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GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

ECONOMIC GEOLOGY SERIES
No. 9

Oil and Gas in Eastern Canada

BY
G. S. Hume

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1932

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Wells at Oil Springs, Lambton county, Ont.

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PREFACE

This volume is complementary to the already issued report on oil and gas in western Canada. The section in the earlier report dealing with the principles of oil formation and accumulation has been repeated with a few additions and changes.

It is now seventy years since the first well was drilled on Black creek at the present site of Oil Springs, Lambton county, Ontario, and the discovery of oil at Petrolia followed soon afterwards. Since that time many oil fields have been discovered in southern Ontario, but Oil Springs and Petrolia, the oldest of all the fields, are still the largest producers of oil. Ontario also has a wonderful record of natural gas production and explorations for this valuable product continue to meet with some success.

East of Ontario there is only one producing oil and gas field, the Stony Creek field near Moncton, New Brunswick. This field has, for many years, supplied natural gas to a thriving community and there is reason to believe this supply can be continued for many years to come. Stony Creek area presents many complexities of geological structure and stratigraphy and it is believed the gradual solution of the many geological problems in this area will not only enrich the science of geology but will point the way to successful exploration for oil and gas in other parts of New Brunswick and Nova Scotia.

"Oil and Gas in Eastern Canada" is a compilation of data from many sources. Much helpful information has been received from Colonel R. B. Harkness, Natural Gas Commissioner of Ontario, and from Dr. J. A. L. Henderson and staff of the New Brunswick Gas and Oilfields, Limited. Two weeks were spent in the autumn of 1928 with Dr. Henderson and W. A. Bell of the Geological Survey, reviewing the geology of Moncton area, New Brunswick, and Mr. Bell has contributed part of the report dealing with this area. Contributions to the report have also been made by Dr. W. S. Dyer of the Ontario Department of Mines and by G. W. H. Norman of the Geological Survey. To these gentlemen, as well as others who have contributed helpful advice, the author wishes to acknowledge his indebtedness.

The present report is in a sense an inventory of available data. This stock-taking will, it is hoped, serve as a basis for new research and indicate the lines along which this should proceed.

Oil and Gas in Eastern Canada

CHAPTER I

ORIGIN AND ACCUMULATION OF OIL AND GAS[1]

ORIGIN OF PETROLEUM

The origin of petroleum is discussed in almost every text book on petroleum geology and, therefore, only a brief outline of the subject need be given here. There are a number of theories and these may be grouped into two major classes: (1) inorganic; and (2) organic.

INORGANIC THEORIES

It has been suggested that water acting on metallic carbides in the earth might produce hydrocarbons. The objections to this theory are clearly presented by Stigand who states:

"The existence of improbably large quantities of metallic carbides, within access in the earth, would be required, if only to suffice for originating the amount of petroleum which has been produced, as the amount of metallic carbides demanded is very great in proportion to the petroleum that can be produced from them. Furthermore, the circumstances that large deposits of bitumen or petroleum are only found in the stratified rocks, that the deposits found in the strata of younger age predominate, and that very frequently barren porous beds are intercalated in the petroliferous beds, or the strata subjacent to an oil series do not contain petroleum, all tend to constitute evidence contrary to the supposition of deep-seated origin."

There are also other theories based on chemical reactions between various substances, but in most cases the objections to these theories are so convincing to the field geologist, that they are dismissed by him as being highly improbable.

ORGANIC THEORIES

Theories of organic origin assume that petroleum is formed by biochemical, geochemical, and geophysical agents acting on plant and animal detritus buried in sediments. There is much field evidence to support this assumption, and in the laboratory petroleum is readily formed by the distillation of certain animal and plant remains. Some difference of opinion exists regarding the character of the material from which the oil is supposed to be derived; in all probability the materials are not the same

[1]Text books on petroleum geology: "Oil Finding," by E. H. Cunningham Craig; "Practical Oil Geology," by D. Hagar; "Geology of Petroleum," by W. H. Emmons; "Outlines of the Occurrence and Geology of Petroleum," by I. A. Stigand; "Popular Oil Geology," by Victor Ziegler; "The Geology of Petroleum and Natural Gas," by E. R. Lilley.

for different kinds of petroleum. Amongst other substances the following have been suggested: (1) marine animals such as molluscs, corals, etc., and, possibly, fish remains; (2) marine plant and animal micro-organisms such as diatoms, algæ, and protozoa (foraminifera); (3) marine plants such as fucoids, etc.; and (4) terrestrial plants.

Since in most cases oil is associated with marine strata or can be shown to have possibly migrated from marine strata, it may be that salt water influenced the changes undergone by the source material before it was deeply entombed in the sediments. Anerobic bacteria work best in the presence of salt water. They destroy the cellulose of plants, leaving the waxy and fatty materials, and these are the substances that give rise to oil according to some exponents of the organic theory, the materials being spores, algæ, and fatty and resinous matter.

According to Rae:[1]

"Microscopic work on shales associated with oil deposits has shown the presence of an unknown, rich, dark, organic, ulmohumic groundmass. . . . . Rivers and streams act as the concentrating agents for millions of tons of organic material, which are later incorporated into marine or inland lake deposits. By subsequent pressure, heat, or catalytic agents, the organic material is converted into petroleum".

Evidence has been brought forward to support the view that petroleum forms from each of the source materials suggested. In certain cases the close association of possible source materials with the petroliferous beds seems to offer almost conclusive evidence of origin. For example, the presence of an abundance of diatoms and foraminifera in the Eocene of California led Arnold to conclude that the oil in the overlying Miocene was derived from them. In other places the association of coal with petroleum has given rise to the suggestion that the petroleum as well as the coal has been derived from terrestrial vegetation, but, as pointed out by Stigand, it may be that it is marine vegetation that is involved for

"It is under shallow water conditions such as on littoral or estuarine tracts or in basins, that petroliferous strata have most frequently been formed. Furthermore, series of strata containing petroleum often exhibit evidence of former land surfaces the presence of which must have been preceded and followed by extensive shallow water conditions and shifting tidal regions; this would be more particularly significant in the case of formations containing successions of coal and lignite seams . . . . . which indicate secular oscillations centring about sea-level."

Such conditions on tidal flats are favourable for the growth of marine vegetation that possibly may have been the source of petroleum in such cases.

Differences in the compositions of the source materials necessarily mean differences in composition of the petroleum formed from them. Changes in the composition of petroleum may arise subsequent to formation as a result of filtration during migration and of interactions between the petroleum and substances in the formations through which it has passed. There may be losses due to natural distillation and the escape of the lighter volatile materials. Thus the petroleum found in an oil field may differ quite widely in composition from the petroleum as first formed, a fact that makes it very difficult to determine the character of the material from which the oil has been derived.

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[1]Rae, Colin, C.: "Organic Materials of the Carbonaceous Shales"; Am. Ass. Petroleum Geologists, vol. VI, No. 4, pp. 340-341.

ACCUMULATION OF OIL AND GAS

There are two opposing conceptions regarding the time of formation of oil from organic debris. The first, sponsored by Murray Stuart[1] and other geologists, is to the effect that the organic material was converted into oil prior to its burial. The oil is believed to adhere to clay particles for which it has great affinity and, later, to be squeezed out into the more porous rocks during the consolidation and deformation of the enclosing strata. The second conception is that the source material of oil is acted on by anaerobic bacteria and a substance called kerogen, low in oxygen, results. After burial of this substance oil is formed from it by heat and pressure during the consolidation or deformation of the enclosing sediments. The kerogen, according to this view, is only an intermediate product between the organic source material and the petroleum, and certain physical and chemical changes are necessary before it is transformed to petroleum. Hawley[2] has demonstrated experimentally that petroleum is not formed by shearing pressures in oil-shales and concludes that "temperature is by far the more important agent in promoting the conversion of bituminous material in rocks to oil."

Regardless of how or when the oil is formed, since the source materials are widely distributed through the containing sediments, the oil when first formed must also be widely disseminated. In order that oilfields may result, the oil must collect in porous strata within limited areas. Many geologists believe that oil collects near where it was generated, others, as for instance, Rich,[3] believe that large quantities of oil formed during mountain building may have, at least in part, moved a long distance from its point of origin.

GRAVITATIONAL THEORY OF ACCUMULATION

If water, oil, and gas are placed in a closed vessel they tend to arrange themselves according to their specific gravities, the gas, the lightest on top, the oil below it, and the water at the bottom. This tendency was long ago recognized as having operated where oil was found in domed-up strata in the Appalachian and Ontario areas, but it is now understood that though gravity tends to cause a rearrangement of the gas, oil, and water after they have arrived at a place where accumulation occurs, yet, gravitational force alone is not sufficient to cause a migration of oil from a source rock to a porous reservoir rock. It has been shown by various authors that capillarity, deformative movements in the earth's crust, the movement of water, and the movement of gas all influence the migration of oil.

