of telling whether or not the Point Edward formation escaped removal, either in whole or in part, before the Morien series began to accumulate there. Perhaps the odds are somewhat in favor of its presence there, inasmuch as erosion would probably be more effective near the periphery of the basin than near its center.

Morien series. The strata referred to the Morien series are of interest to the petroleum geologist primarily because of the information concerning geologic structure that may be secured from them. Bell and his associates have identified and correlated the numerous coal seams occurring within the series, and these serve admirably as key horizons. Details concerning these coal seams and the associated non-marine sedimentary strata are presented in the reports listed in the accompanying bibliography.

GEOLOGIC STRUCTURE

Regional structure. The Sydney Area occupies the southwest quadrant of a large structural basin, the greater part of which is submerged beneath the sea. The Carboniferous rocks in this Area therefore display a regional dip toward the northeast. Several broad flexures trend in northeast to east directions, more or less radial to the basin as a whole. Bell describes these structures as follows (Bibliography item 1, pp. 7, 8): "The principal folds from northwest to southeast are the Boularderie syncline, Boisdale anticline, Sydney Harbour syncline, Bridgeport anticline, Glace Bay syncline, Cape Percy anticline, and Morien syncline. Of these the Boisdale anticline and the Bridgeport anticline are extensions of the anticlinal folds that raised the crystalline rocks of the Boisdale and Coxheath Hills respectively; the Boularderie syncline is a faulted downfold between the Boisdale Hills and Kelly Mountain; and the western end of the Sydney Harbour syncline is a downfold between the Boisdale Hills and Coxheath Hills. The remaining folds are structures confined to the Coal Measure rocks; their axes, like those of the other folds, plunge gently seaward and the structures apparently all close in that direction. The coal seams, therefore, seemingly isolated in the main synclines on land, where each has been given a variety of names, are continuous in the submarine areas.

"A minor belt of folding is present near, and southeast of, Sydney. The main structure, the Wentworth syncline, is a closed syncline that trends about 20 degrees south of east, and has associated, secondary, gentle flexures that plunge into it. These structures lie in such relation to the crystalline rocks of the Coxheath Hills and their bordering Lower Carboniferous, thick conglomerates that their presence and orientation may be reasonably ascribed to a torsional movement consequent upon the greater resistance to stresses offered by the Coxheath rocks.

"The slightly sinuous trends of the axes of the main folded structures farther east likewise indicate the influence of torsional stresses that were secondarily developed by compressive forces operating in a northwest direction. To these torsional stresses, also, are perhaps due local steep dips in some of the folds, for example in the northern limb of the Bridgeport anticline near Victoria Mines where dips of 40 degrees occur; in the northern limb of the Cape Percy anticline at the Cape Percy headland where dips of 35 to 40 degrees likewise occur; in the southern limb of the Cape Percy anticline north of Port Morien where the dips reach 45 degrees; and finally in the southern limb of the Wash Brook anticline (or northern limb of the Wentworth syncline) with dips up to 50 degrees. The prevailing dips throughout the coalfield are from 4 to 15 degrees.

"Resistance of the crystalline rocks to folding resulted also in faults between them and the stratified Carboniferous rocks. Most of these faults extend very little beyond the plunging ends of the crystalline cores and affect only the Lower Carboniferous rocks at the borders of the coalfield. The Morien series, however, is downthrusted northwestward by a fault of this character against the crystalline rocks of Kelly Mountain and also downthrusted southerly against Lower Carboniferous and probably also against Cambrian rocks along the border of the volcanic mass of the southeastern upland. Elsewhere in the Morien series faults are exceedingly rare. Two, seemingly strike faults, affect strata between the McRury and Gardiner seams on Cape Percy Headland where the dips are highest. The displacements, apparently normal downthrows on the north, are measurable in tens of feet. A fault, striking about magnetic north in the Morien district has a downthrow to the west of several tens of feet and an assumed fault with downthrow on the east offsets the Mullins seam near North Sydney."

Birch Grove dome. The accompanying structure contour map, Plate II, indicates the presence of an elongated dome on the rounded crest of the Cape Percy anticline. This is the only structure in the entire Sydney Area known to fulfill the requirements for a structural trap for oil, but it meets perfectly the specifications for such a trap. It may be designated the Birch Grove dome because of its proximity to the town of that name.

The structure contours on Plate II are drawn by using the coal seams as key horizons, with additional data derived from observed dip and strike of outcropping beds. The datum plane is the base of the Middle Morien series, the Tracy seam. The stratigraphic intervals between that and higher seams differ somewhat from place to place and therefore the following average figures were used:

Table 3.