CAPILLARY THEORY OF ACCUMULATION

If a clean glass tube of fine bore is dipped into water, the water rises inside the tube to a higher level than the surface of the external water. This tendency of liquids to enter minute openings or pores, such as is illustrated by a glass tube or by the absorption of water by blotting paper, is the result of capillary action.

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[1]Stuart, Murray: "The Geology of Oil, Oil-shale, and Coal," 1926.
[2]Hawley, J. E.: Am. Ass. of Pet. Geol., vol. 13, No. 4, p. 365 (1929).
[3]Rich, John L.: "Generation of Oil by Geologic Distillation during Mountain Building"; Am. Ass. of Pet. Geol., vol. 11, No. 11, pp. 1139–1149 (1927).

Experimental evidence led McCoy[1] to believe that capillarity is the main force causing oil in a water-saturated sand to migrate, thus making possible the accumulation of oil in reservoirs capable of retaining it. Washburne[2] has stated that, "since water has about three times the surface tension of crude oil, capillary action must exert about three times as much pull upon it. The amount of the capillary pull varies inversely as the diameter of the pore. Hence the constant tendency of capillarity is to draw water, rather than oil, into the finest openings, displacing any oil or gas in the latter." Shale contains much smaller pore spaces than sand and consequently any slow flow between shale and sand would drive oil from the fine pores in the shale and concentrate it in the coarser pores of the sand. Since gas is not drawn into capillary openings by the action of surface tension and there is no capillary resistance to its movement, it is much more readily concentrated in the coarser pores than oil. It is possible, according to Washburne, where there is no flow between shale and sand, that the force of capillarity alone would be sufficient to draw enough water into the shale to displace the oil and to concentrate it in the coarser pores of the sand. In water-free rocks, oil, because of capillarity, would be drawn into the finer pores and hence the result would tend to be diffusion rather than concentration.

There are limits to the sizes of pores in which capillarity can act. In pores greater than 0·508 mms. in diameter there is no capillary action in the case of pure water. The minimum diameter, according to Washburne, is more uncertain, but is usually placed at 0·0002 mms. In such small openings it has been shown[3] that the adhesion is so great that it overcomes the capillary force.

Though in the case of small pores the capillary attraction of water is, theoretically, three times as great as that of oil, certain conditions may greatly modify this force. The capillary action of water in a pore having a thin film of oil is not nearly as great as in a pore that contains no oil, therefore, where water is moving into a finely porous bed and displacing oil originally in that bed, the capillary force exerted by the water is not three times that of oil. Under such conditions the force of capillarity will not be nearly as effective in concentrating oil in the coarser pores as might be supposed.

HYDRAULIC THEORY OF ACCUMULATION

Experimental studies by Mills[4] led him to believe that capillary adjustments between oil and water in saturated strata are restricted to short lateral ranges and that wide movements of oil due to such forces are the exception rather than the rule. He concluded that the up-dip migration of oil and gas under the propulsive force of their buoyancy in water, as well as the migration of oil either up- or down-dip caused by hydraulic currents, is among the primary factors influencing the accumulation of oil. The movement of oil under the action of currents is what has been termed the hydraulic theory of oil and gas accumulation.

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[1]McCoy, A. W.: "Some Effects of Capillarity on Oil Accumulation"; Jour. of Geol., vol. 24, No. 8, pp. 798-805 (1916).

[2]Washburne, C. W.: "The Capillary Concentration of Gas and Oil"; Trans. Am. Inst. Min. Eng., vol. 50, pp. 830 (1914).

[3]Johnston and Adams: Jour. of Geol., vol. 22, pp. 1-15 (1914).

[4]Mills, R. Van A.: "Experimental Studies of Subsurface Relationships in Oil and Gas Fields"; Ec. Geol., vol. 15, pp. 398-421 (1920).

This theory was developed by Munn[1] and a general statement regarding it was published by Rich[2] who states:

"The principal cause of the migration of oil and gas is the movement of underground water which carries with it minute globules of oil and bubbles of gas, possibly as fast as they are formed. Accumulation results from the selective segregation of oil and gas, which on account of their buoyancy always tend to work their way upward as they are carried along and are caught and retained in anticlinal or other suitable traps.

The nature of the trap necessary to cause accumulation depends on the rate of movement of the water and corresponding texture of the sands or other medium through which it flows. Where the sands are porous and there is a strong hydraulic head a sharp anticline with large closure is necessary to retain the oil; in fact where the movement is especially rapid, even such a structure may be inadequate. Where the sands are fine and the water movement is slow, slight structural and textural variations are enough to arrest the movement of the oil and gas. Under such conditions broad, flat anticlines with very little closure, terraces, or even minor flattenings of the regional dip, are enough to cause accumulation."

According to this theory any condition which retards the movement of underground water carrying globules or bubbles of oil and gas, will tend to bring about the accumulation of the oil and gas. Such retarding conditions, according to Rich, may be assumed to be present: (1) in anticlinal traps, (2) where the size of rock pores decreases, and (3) where a decrease in the rate of water movements is caused under certain conditions. Rich points out that where oil and gas are carried to an anticline, the buoyancy of oil and gas in the water becomes effective and, as a result, they tend to rise to the top of the structure and to become concentrated there. In cases where the regional dip decreases in amount, giving rise to a terrace structure, there will be a slowing down of the movement of the circulating solutions, and this may be sufficient to cause an accumulation of oil and gas without any reversal of dip. A change from a relatively porous rock to one of less porosity will also cause at least a partial stagnation, allowing the oil and gas to accumulate in the more porous rock, as where a sand lens is surrounded by less pervious parts of the same stratum. It is probable, in such cases, that capillarity plays a considerable part in the accumulation of the oil and gas in the rock with larger pore spaces.

Mills and Rich[2] deduced from experiments that a strong water movement through an anticlinal trap might carry along with it all the oil and gas, allowing no opportunity for them to collect in the top of the trap. Moreover, a strong water flow through an anticlinal trap in which there has already been some accumulation of oil and gas might flush away the accumulated oil and gas or, if only a partial flushing resulted, the oil would probably extend farther down the dip on the lee side of the anticline than on the side by which the water entered. Where the water movement is slow, the oil and gas would first concentrate in the crest of the trap and later additions would be on the side from which the water comes. These two cases explain why in some instances the division between oil and water is not at the same level on the two flanks of an oil pool.

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[1]Munn, Malcolm J.: "The Anticlinal and Hydraulic Theories of Oil and Gas Accumulation"; Ec. Geol., vol. 4, pp. 509-529 (1909).

[2]Rich, John L.: "Moving Underground Water as a Primary Cause of the Migration and Accumulation of Oil and Gas"; Ec. Geol., vol. 16, pp. 347-371 (1921).

ACCUMULATION DUE TO DEFORMATIVE MOVEMENTS

As pointed out by Lilley,[1] the "compacting of sediments through increasing static pressure plays an important rôle in causing the reduction of pore space in sediments and thus is directly responsible for the initiation of movements" of contained fluids or gases. As a result of experiments carried out in 1928, Beckstrom and Van Tuyl[2] came to the conclusion that "compaction is by far the most important cause of migration of oil from shale into porous reservoirs". Certain authors believe movement is started by differences in pressure due to varying amounts of diastrophism from place to place, although others regard this as but a minor factor in movement.

ACCUMULATION OF OIL AS RELATED TO MOVEMENT OF GAS

Gas has the property of diffusion, but is not drawn into capillary openings by surface tension and hence there is no capillary resistance to its movements. It thus moves through pore spaces in rocks with much greater ease than oil. Gas is soluble in oil in proportion, roughly, to the pressure exerted. The pressure created by gas in the oil and the buoyancy given to the oil by the dissolved gas are both factors in the movement of oil. Absorbed gas also tends to lower the viscosity of the oil and especially so if the gas forms minute globules. According to Mills[3] "the escape of gas with entrained oil through fissures has been an important factor in the migration and accumulation of oil in many faulted areas. Compressed gas is the propulsive force by which oil generally moves to producing wells."

STRUCTURAL FEATURES OF OIL POOLS

Oil and gas accumulations are associated with various structural features.[4] The structures of the fields of eastern Canada are indicated in some detail on later pages, and in this place, therefore, only a generalized consideration is given to the subject, omitting all reference to types of structure not yet recognized in Canada.

ANTICLINAL OR DOMED STRUCTURE

An anticline is an arch-like or dome-shaped fold. If the angle of dip of the two sides or limbs is the same and in opposite directions, the fold or anticline is symmetrical. Any marked departure from this condition produces an asymmetrical fold (*See* Figure 1), and names have been applied to different variations from the ideal form. A dome is a special form of anticline in which the beds dip away from the crest in all directions or quaquaversal fashion (*See* Figure 2).

Regardless of the various theories advanced to account for the accumulation of oil and gas, it is generally agreed that one of the commonest structures in which oil and gas are found is the anticline. In order that oil and gas may accumulate in any anticlinal structure certain conditions are

[1]Lilley, E. R.: "The Geology of Petroleum and Natural Gas," 1928, p. 201.
[2]Beckstrom, R. C., and Van Tuyl, F. M.: Am. Ass. of Pet. Geol., vol. 12, No. 8 (1928).
[3]Mills, R. Van. A.: "Natural Gas as a Factor in Oil Migration and Accumulation in the Vicinity of Faults"; Am. Ass. of Pet. Geol., vol. 7, pp. 14-21 (1923).
[4]Clapp, Frederick G.: Bull. Geol. Soc. Am., vol. 28 (1917).
Emmons, W. H.: "Geology of Petroleum," p. 123.

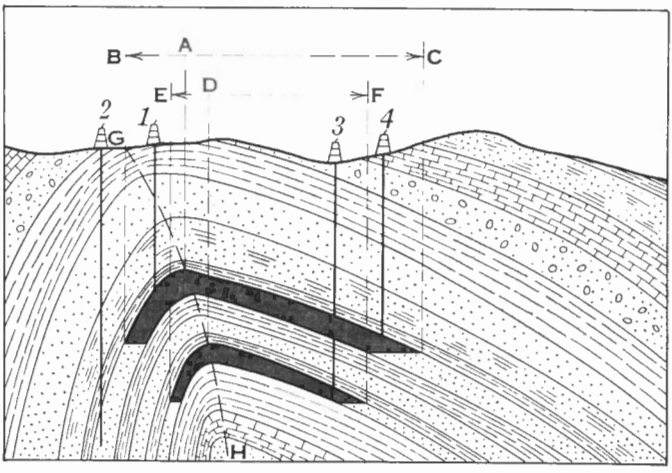

Figure 1. (After L. C. Uren). Simple asymmetric anticline with oil-bearing strata (shown in solid black) reached by three wells (Nos. 1, 3, and 4). The strata on the left dip more steeply than the strata on the right, and the dip of the axial plane changes with depth as shown by the curving line G-H.

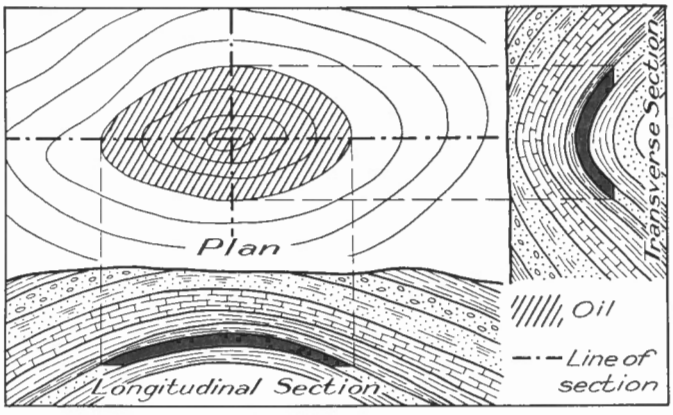

Figure 2. (After L. C. Uren). Dome structure illustrated in plan and vertical sections; an oil-bearing stratum (shown in solid black) is depicted in the vertical sections and the area underlain by it is shown on the plan.

essential. (1) There must be a petroliferous stratum from which oil and gas can be derived. It is thought that oil and gas form from organic materials and originate, respectively, as small globules and bubbles. These must collect if a pool of oil or gas is to form and, no matter what explanation is adopted as the cause of movement, it is agreed that there must be migration of the oil and gas to points where structural conditions allow their accumulation. (2) There must be a porous horizon into which and along which the oil and gas may migrate and be collected in pools of commercial size. Migration for the most part must take place through the pore space of the rocks and the rock of the structural reservoir must be sufficiently porous to hold a large amount of oil and gas if an oil field is to be formed. The amount of oil and gas at any point will depend, among other things, on the amount of oil and gas available, on the size of the reservoir, and on its efficiency as a retainer of the oil and gas. The size of the reservoir will, in turn, depend on the size of the structure and the degree of porosity of the strata. (3) There must be an impervious cap to prevent upward dissipation of the gas and oil after arrival in a structurally favourable reservoir. A highly suitable cover for an oil reservoir is a fine-grained, wet shale. It has been calculated[1] that at a depth of 1,500 feet the force necessary to make oil migrate through a wet shale (openings 0·01 micron) is about 4,000 pounds per square inch and, therefore, that there could be no migration of oil through such a shale.

In a symmetrical anticline under ideal conditions, the arrangement of gas, oil, and salt water in a porous stratum acting as a reservoir is as follows: the gas occurs on the crest of the fold, the oil underlies the gas and occurs in the limbs of the fold, and the salt water underlies the oil. This arrangement is such as would result from gravitational segregation. So symmetrical a disposition of the gas, oil, and water does not usually obtain in nature. The anticline may not be of symmetrical form and other factors governing accumulation may also lack symmetry, with the result, for instance, that the oil may be largely concentrated in one limb of a fold. Furthermore, in many oil fields the high pressures revealed in the early stages of production indicate that much of the gas must be absorbed in the oil. As is the case in a number of Canadian gas fields a structure may contain gas and salt water, but no oil. The lack of oil in such cases may be due to the fact that gas is much more mobile than oil and consequently may move much farther from its place of origin or may pass through beds so finely porous as to hold back any oil. Other explanations of the absence of oil might be given, as, for example, that metamorphism has proceeded to such a stage that only gas may be present. Regardless of what the explanation may be the fact remains that many gas fields yield only "dry" gas which shows no evidence of associated oil.

SYNCLINAL STRUCTURE

A syncline is a trough-like fold. If a porous stratum in such a fold contains oil and gas, but no water, the gas will tend to rise along the limb of the syncline and to segregate at the crest of the succeeding anticline, whereas the oil will tend to sink to the bottom of the downwarp or syncline, the movements in both cases being due to gravity. Such occurrences

[1]McCoy, Alex. W.: "Principles of Oil Accumulations"; Jour. of Geol., vol. 27, p. 258 (1919).

of oil in synclines are known in Canada, but are exceptional. It is probable that the movement of oil under the influence of gravity alone is relatively weak, because other forces, particularly that of capillarity in a fine-grained stratum, are much stronger. The action of capillarity alone in a water-free sand, is one of diffusion rather than concentration, but, acting in conjunction with gravity, there might be some concentration, especially in the case of a porous stratum having relatively easy channels of movement through large pores where the force of capillarity would be small. It is probable, however, that irregularities in the character of the pore spaces in a sand would tend to make concentration relatively incomplete.

SAND LENSES

It has already been stated that capillary attraction in the case of pores within the critical limits of size is three times as great for water as for oil and for this reason water will penetrate the finer parts of a sand and force oil to the coarser parts. This, probably, is the controlling factor governing the accumulation of oil in those parts of a porous stratum where the pore spaces are largest. These coarsely porous parts of a stratum usually have irregular forms, pinch out laterally, and are in general lens shaped (*See* Figure 3). Where gas and oil are concentrated in such coarser sand

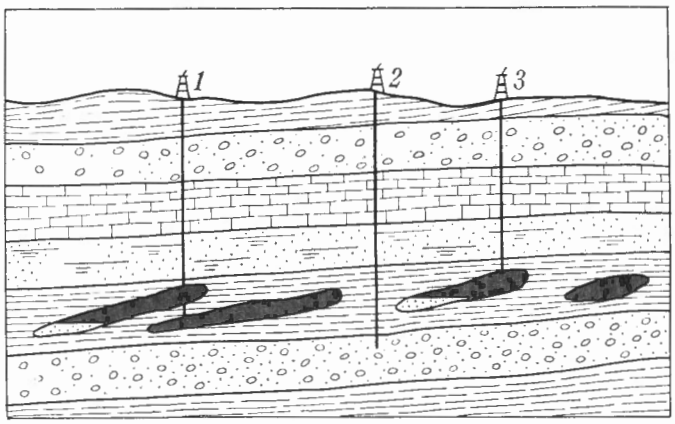

Figure 3. (After L. C. Uren). Lenticular deposits. Lenses of coarse sand in oil-bearing shales serve as local centres of concentration.

lenses, they may be under high pressure. It has been suggested that the pressure may be due to capillarity, but this idea has been refuted by Washburne.[1] Possibly it is partly due to hydrostatic pressure which in many gas and oil fields is nearly equalled by the gas and oil pressure. Sand lenses containing oil and gas may occur without any relation to other structural features. Since most such lenses are irregular, the gas and oil collect in the higher parts, as in anticlinal structures.

[1]Washburne, C. W.: "The Capillary Concentration of Gas and Oil"; Trans. Am. Inst. Min. Eng., vol. 50, p. 852 (1914).