Stratigraphic interval between coal seams in Sydney Area and the datum surface contoured on structure contour map, Plate II.

Coal seam	Feet
Point Aconi = Cranberry Head	3750
Harbour = Blockhouse = Sydney Main	2900
Backpit = Trunnelshed = Indian Cove = Greener	2500

Table 3 (cont.)

	Feet
Phalen = Gowrie = McAuley	2400
Emery = Spencer = Wilson = South Head	2200
Gardiner = Long Beach	1900
Mullins = Martin	1300
Buchanan = Le Cras	900
Ormond	660
Tracy = Broughton = Fitzpatrick	0

As thus outlined, the Birch Grove dome extends for 5 or 6 miles in an east-west direction and is from one to one-and-a-half miles wide. On the north side the rocks dip northward at angles ranging from 4° to 12°. On the south side the southerly dip is at angles ranging from 15° to 50°. The closure is probably in the neighborhood of 400 or 500 feet. It cannot possibly be less than 200 feet and might be as great as 600 or 700 feet.

Our inability to state with precision the amount of closure is due to the fact that there is an area of three or four square miles west and southwest of the top of the dome in which there are neither outcrops nor bore holes. The fact that the axis of the elongated dome plunges downward toward the west or southwest in this area is, however, clearly indicated by the data shown on Plate II. The structure contours drawn as continuous lines in this portion of the map are firmly established by the coal seams encountered in prospect pits, bore holes and mine workings or by surface outcrops on which the dip and strike may be measured with confidence. The identification of the coal seams was made on the basis of associated fossil floras identified by Bell. The critical facts include (1) the presence of the Buchanan and Mullins seams, striking in a general north-south direction and dipping steeply eastward at points four to five miles west of the apex of the dome; (2) the presence of the Mullins seam in the shallow bore hole and prospect pit indicated by the -X- on our map, one-half mile northwest of the apex of the dome; and (3) the dips and strikes shown by the symbols on our map. The structure contour lines drawn discontinuously represent a conservative interpretation of the attitude of the beds in the concealed area. They could have been drawn in such a way as to indicate a much larger closure and still would have accorded with all known data. No fault has been assumed because of the almost complete absence of faulting throughout the entire region of Morien strata. Even were a fault present, comparable to the one shown in the syncline south of the east end of the dome, it would not materially alter the effectiveness of the structure as a trap for oil.

APPRAISAL OF PETROLEUM POSSIBILITIES

Structural trap. The Birch Grove dome as described above and delineated on Plate II is obviously an ideal trap for oil. It is a large, doubly plunging anticlinal fold with only one small tear-fault on its flank. Oil could migrate up-dip into this trap from an area of at least 50 square miles. This potential "drainage area" is bounded on the south by the bottom of the Morien syncline and on the north by the bottom of the Glace Bay syncline. Toward the east and northeast it extends an unknown distance beyond the shore of Cape Breton Island.

The depth to the bottom of the Morien series at the apex of the dome is approximately 4500 feet. Around the periphery of the "closure" it is approximately 5000 feet.

Source beds. The most likely source of oil beneath this district is in the marine strata of Windsor age. The potentialities of those beds at their outcrops, 12 miles west and 9 miles south of the dome, are apparent from the descriptions and section recorded on preceding pages of this report. As already stated, the probability is great that those beds are even better qualified to serve as a source of oil beneath the "drainage area" of the Birch Grove dome, several miles from the shore of the Windsor sea, than at their outcrops close to that shore. Any estimate of the thickness of the marine Windsor beneath the Birch Grove locality is perforce only a guess in the present state of knowledge. Presumably, however, the figure is somewhere between 1000 and 2000 feet.

Attention has already been called to the possibility that the Point Edward formation may also be a source of oil, if it is present beneath the "drainage area" of the Birch Grove dome. The chances are good that marine waters were present in that somewhat centrally located portion of the Sydney basin during at least a part of Canso time. Moreover, it cannot be said dogmatically that under no conditions can a freshwater limestone be a source of petroleum. The possibility should therefore be entertained that there may be a few hundred feet of source beds belonging to the Point Edward formation that may contribute oil to Birch Grove dome. The total thickness of the potential source beds may therefore appreciably exceed 2000 feet.