TERRACES

A local flattening of the strata in a region otherwise characterized by a uniform dip gives the terrace structure (*See* Figure 4). Where water carrying along with it oil and gas is moving up the dip and where,[1] the movement is

"so slow that, assisted by the gravity component of buoyancy, it is little more than able to move the oil with it, the flattening at the down-dip edge of a terrace might be enough to arrest the movement of the oil and gas and start an accumulation . . . . . This pool would grow from accretions added on the down-dip side and in time might extend for a considerable distance down the dip from the edge of the terrace. In general a terrace should be able to cause oil accumulation only where the movement of the rock fluids is comparatively slow, so that slight obstacles suffice to arrest the movement of the oil globules."

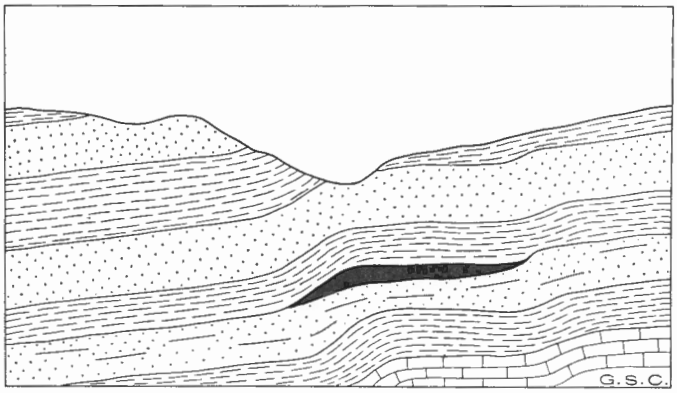

Figure 4. Terrace structure; an accumulation of oil is shown (solid black).

Johnson and Huntley[2] in discussing the terrace structure assume that where there is a gravitational separation of oil and gas through water there is a critical gradient which will allow oil and gas to accumulate. Where the dip exceeds in amount the critical gradient, the oil and gas will be carried up the dip, but where the dip falls below the critical gradient the oil and gas will tend to accumulate. It is stated, however, that "it is difficult to ascertain the critical gravitational gradient because of two variables: *(a)* degree and types of porosity, and *(b)* direction and effectiveness of the current within the reservoir"; the current is considered as generally flowing up dip. The terrace, these authors believe, must also be wide, otherwise the oil and gas may escape up the dip. These and other factors have led Johnson and Huntley to regard terraces as of low rank among favourable structures and especially so since structures that appear as terraces on the surface may be absent at depth. Small folds on a terrace structure, however, offer favourable conditions for accumulation, since they combine the anticlinal fold with the terrace structure.

[1]Rich, John L.: "Underground Water as a Primary Cause of the Migration and Accumulation of Oil and Gas"; Ec. Geol., vol. 16, No. 6, p. 355 (1921).

[2]Johnson, R. H., and Huntley, L. G.: "Text Book Oil and Gas Production," p. 72, 1916.

FAULTED STRUCTURES

Earlier views that faulted structures were not favourable for the accumulation of oil and gas have been greatly modified by the discovery of many highly productive faulted structures and certain investigators have concluded that in some fields the accumulation of petroleum has occurred as a result of faulting. It has been stated[1] that "faulting is associated with, and probably is, the controlling structural feature of all the oil fields in the relatively flat-lying beds of the Gulf Coastal plain, from the Lower Cretaceous up to the Pliocene." Faulted structures affording oil production are also known in many other oil fields, especially the Rocky Mountain fields, where the accumulation is thought to be closely related to the faulting. Rich[2] has pointed out that too much emphasis may be placed on faulting and that although it may be beneficial in some instances it may be decidely detrimental in others by providing a channel of escape for oil and gas that would have been retained in an anticlinal structure. Mills[3] states that:

"The escape of water through natural passages, such as fault fissures, has induced widespread hydraulic currents through the beds toward these points of diminished pressure, and these water currents, plus buoyancy, have contributed largely toward the migration of oil to favourable rock entrapments in the vicinity of the faults. The propulsive force of expanding gas has been one of the contributing causes for the hydraulic currents.

Paradoxical as it may seem, the escape of gas with entrained oil through fissures has been an important factor in the migration and accumulation of oil in many faulted areas. Compressed gas is the propulsive force by which oil generally moves to producing wells. It is also one of the propulsive forces by which oil has moved with or even ahead of water under conditions of differential pressure brought about by faulting.

The concomitant formation of gas and oil, together with the diffusion of absorbed gas under high pressure throughout the underground water and disseminated oil, are assumed to have preceded the processes herein outlined and have made them possible. Absorbed gas tends to lower the viscosity as well as the specific gravity of the oil, especially where the absorbed gas expands sufficiently to form minute bubbles within the oil. Again under the propulsive force of water currents alone, the oil tends to move less readily than the water, as exemplified by the formation of water cones around producing wells, but where there are considerable proportions of rapidly expanding gas, the oil is propelled ahead of the water. There are, of course, limiting conditions beyond which the folding and fracturing, or even the erosion of petroliferous strata, have permitted the excessive loss of oil and gas. There are also conditions under which faulting has caused barriers to migration . . . . . where open fissures cutting deeply buried petroliferous beds have formed channels for the migration of oil, gas, and water and have then become sealed sufficiently to retain a part of the oil and gas in the reservoir rocks, the processes herein outlined have evidently functioned. . . . . During the more or less extensive movements of oil, gas, and water toward producing wells, the gas and oil tend to segregate above the water into favourably situated parts of the sands. This has been termed induced segregation. It is mildly analogous to what happens when hard or lithified strata containing unsegregated gas, oil, and water under pressure are fractured by faulting or fissuring.

Another important analogy between the deep-seated effects induced by oil and gas wells and the effects of faulting is the deposition of practically the same minerals in the wells and in the natural fissures. Calcite, barite, and gypsum, with inclusions of waxy hydrocarbons, accumulate in such quantities in the wells of the Appalachian and Mid-continent fields as to cause serious production troubles. Calcite, gypsum, and waxy hydrocarbons occur in the natural fissures cutting petroliferous strata in many fields. The origin of both types of deposits, those in the wells and those in the rock fissures, can be traced to the escape of water, gas, and oil from petroliferous strata.

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[1]Pratt, W. E., and Lahee, F. H.: "Faulting and Petroleum Accumulation at Mexia, Texas"; Bull. Am. Ass. Pet. Geol., vol. 7, No. 3, p. 231 (1923).

[2]Rich, John L.: "The Hydraulic Theory of Oil Migration"; Bull. Am. Ass. of Pet. Geol., vol. 7, No. 3, p. 222 (1923).

[3]Mills, R. Van A.: "Natural Gas as a Factor in Oil Migration and Accumulation in the Vicinity of Faults"; Am. Ass. of Pet. Geol., vol. 7, pp. 14-21 (1923).

Where the gas originally accompanying the oil and water (primary gas) has escaped through the fissures, the accumulated oil may be practically devoid of gas. . . . . But where considerable gas under high pressure accompanies oil in faulted and fissured structures it seems probable that this gas is either primary gas retained by the early sealing of the fissures, or that it is secondary gas which formed in, or migrated to, the entrapment after the fissures were sealed. It is possible that both phases of gas accumulation are represented in many structures. That there has been an enormous escape of gas incident to the migration and accumulation of oil in most fields is indicated by the high concentration of salts in the waters associated with the oil. This concentration has undoubtedly been brought about through the removal of water vapour in escaping gases."

Discussing the question as to why all the oil and gas does not escape from faulted areas before the fissures are sealed, Mills writes:

"The question might just as well be asked: Why does all the oil not flow from a productive sand through the wells that tap that sand? In both cases, the flow ceases when the propulsive force becomes inadequate to propel the oil to the surface. Let it be remembered that under ordinary conditions of recovery, about 80 per cent of the oil originally contained in a productive sand may, and probably does, remain underground when an oil field is abandoned. As is the case with wells, the complete escape of oil through open fissures has probably failed largely because of dissipated gas pressures, whereas the final retention of the oil is due to the sealing of the fissures before the gas pressures in the vicinity of the faults have again built up through regional adjustments."

Fault fissures may be sealed by the minerals mentioned by Mills and also by tar or asphalt. It has been shown[1] that sulphate waters react with oil, the sulphates being reduced by the hydrocarbons of the oil or gas to sulphides and the oil and gas in part being oxidized. Hydrogen sulphide thus formed is readily oxidized to give sulphur which is quite soluble in petroleum. The high sulphur content of some oils may be in part at least accounted for in this way. As sulphate waters are much more common near the surface than at depth, this action is probably greater near the surface and as the lighter oils are changed into heavier oils by this action, and as evaporation and oxidation also take place near the surface, the oil may be changed to tar or asphalt and thus seal the avenue of escape. According to Pack[2] "the effect of the deeper waters on the oil is not so extensive as that of surface waters, but it is evident none the less, for in place after place (in the Sunset-Midway field) where water is found in the oil sand a deposit of tar or heavy oil separates the portion of the sand occupied by oil from that occupied by water." It is thus evident that in this case even at depth tarry materials can effectively seal off a channel of escape for oil.

POROSITY OF RESERVOIR ROCKS

The commonest rocks acting as reservoirs for accumulations of oil and gas are porous sandstones, and dolomites or dolomitic limestones. Other rocks are not of so great importance, although in some fields oil has been produced in quantity from crevices in shales.

The porosity of a sandstone depends on a number of factors, as for example the shape of the sand grains, the manner in which they are packed, the variation in size of the individual grains, and the amount of clay or

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[1]Rogers, G. S.: "The Sunset-Midway Oil Field, Calif."; U.S.G.S. Prof. Paper 117, 1919.
Pack, R. W.: "The Sunset-Midway Oil Field, Calif."; U.S.G.S. Prof. Paper 116, 1920.

silt or of calcareous or siliceous cement between the sand grains (*See* Figure 5). If the grains are uniform in size and shape, the amount of pore space is the same no matter how small or large the grains may be, provided they are packed in the same fashion. If the grains are large there will be a comparatively small number of large pore spaces, if the grains are small there will be a large number of small pore spaces, but the total amount of pore space will be the same. Where the grains are arranged in the most compact manner, the amount of pore space is about 25 per cent of the whole volume; where the grains are arranged so as to give the maximum pore space this amounts to nearly 50 per cent of the whole.[1] As has been pointed out by Johnson and Huntley:[2]

"A distinction should be made between the theoretical porosity of a rock and its effective porosity. Owing to the fact that in many rocks a considerable proportion of the pores do not communicate, even though the theoretical porosity may be high, the yield (of oil) is necessarily very low. A rock with very small pores cannot be drained of its oil content even though such pores communicate, because of friction and where gas or water is also present because of capillarity."

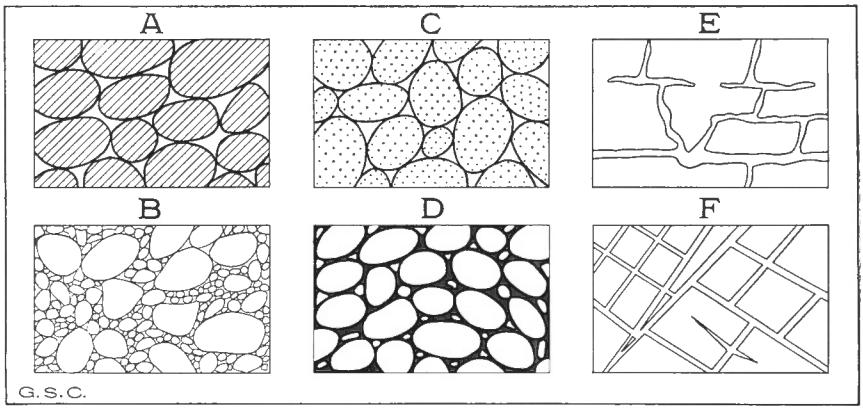

Figure 5. (After E. R. Lilley). Some types of rock textures and structures that affect porosity. A: sedimentary deposit of grains well sorted according to size, interstices comparatively large, degree of porosity high. B: sedimentary deposit of grains poorly sorted according to size, interstices comparatively small, degree of porosity low. C: sedimentary deposit of grains well sorted according to size, the grains themselves porous, the interstices comparatively large, degree of porosity very high. D: sedimentary deposit of grains well sorted according to size, the comparatively large interstices reduced in size by deposition of mineral matter, the porosity diminished. E: rock rendered porous by presence of fissures produced by solutions. F: rock rendered porous by presence of fractures.

Thus, although a fine-grained sand may have as much porosity as a coarse-grained sand, its effective porosity may be very small and in some cases may even be nil. As already indicated, if the grains of a sand are not uniform in shape and size, the smaller grains may fill part of the spaces between the larger grains and consequently reduce the porosity. Silt and clay or materials cementing the sand grains will also diminish the amount of pore space.

[1]Slichter, C. S.: "Theoretical Investigation of the Motion of Ground Water"; U.S.G.S. 19th Ann. Rept., pt. 2, p. 305 (1899).
[2]Johnson, R. H., and Huntley, L. G.: "Principles of Oil and Gas Production," p. 34, 1916.

Next to porous sands, dolomites and dolomitic limestones form the most important reservoirs for oil and gas.

Analyses, published by Orton,[1] of rock from different parts of the Trenton formation first drew attention to the fact that in the Trenton oil fields of Ohio the oil is associated with dolomite. Pieces of reservoir rock, dolomite, blown from the wells, are very porous, whereas the compact limestone with a low magnesium content holds little if any oil and gas. It has been thought that the porosity of the dolomite is due to its formation from limestone, since in the change of a relatively pure limestone to dolomite a shrinkage of as much as 12 per cent may take place. The view that the porosity is wholly due to dolomitization was questioned by Phinney[2] because "chips and larger masses thrown out of the wells by the force of gas show that even where the rock is hard and compact small cavities are scattered throughout in such a manner as to suggest that a part of its substance had been removed by solution." It is now generally known that porous limestones and dolomites in certain cases furnish suitable reservoirs for very large amounts of both oil and gas.

Dolomite forms in several ways,[3] as for example by: (1) deposition, (2) replacement, (3) leaching. Twenhofel concludes that:

"Unless the environmental conditions in the seas of the geologic past were greatly different from what they are at present, there is little possibility that the dolomites were formed by primary organic or chemical deposition. On the other hand, sediments which originally were deposited on the sea floor as calcium carbonate, or with calcium carbonate as the most important constituent, are known to have become dolomitized a few feet below the surface. . . . . The high content of magnesium carbonate arose either from leaching or replacement of calcium carbonate.

It has been commonly assumed that in the formation of dolomite by replacement, there is an increase in the porosity of the rock formed"

and that the reaction involves:

"A shrinkage of 12·30 per cent in volume. Many dolomites are porous and cavernous, and this characteristic has been assumed to be typical of all dolomites and to have arisen through replacement after solidification. However, many dolomites have more than the required pore space, while others, in essentially horizontal positions, have less than 0·1 per cent. It is difficult to explain these variations as due to replacement alone. Shells which have undergone partial or complete replacement by dolomite in numerous instances show no decrease in volume, and it is obvious that field observations do not support the view that dolomitization involves a decrease in volume. Although it has not been proved that the porosity of some dolomites is due to replacement it is probable that a part of it may arise in this way, but there is a variety of other factors which are determinants of the pore space, among which are the physical characters of the particles composing the original calcite sediments, the cementation, the leaching subsequent to deposition, and the pressure to which the sediments were subjected.

One feature in the distribution of dolomites which is of interest is the fact that the occurrence of dolomite very frequently is regional rather than local."

According to Howard[4] porous limestones may be classified according to the origin of their porosity as follows:

(1) Limestones with primary porosity
- *(a)* Chalk
- *(b)* Oolitic limestone
- *(c)* Primary crystalline dolomite and limestone
- *(d)* Coral reefs

[1]Orton, Edward: Geol. Surv., Ohio, vol. 6, pp. 103-105.
[2]Phinney, A. J.: "The Natural Gas Fields of Indiana"; U.S.G.S., 11th Ann. Rept., p. 658 (1889).
[3]Twenhofel, H., and Collaborators: "Treatise on Sedimentation," 1926, p. 257.
[4]Howard, W. V.: "A Classification of Limestone Reservoirs"; Bull. Am. Ass. Pet. Geol., vol. 12, No. 12, p. 1155 (1928).

(2) Limestone with secondary porosity
  (a) Limestone associated with former erosion surfaces
  (b) Limestone with porosity developed as a result of mineralogical changes
(3) Fractured limestones
  (*a*) Strongly jointed limestone
  (*b*) Limestone fractured as a result of crustal movement
  (*c*) Limestone fractured as a result of mineralogical changes

According to this author limestones with primary porosity rarely form oil reservoirs, and limestones in which the porosity has developed below an erosion surface probably form "fully 95 per cent of the known limestone reservoirs."

An unconformity represents a break in sedimentation and may or may not represent a period of time during which the already deposited sediments were subjected to erosion. It is thought that secondary porosity may develop in limestones as a result of leaching and solution during a period of erosion, the porous horizons being confined within the depth of groundwater penetration.

According to Beal and Lewis:[1]

"Many geologists and engineers engaged in estimating, by the use of porosity, the oil content of sands in the Mid-continent field ordinarily use a factor of 17½ per cent. . . . . The porosity of the ordinary oil sand in California is usually taken as about 25 per cent, undoubtedly a low figure, since sands as loose as those generally average 36 per cent or more in porosity. Porosity in the Appalachian field is estimated at 10 to 12½ per cent, but actually productive portions of the sands probably average at least 15 per cent."