Reservoir rocks. At their outcrop, many of the Windsor strata are coarse, gritty sandstones or fine, pebbly conglomerates displaying all the characteristics that make for high porosity and permeability. Variations in texture and composition along the strike of these beds are, however, so great that no well-based predictions can be made concerning their characteristics at places several miles distant in a direction at right angles to their strike. Presumably their texture would be finer beneath the Birch Grove locality, several miles from the Windsor shore, than near the periphery of the Sydney basin. It is, however, almost certain that somewhere in the stratigraphic sequence of the Windsor series there would be strata suitable to serve as a reservoir rock, even near the center of the basin. It is apparent that the Windsor seas oscillated in level throughout Windsor time. The delta responsible for the Grantmire member at the base of the Point Edward peninsula could not possibly have been the only delta built out into the Windsor sea. Shifting currents must have swept coarse sandy sediments to various portions of the embayed sea at different times. Although no one can now predict the precise horizons between the top and bottom of the Windsor series in the Birch Grove dome at which highly porous and permeable strata would be encountered by the drill, the probability becomes almost a certainty that at least a few such horizons are present somewhere in the 1000 to 2000 feet of thickness of that series there. Only the drill can reveal the desired information.

Similarly, it is practically certain that if the Point Edward formation is present there, between the underlying Windsor and the overlying Morien, it also includes satisfactory reservoir rocks. Moreover, there are many sandstones and grits near the base of the Morien series that display all the desirable characteristics of reservoir beds. If no Point Edward beds escaped removal during the pre-Morien erosion episode, or if the remaining Point Edward beds are actually good source beds, oil could have migrated directly into the basal Morien strata.

Oil-bearing, reservoir rocks may therefore be found anywhere between the bottom of the Windsor and the top of the lower few score feet of the Morien. This means that in the first exploratory well, drilled presumably at the apex of the Birch Grove dome, an oil sand might be encountered at any depth between a little less than 4500 feet and a little more than 7500 feet. The maximum figure is based upon the possibility that there might be as much as 1200 feet of Point Edward beds and 2000 feet of Windsor beds at that locality and that there might be oil sands in the lowermost portion of the Windsor. There seems to be no indication that oil might be recovered from formations below the Windsor in this area.

Induration and metamorphism. The amount of induration and intensity of metamorphism of the Carboniferous strata in the Sydney Area are in striking contrast to that displayed in the Mabou and Richmond areas, elsewhere on Cape Breton Island. The Grantmire member of the Lower Windsor consists, for example, of loosely cemented gravel and sand, so slightly indurated that at many exposures the rock crumbles apart in one's hand. None of the Windsor limestones in the Point Edward district display the numerous veins and veinlets of calcite that are so characteristic of certain of the Windsor limestones elsewhere. At no place within the Sydney basin have we seen any Carboniferous sandstones that could be called "quartzitic sandstone," much less "quartzite," terms that are appropriate for much of the Horton series in the Richmond Area and the Ainslee sandstone at certain places in the Mabou-Lake Ainslee region.

Proximate analyses of the coals, reported by Hayes and Bell (Bibliography item 11), indicate the following carbon ratios:

Upper Morien series

Blockhouse seam.................................... 60.9

Gowrie seam.. 60.4

Spencer seam 60.7, 62.2, 59.6, 60.6, 60.8, average 60.8

Middle Morien series

Long Beach seam 63.2, 63.7.................. average 63.5

Thin seam slightly below Long Beach horizon.......... 65.0

Average of all 10 analyses.............................. 61.7

Rigid application of the carbon-ratio theory developed by several geologists from the data of the Appalachian coal and oil fields would interpret these percentages as indicating the presence of gas rather than of oil in the Sydney Area. There are, however, many exceptions to the carbon-ratio "rule," and several oil fields of considerable value have been developed in regions where coal analyses indicate carbon ratios of 62 or more. Jones in particular has shown (Economic Geology, vol. 23, pp. 353-380, 1928) that "in western Canada the fixed carbon content of coals cannot be used to measure the regional dynamic metamorphism, nor can it serve as an index to possible oil and gas accumulations."

Especially puzzling is the apparent increase in carbon ratio with original depth of burial, as indicated by the higher fixed carbon content of the Middle Morien coal when compared with the seams in the Upper Morien. This would seem to indicate excessive induration of the even more deeply buried Windsor sediments. Yet those rocks display at their outcrops, only a few miles distant, a striking lack of induration. One may perhaps be justified, therefore, in looking with suspicion upon the accuracy of the analyses of the three samples from the Long Beach zone.