RELATION OF OIL PRODUCTION TO GAS PRESSURE

The amount of oil recovered from oil sands by ordinary methods is by no means the total amount in the sand. Some estimates place the recovery at only 10 to 20 per cent. The amount recovered "depends mainly upon the porosity and size of the pores, upon the available energy within the sand for expelling the oil from the pores of the sand, and upon the efficiency of this energy." The gas dissolved in the oil under pressure is the main force that expels oil from a sand, although gravitation and water pressure are important in some instances. The failure of a well to produce more oil, even though only 10 to 20 per cent of the oil in the sand has been extracted, is not, according to Beal and Lewis, the result of exhaustion of the oil, but is due to the exhaustion of the gas associated with the oil. The conservation of gas in connexion with producing wells is thus of vital importance.

Beal and Lewis have discussed the effect of gas pressure on production. and the following statements are mainly based on their treatment of the subject. Since the amount of gas that can be dissolved in the oil is proportional to the pressure, "doubling the pressure, therefore, doubles the quantity of absorbed gas and hence the energy, being the pressure multi-

[1] Beal, Carl H., and Lewis, J. O.: "Some Principles Governing the Production of Oil Wells"; U.S. Bur. of Mines, Bull. 194, p. 7 (1921).

plied by the gas volume, is quadrupled. The expulsive energy thus increases as the square of the pressure, provided there is enough gas associated with the oil to saturate the oil at the existing pressure." Some of the gases present are condensible at the higher pressures and thus go into solution as liquids. The effect in the field is that the expulsive energy may increase at even a greater ratio than the square of the pressure. It is essential, therefore, in the best interests of the life of an oil field, that an amount of gas as small as possible be used to produce each barrel of oil. If large quantities of gas are allowed to escape freely in the initial stages of production it is obvious that the recovery of oil will be much less than the possible maximum.

In many fields the gas pressure is about equal to the hydrostatic pressure, a condition that has been explained[1] by the "fact that the weight of water in the rock pores resists the slow outward movement, and that equilibrium is established when the outward pressure is equal . . . . . to the hydrostatic head." There are many instances however, where the gas pressure is much in excess of the theoretical hydrostatic pressure and Washburne believes this excess of pressure may be "assigned in general to greater freedom of communication underneath the sand . . . . . to locally more active ascent of rock fluids from any cause, or to greater resistance above the sand." Pressures lower then the theoretical hydrostatic pressure may, on the other hand, be "assigned to the opposite causes, or to leakage, or to dryness of parts of the overlying rock." As proof of the origin from below of pressures in excess of the theoretical hydrostatic pressure Washburne cites[2] the fact that such excess pressures are most common in areas where fracturing is prevalent. Also, excess temperatures in oil fields, excess of chlorine in associated waters, and the abundance of helium in some deep wells, point to the same conclusion. It has been shown that capillary pressure under certain conditions is quite large, but Washburne believes since there is no change in volume in capillary movement that capillarity itself could not produce any great pressure in an oil sand.

RELATION OF OIL PRODUCTION TO THE SPECIFIC GRAVITY OF THE OIL

A heavy oil being more viscous than a light oil requires more energy to expel it from the pores of a sand. Since in any reservoir there is only a certain amount of available energy due to the gas pressure, it follows, therefore, other factors being equal, that there will be a larger ultimate recovery of the oil if it is light than if it is heavy. For the same reason the initial flow of oil from a sand is likely to be smaller if the oil is heavy than if it were light. The general tendency, however, for an oil well producing heavy oil, is to decline less rapidly than one producing light oil under similar conditions.

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[1]Washburne, C. W.: "The Capillary Concentration of Gas and Oil"; Trans. Am. Inst. Min. Eng., vol. 50, p. 857 (1914).

[2]Op. cit., p. 856.

RELATION OF OIL PRODUCTION TO SPACING OF WELLS

The relationship of production to spacing of wells has been discussed by Beal and Lewis,[1] and they point out that the closer the spacing of wells the greater the ultimate recovery of oil. The gas absorbed in the oil is the propulsive force driving the oil to a well and for each reservoir only a certain amount of energy is available. The energy due to the gas pressure may be dissipated in driving either a small amount of oil a long distance or a large amount of oil a short distance. It is desired, of course, to obtain the maximum possible recovery of oil and it is obvious that this end will best be accomplished where the energy is used in driving a large amount of oil a short distance, or in other words where the spacing of the wells is close. There are, naturally, limits to the close spacing of wells and for each field there is a certain spacing which is the most economical.

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[1]Beal, C. H., and Lewis, J. O.: U.S. Bur. of Mines, Bull. 194, p. 25 (1921).

CHAPTER II

PHYSICAL FEATURES, STRATIGRAPHY, AND STRUCTURAL GEOLOGY OF SOUTHERN ONTARIO

PHYSICAL FEATURES

The part of Ontario lying between lakes Ontario, Erie, and Huron, and extending eastward to about the vicinity of Kingston comprises the western part of what has been termed the St. Lawrence region (*See* Figure 6). It is underlain by almost horizontal Palæozoic strata and its general level character contrasts greatly with the more rugged topography of the Canadian Shield which forms its northern boundary from the vicinity of Kingston to the southern end of Georgian bay. To the east, between Kingston and Brockville, a southern projection of the Canadian Shield crosses St. Lawrence river. East of this projection the St. Lawrence region is again underlain by flat, Palæozoic sediments.

The known oil and gas fields of Ontario are confined within the more westerly division and this consists of two areas, a western highland and an eastern lowland, divided by the northeasterly facing Niagara escarpment (*See* Figure 6) that stretches from Niagara river at Queenston around the west end of lake Ontario at Hamilton, extends northwesterly to Bruce peninsula between lake Huron and Georgian bay, and reappears to the northwest in Manitoulin and adjoining islands in lake Huron. The Niagara escarpment is an erosional feature and owes its formation and preservation to the fact that it is capped by relatively hard, resistant limestone and dolomite (of Niagara age) overlying easily eroded, soft shales. The beds dip into the escarpment and the weathering away of the soft shales at the base undermines the upper hard layers, these break off in large blocks and the abrupt rise of the escarpment front is preserved as it slowly retreats westward. The Niagara escarpment is a true cuesta.

The lowland north of lake Ontario rises gently northward from the lake shore. It commences at Kingston, its north boundary passing gradually away from the lake in a northwesterly direction, the width increasing from zero at Kingston to almost 100 miles between the west end of lake Ontario at the Niagara escarpment and Midland on the north boundary at Georgian bay. The escarpment at the west end of lake Ontario at Hamilton rises abruptly from an elevation of 400 feet at the base to 650 feet at the crest and elevations somewhat higher are reached at some distance south of the edge. At various places along the escarpment, which trends northwesterly, there is a sharp rise of about 300 feet and an elevation of 1,706 feet is reached on the top of the highland in the vicinity of Dundalk in Grey county 10 miles west of the escarpment face, although the elevation in front of the escarpment is only about 1,000 feet. At Collingwood, the escarpment is only a short distance from Georgian bay with an eleva-