In any event, it is probably wiser to judge the intensity of metamorphism in this region from the lithologic characteristics of its shales and sandstones rather than from the proximate analyses of its coals. In the present state of knowledge concerning the relations between the occurrence of petroleum and the carbon ratios of associated coal, the data now in hand should certainly not be considered so discouraging as to cast doubt upon the wisdom of drilling for oil.

Closely connected with the enquiry concerning induration and metamorphism is the question of the possible effect of crustal movements upon the salt and gypsum beds that may be present in the Windsor series in the Birch Grove dome. Is it likely that the drill will encounter two thousand feet or more of rock salt on the crest of that fold as it did on the Mabou anticline, 60 miles to the west? All the evidence combines to give a negative answer to that question. The anticlinal folds of the Sydney-Glace

Bay-Morien region are a result of response to torsional and more or less horizontal stresses. They are, however, broad and open folds, quite different from the closely compressed folds of the Mabou-Lake Ainslee region. Moreover, there are no major faults along or parallel to the anticlinal axes. It is almost inconceivable that the stresses indicated could have stimulated such movement of salt and gypsum to the crest of the Birch Grove dome as that responsible for the "reef" of salt at Mabou, even if there is any considerable thickness or number of beds of salt and gypsum in the midst of the Windsor series in this part of the Sydney basin.

RECOMMENDATIONS

The foregoing description of the geologic features of the Sydney Area and the consideration given to the deductions from geologic theory undergird the following conclusions.

Drilling for oil. The Sydney Area is underlain by adequate source beds and reservoir rocks for petroleum. Dynamic and static metamorphism have not been so excessive as to make it unlikely that oil is present in suitable traps. There is one structural trap, the Birch Grove dome, that appears to be an ideal locus for an oil pool. Its large drainage area suggests the probability that a very considerable volume of petroleum may be recovered from it. Depths to the prospective oil sands--4500 to 7500 feet--are well within the range of modern drilling operations. Field studies to date indicate that the proper location for the first test well is on the apex of the dome at a point close to the bed of McAskill Brook about 150 yards due west of the mouth of the second tributary joining that stream from the northwest, counting the tributaries upstream from the mouth of McAskill Brook on its left bank. This location is a little more than one and five-eights miles northwest of the town of Birch Grove.

Further geologic prospecting. It is an open question whether or not additional field studies should precede drilling operations. We believe that all available data obtainable by ordinary geologic surveying methods are now in hand. One or more additional procedures might, however, be followed in the hope of determining more precisely the amount of closure in the dome, the delineation of its structure beneath the district devoid of outcrops at its western end, and the thickness and nature of the strata beneath the Lower Morien series within its area.

The digging of a number of shallow pits in the district marked by the discontinuous contour lines on our structure contour map, Plate II, would almost certainly make possible the determination of the strike and dip of sandstone beds concealed by glacial drift and surficial debris. The drilling of shallow bore holes might possibly reveal identifiable coal seams or associated fossiliferous shales in the Middle Morien series, the stratigraphic relations of which to the Tracy seam might be ascertainable. This would involve the services of an expert paleobotanist such as Dr. W. A. Bell. With good luck in encountering fossiliferous beds, the information thus obtained would permit more precise delineation of the structure in this critical area. The best that could be expected from either or both of these two procedures would be an answer to the question whether the closure is as little as 200 feet or as much as 700 or 800 feet. We are already confident that we know the position of the summit of the dome and that its closure is at least 200 feet.

Geophysical surveys. Consideration should also be given to the application of geophysical surveys to the search for additional information in advance of drilling. It is possible that a gravity meter survey might yield data of significance, although it is highly probable that no reliable interpretation of the phenomena displayed by the resulting gravimetric map could be made in advance of drilling. Obviously, the pre-Carboniferous floor of the Sydney basin must be higher beneath the apex of the Birch Grove dome than around its periphery. Probably the greater density of those basement rocks in comparison to the unmetamorphosed Carboniferous sediments would have a recognizable influence upon the gravimetric contour lines. It is, however, equally probable that the variable and lenticular sandstones in the Morien series and the lenticular masses of gypsum and salt (if present) in the Windsor series would mask that influence so effectively as to render quite inconclusive the results of such a survey.

It is our opinion that a seismic survey would be more likely to yield valuable results than a gravimetric survey. The surface features and near-surface rocks of the Sydney basin are much more favorable for seismic prospecting than are those of western Cape Breton Island. It is almost certain that the pre-Carboniferous basement floor would give indentifiable reflections and that therefore both its configuration in the Birch Grove district and the thickness of the pre-Morien Carboniferous strata in the domal structure could be ascertained in advance of drilling. There is also the possibility that other reflecting horizons might be recognizable and that any differences between the structure of the rocks below and above the pre-Morien unconformity might be revealed. It is, however, practically out of question that the data revealed by a seismic survey would make it unwise to test the Birch Grove dome by drilling for oil, although they might either increase or decrease confidence in the success of such drilling.

Licenses. The foregoing considerations make it plain that arrangements should be made for the continuation of control over this property in accordance with The Petroleum and Natural Gas Act of the Province of Nova Scotia. The area that should be retained under license is shown on Plate IV. It comprises 20 "mining tracts" of approximately one square mile each in the southwestern part of License Map 11-J-4-C, 9 such tracts in the southeastern corner of License Map 11-K-1-D, 4 in the northeast corner of License Map 11-K-1-A, and 4 in the northwest corner of License Map 11-J-4-B.

Kirtley F. Mather

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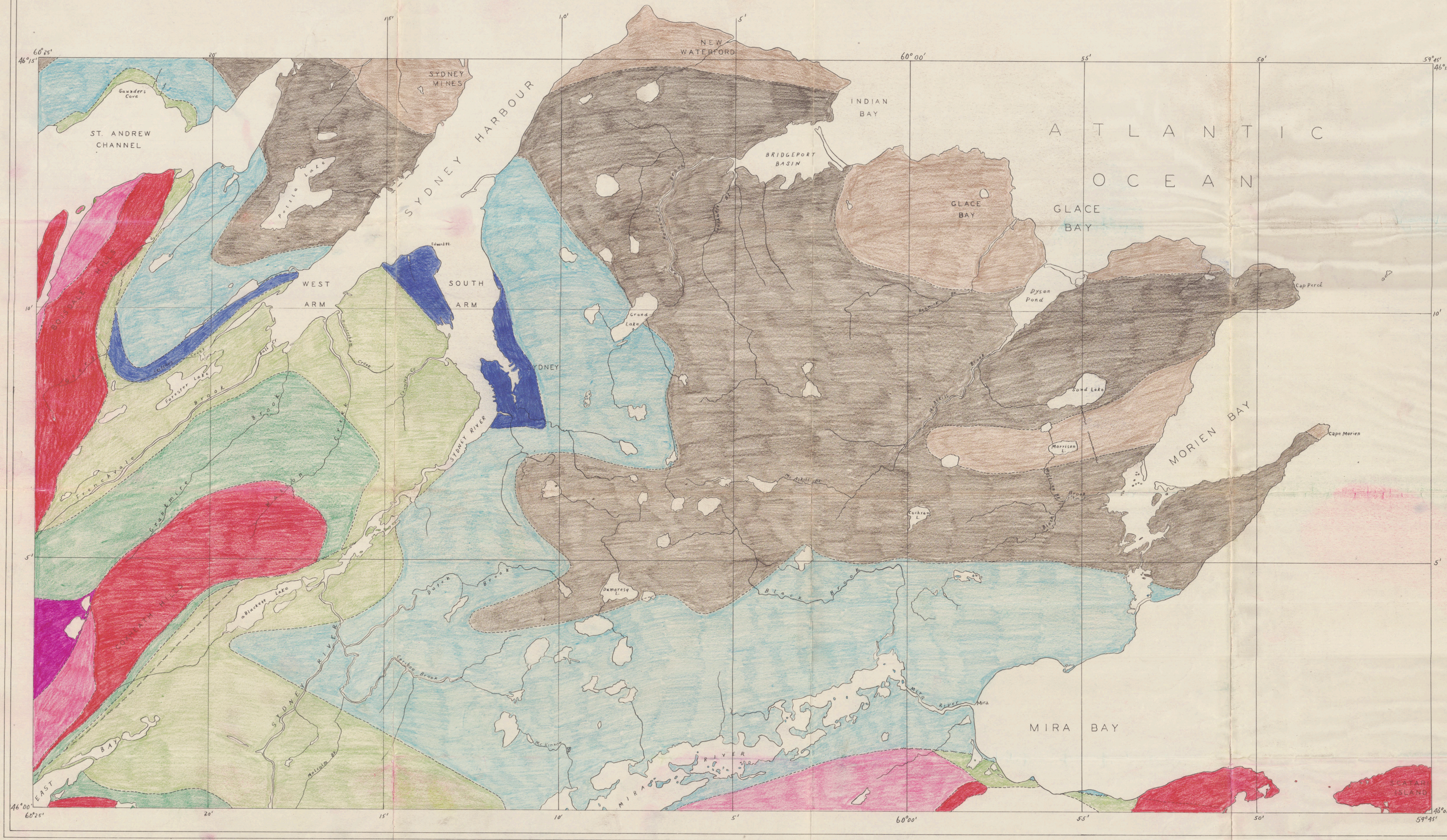