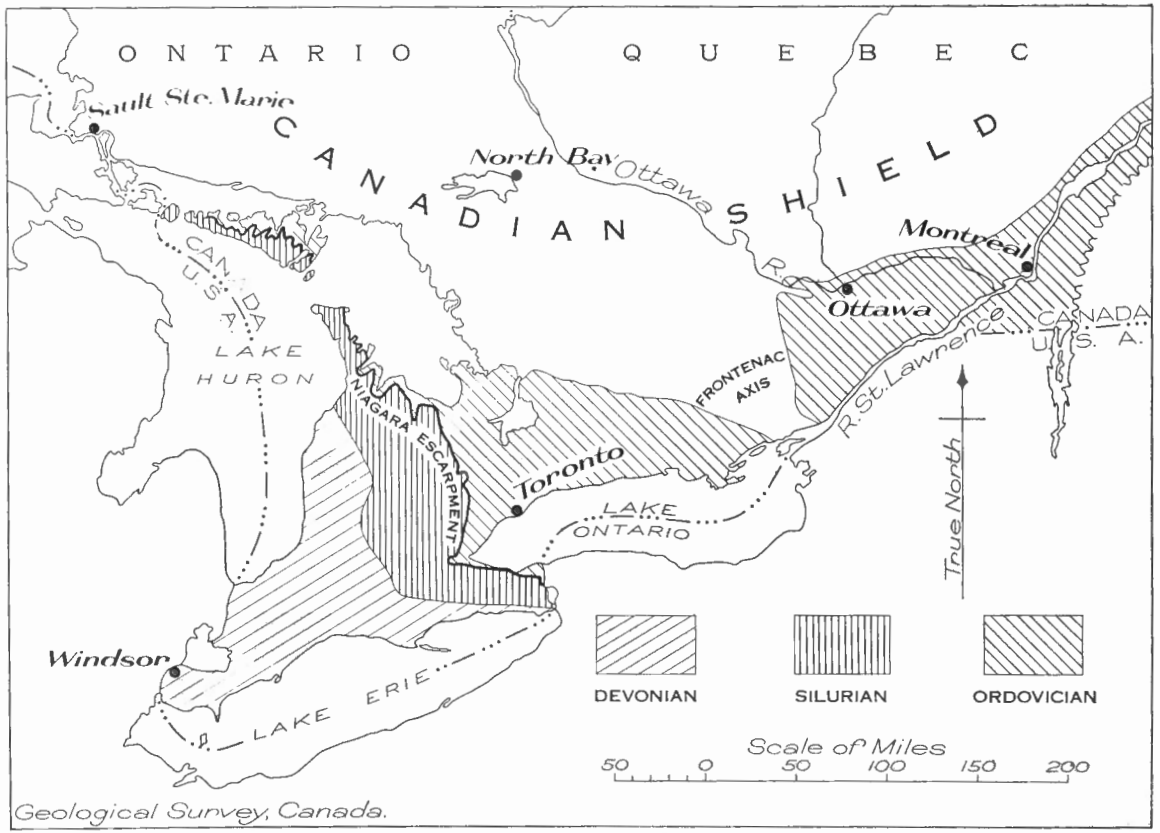

Figure 6. Southern Ontario and part of western Quebec, showing main physiographical and geological divisions.

tion of 580 feet and the top of "Blue mountain" on top of the highland in Collingwood township has an elevation of 1,655 feet. The escarpment follows the east side of Bruce peninsula to its north end where it forms cliffs which rise abruptly from the shore for a height of 300 feet. The same steep front characterizes the east and north shores of Manitoulin and adjacent islands.

The highest part of the upland surface is found south and west of Collingwood where elevations of from 1,600 to 1,700 feet occur. The surface, however, slopes southwesterly to the levels of lakes Huron (578 feet) and Erie (571 feet).

The whole of the surface of southwestern Ontario has been glaciated and is, for the most part, covered by a mantle of glacial materials consisting of gravel moraines and boulder clay. It is thought that in the region of the Great Lakes the ice advanced and retreated five times and one interglacial period was sufficiently long for the deposition of about 400 feet of interglacial beds in Toronto area. The ice-sheet removed the soil and weathered rock formed during the long period of erosion prior to the advance of the ice, and widely distributed boulders of Precambrian rocks over the whole of the glaciated surface. Previously formed stream valleys were filled with glacial debris and the Great Lakes in their present form did not originate until the drainage, after the final retreat of the ice, had become adjusted to the new topography. From borings that have been made and from a study of glacial materials in reference to the underlying rock surface, it is now known that an old, buried channel extends from the Whirpool rapids on Niagara river to St. David on the Niagara escarpment. Evidently at one time the ancestral Niagara river flowed over the escarpment at St. David and during a long period of time the falls gradually retreated and a gorge was produced similar in character to the present gorge below Niagara Falls and which intercepts this old gorge at the Whirlpool on Niagara river, in fact the Whirlpool is due to erosion of the present river in the glacial debris filling the old channel. Another old river channel occurs between Barrie and Toronto.[1] Wells bored in the glacial and interglacial materials filling this old channel reach great depths. Some of the depths recorded are: Barrie 280 feet, Richmond Hill 400 feet, Newmarket 265 feet, Bradford 330, and one well 2 miles west of Thornhill reached a depth of 650 feet before the underlying rock was encountered. The last-mentioned well was drilled at an elevation of 650 feet, so that the bottom of the glacial and interglacial materials is now at sea-level or 246 feet below the level of lake Ontario. It is obvious, therefore, that at the time this old channel was formed the region stood higher than at present.

The glacial drift that covers the bedrock has a variable thickness and hence the present topography does not express the relief of the underlying rock surface nor does it show any relationship to the underground structure. The glacial drift conceals the underlying rock over a great part of both the upland and lowland, but many streams have cut through the surface cover and, especially where the rock formations are fairly massive and resistant limestones, many good sections are to be found.

[1]Coleman, A. P.: Univ. of Toronto Studies, Biological Series No. 21, 1922.

STRATIGRAPHY

St. Lawrence region westward from Kingston at the east end of lake Ontario is underlain by sedimentary strata ranging in age from Ordovician to late Devonian (*See* Figure 6). The strata, in general, have a low, southwesterly dip, so that proceeding southwest younger formations appear at the surface and each formation occupies a belt of country striking northwest and southeast. The oldest of these sediments were deposited in a sea that advanced from the south over a surface formed of Precambrian rock and having a relief that, presumably, was of much the same character as that of the Canadian Shield of today. In certain parts of North America the close of the Precambrain was followed by the deposition of Cambrian sediments, but apparently the Cambrian seas did not extend into southern Ontario west of the Frontenac axes, as no Cambrian beds have been recognized there and the incoming seas of early Ordovician time deposited a basal series of coarse sandstones or arkoses composed of materials derived from the underlying Precambrian rocks. As the surface on which these materials were deposited was very irregular, it was inevitable that the thickness of this basal member should be highly variable and from well records it is known to range from less than 1 foot to 75 feet. In Simcoe district, where these basal beds are exposed, Johnston[1] has stated that they pass upward "into red and green shales with intercalcated lenses of thin beds of sandstone and occasionally thin beds of fine-grained limestone." The beds are

"frequently absent on the sides and tops of ridges or domes of the crystalline rocks. . . . . The sandstone and shales are best developed in basins between ridges of the crystalline rocks where they occasionally have a maximum thickness of about 40 feet. They are local in character and derivation and evidently represent the old soil covering of the Precambrian rocks somewhat sorted, rearranged, and recemented and it seems probable that they represent the initial, near-shore deposit of the next succeeding formation."

In northwest New York state east of the southern extension of the Frontenac axis from Canada, the basal formation of the Palæozoic is the Potsdam sandstone of Cambrian age. This in many cases has been confused with the basal arkose and sandstones of the southwestern peninsula of Ontario, but all available evidence seems to show that the Potsdam sea came from the south and that though it invaded Canada east of the Frontenac axis, it did not extend west of it.

Near Kingston, at the west edge of the Frontenac axis, the basal sandstones have been named the Rideau beds.[2] They have been included by Kindle[3] in the Pamelia formation which in this area consists of about 40 feet of limestones, above 5 feet of sandy calcareous beds carrying quartzite pebbles and small boulders up to one foot in diameter. The limestones have a fine, even texture and in part show much sun-cracking, indicating shallow water deposition. As the sea gradually encroached over the region west of Kingston, sands and arkoses continued to be deposited on the Precambrian surface along the advancing shoreline, but they are not necessarily of the same age as the lithologically similar beds in the Kingston area, in fact these basal sandstones and arkoses constitute what has been called a tangential formation.

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[1]Johnston, W. A.: Geol. Surv., Canada, Sum. Rept. 1911, p. 254.
[2]Ami, H. M.: Geol. Soc. Am., vol. XIII, pp. 517–18 (1902).
[3]Kindle, E. M.: "The Ordovician Limestone of the Kingston Area"; Ont. Bureau of Mines, vol. XXV, pt. 3, p. 40 (1916).

The Black River group in New York state has been there defined[1] as including in ascending order, the Lowville with the Leray member, the Watertown, and the Amsterdam[2], the latter only present in the east. According to Kindle the Lowville with the Leray succeeds the Pamelia in Kingston area, but the Watertown is absent. In Simcoe area, the basal sandstones and shales and closely associated limestones are overlain by the Lowville above which lies the Coboconk limestone which is correlated with the Leray of New York. The Coboconk is about 35 feet thick and the upper part is characterized by a great abundance of chert. Chert is evidently a prevalent feature of this formation and occurs in beds assigned to the Leray at Kingston, as well as in the type section in New York state. Black River strata with basal arkose beds lie on the Precambrian in Manitoulin Island region and it is evident, therefore, that a belt of Black River strata stretches all the way from Kingston westward along the northern edge of the region.

The Black River strata dip gently southwestward and pass beneath limestones of Trenton age and these, like the Black River strata, form a belt stretching from Kingston on lake Ontario to Georgian bay and appearing also on Manitoulin island. The Trenton consists of limestones with shaly partings. These limestones, as indicated by bore-hole records, extend westward and southward beneath the younger strata of the peninsula area lying between lakes Huron and Erie, but in this area it is not possible from the drill records to distinguish between the strata of the Trenton and the Black River groups whose combined thickness in the Essex-Kent area appears to be as much as 500 feet.