LEGEND

PENNSYLVANIAN

- UPPER MORIEN SERIES
- MIDDLE MORIEN SERIES
- LOWER MORIEN SERIES
- POINT EDWARD FORMATION

MISSISSIPPIAN

- WINDSOR SERIES
- WINDSOR SERIES GRANTMIRE MEMBER

DEVONIAN

- MCADAM LAKE FORMATION

ORDOVICIAN & CAMBRIAN

PRE-CAMBRIAN

- METAMORPHIC & IGNEOUS ROCKS

SYMBOLS

GEOLOGICAL BOUNDARIES

FAULTS

STRIKE & DIP

DATA

GEOLOGICAL BOUNDARIES, COAL SEAMS, AND FAULTS FROM GEOLOGICAL MAPS BY A.O. HAYES, W.A. BELL, AND E.A. GORANSON, 1917 TO 1938.

FIELD STUDIES OF KIRTLEY F. MATHER, E.L. TULLIS, & CARL W. BECK, 1944.

Kirtley F. Mather

Tracing Arc File

GEOLOGICAL MAP of SYDNEY AREA

NOVA SCOTIA

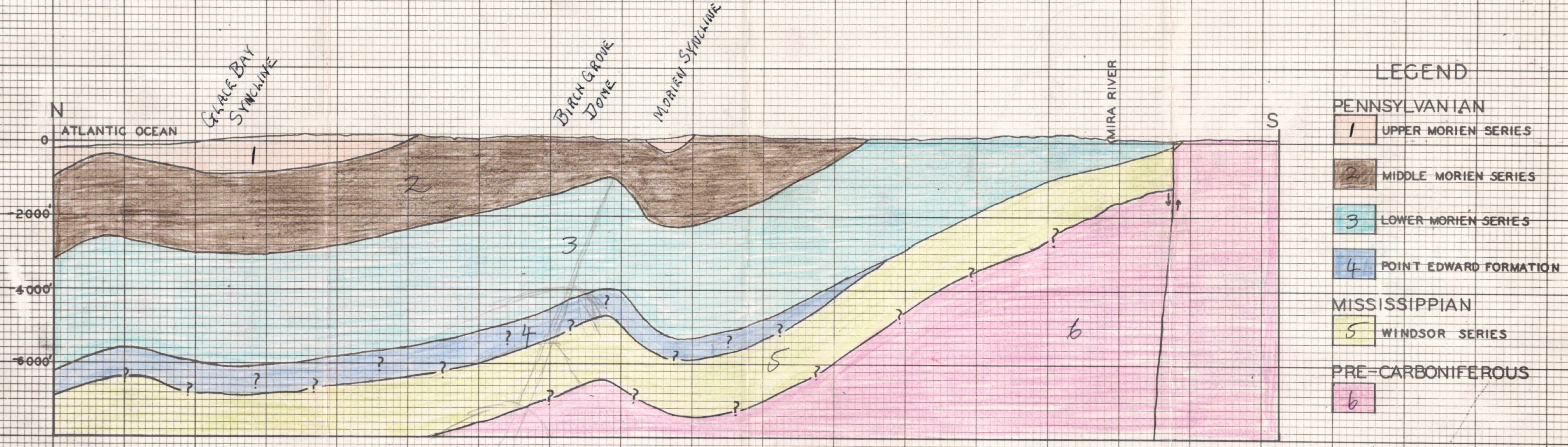
Scale: 1 inch = 1 mile

1 ½ 0 1 2

Kirtley F. Mather

GEOLOGICAL MAP
of
SYDNEY AREA
NOVA SCOTIA

Scale 1 inch = 1 mile



SCALES:

HORIZONTAL: 1 INCH = 1 MILE
VERTICAL: 1 INCH = 2000 FEET

STRUCTURE SECTION DRAWN ACROSS BIRCH GROVE DOME FROM NORTH TO SOUTH

SYDNEY AREA, NOVA SCOTIA

Kirtley F. Mather

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LICENSE MAP, SYDNEY AREA
NOVA SCOTIA