At one time the whole series of limestones above the Black River and beneath a succeeding assemblage of black shales, was considered to be Trenton and the overlying shales were called Utica. Raymond[3] gave the name Cobourg formation to an upper part of the limestone series. This same formation has been recognized[4] at Collingwood on Georgian bay and presumably extends in a continuous belt from there eastward to Cobourg and on east along the shore of lake Ontario. For a number of reasons the Cobourg limestone is now considered to be of Utica age. Thus the thick limestone series penetrated by many bore-holes in the southwest peninsula of Ontario and customarily reported as Trenton probably includes not only Black River limestones in the lower part but Utica limestones in the upper part.

The Cobourg limestone, 40 miles east of Toronto, is overlain by dark or nearly black shales with thin limestones belonging to the Collingwood formation. These beds, with overlying dark shales constituting the Gloucester formation, extend northwestward to the foot of Georgian bay where, however, the Collingwood is largely limestones.[5] The two formations are of Utica age and the dark shales are commonly referred to as Utica shales. They disappear westward below a younger series of grey shales with thin interbeds of sandstone, formerly known as the Hudson

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[1]Cushing, H. P., Fairchild, H. L., Ruedemann, R., Smith, C. H., jun.: "Geology of the Thousand Islands Region"; N.Y. State Mus. Bull. No. 145, p. 85.

[2]Cushing, H. P., and Ruedemann, R.: "Geology of Saratoga Springs and Vicinity"; Bull. N.Y. State Mus. No. 169, 1914, p. 45.

Also

Cushing, H. P.: "Lower Palæozoic Rocks of New York"; Am. Jour. Sci., vol. XXXI, p. 143 (1911).

[3]Raymond, P.: Geol. Surv., Canada, Mus. Bull. No. 31, p. 1 (1921).

[4]Parks, W. A.: Roy. Soc. Canada, sec. IV, vol. XXII, p. 46 (1928).

[5]Parks, W. A.: Roy. Soc. Canada, vol. XXII, sec. IV, p. 46 (1928).

River group, and to which Foerste[1] applied the name Lorraine, a name introduced long ago to designate related strata in New York state. Owing, however, to difficulties encountered in correlating these strata in Ontario with those of the New York section, Parks[2] introduced the name Dundas formation for these grey shales overlying the Utica in Toronto and Georgian Bay areas. The Dundas formation has been divided into four members which from lowest to highest are as follows: Rosedale 10 or more feet thick, Danforth 57 or more feet thick, Humber 282 or more feet thick, and Credit 50 feet thick. The fauna of these strata is in part similar to the Lorraine fauna of New York and in part similar to the Maysville of Ohio, a formation considered to be the approximate equivalent of the Lorraine of New York. The Dundas beds occur in the vicinity of and to the west of Toronto, and extend to Georgian bay and along the east side of Bruce peninsula. Westward they dip gently beneath succeeding formations and both the Dundas and Collingwood or equivalent formations have been penetrated by many drill holes in the southwestern peninsula of Ontario. In the logs of such wells the lower, nearly black shales are usually designated as Utica and the overlying, greyer shales with intercalated sandstones are termed Lorraine.

The Dundas, grey shales with their thin interbeds of sandstone are overlain west of Toronto by greyish shales with interstratified limestones and sandy beds and these are followed by red shales, the whole constituting the Richmond group, the youngest division of the Ordovician. The lower, greyish strata are about 100 feet thick in the Credit River section near Toronto and have been divided by Dyer[3] into three members which from lowest to highest are as follows: Erindale, Streetsville, and Meadowvale. The division between the Dundas and the overlying Richmond is made on faunal differences, there being no apparent break in sedimentation. The uppermost division of the Richmond, the red shale member, is known as the Queenston. It occurs at the foot of the Niagara escarpment from north of Meaford on Georgian bay to Niagara river, increasing in thickness southward to about 1,000 feet[4] as shown by wells drilled in Niagara peninsula. On Manitoulin island the position of the Queenston is occupied by grey, fossiliferous limestones and shale, the Queenston red shales farther south being, according to Foerste,[5] "the estuarine representatives of a part of those marine strata which elsewhere are known under the term Richmond formation." The red, Queenston shales extend far to the west beneath the covering of later strata and have been penetrated by deep wells, as in Kent county for example. Presumably the underlying, grey, shaly, Richmond strata also extend under the whole peninsula west of the Niagara escarpment, although in the logs of wells these strata are difficult to separate from the underlying, shaly formations.

The red Queenston shales of the southwest peninsula of Ontario and the grey limestones and shales that are their equivalents on Manitoulin island are the youngest Ordovician beds in this part of Ontario. After the deposition of the Queenston the Ordovician seas withdrew from this

[1]Foerste, A. F.: "Upper Ordovician Formations in Ontario and Quebec"; Geol. Surv., Canada, Mem. 83 (1916).
[2]Parks, W. A.: "The Stratigraphy and Palæontology of Toronto and Vicinity"; Ont. Dept. of Mines, vol. XXIX, pt. 6 (1920).
[3]Dyer, W. S.: "Stratigraphy and Correlation of the Credit River section"; Ont. Dept. of Mines, vol. XXIX, pt. VI (1920).
[4]Malcolm, W.: "The Oil and Gas Fields of Ontario and Quebec"; Geol. Surv., Canada, Mem. 81 (1 15).
[5]Foerste, A. F.: Geol. Surv., Canada, Mem. 83, p. 175 (1916).

region. In early Silurian time a sea again advanced over the region and in it deposits belonging to the Medina-Cataract series[1] were laid down. The oldest member of this series as exposed on Niagara river is the Whirlpool sandstone about 22 feet thick; it outcrops along the Niagara escarpment, but thins to the northwest and disappears south of Collingwood. As indicated by borings it extends beneath younger strata westward to Elgin county, but does not occur at Petrolia nor at Oil Springs in Lambton county.

Along Niagara river the Whirlpool sandstone is overlain by about 30 feet of strata, mainly shales, constituting the Manitoulin formation. As traced northwest along the Niagara escarpment, the Manitoulin formation becomes a dolomite about 30 feet thick at Cabot head on Bruce peninsula and at least 60 feet thick on Manitoulin island where it rests directly on the shales and limestones of the Richmond formation. The Manitoulin formation is thought to underlie all of southern Ontario west and south of the Niagara escarpment. In Niagara peninsula it is a shale formation, but elsewhere is mainly dolomite.

Along Niagara river the Manitoulin formation is overlain by a few feet of grey shale, representing the Cabot Head formation, which in turn is succeeded by 50 feet of red and grey shale and sandstone constituting the Grimsby member. The Grimsby decreases in thickness westward and not far beyond Hamilton is no longer recognizable. On Niagara river the Grimsby is overlain by the Thorold grey sandstone, 7 feet thick and traceable nearly to Hamilton. Northward from Hamilton the three formations merge into one known as the Cabot Head and consist of red and grey shales, shaly sandstones, and shaly dolomites, 110 feet thick at Owen Sound. The Cabot Head formation, as shown by well records, underlies the southwestern peninsula of Ontario.

The strata from the Whirlpool sandstone to the Thorold sandstone constitute the Medina-Cataract series. This series, as exposed along Niagara river, is overlain by the Clinton formation, there consisting of three members, namely, the Furnaceville shale 4 feet thick, the Reynales or Walcott dolomite 12 feet thick, and the Irondequoit dolomite 7 feet thick. The Clinton beds thin to the northwest and do not appear to reach farther than 20 miles north of Hamilton, but boring records show they extend beneath younger beds westward to lake St. Clair.

The Clinton strata on Niagara river are overlain by about 85 feet of dark grey shales with some calcareous beds constituting the Rochester which also has been called the Niagara shales. These in turn are overlain by the Lockport or Niagara dolomite which forms the summit of the Niagara escarpment. The Rochester shale thins to the westward and ends not far north of Hamilton, but the Lockport dolomite continues north, increasing in thickness from 80 feet at Niagara to more than 160 feet at Cabot head on Bruce peninsula and to more than 200 feet on Manitoulin island where it forms the uppermost strata preserved there. The Lockport dolomite presumably extends westward and southward beneath the younger formations of southern Ontario, but is not easily distinguished in the logs of wells from the overlying Guelph dolomite. The basal member of the Lockport in Niagara peninsula, according to Williams,[2] "consists of a bed of argillaceous dolomitic limestone, 8 to 9 feet thick, which was

[1]For a full description of the Silurian strata *See* Williams, M.Y.: "The Silurian Geology and Faunas of Ontario Peninsula, the Manitoulin and Adjacent Islands"; Geol. Surv., Canada, Mem. 111 (1919).

[2]Williams, M. Y.: Geol. Surv., Canada, Mem. 111, pp. 58-59 (1919).

formerly extensively worked at Thorold for the manufacture of natural rock cement." This is what has been locally called the DeCew waterlime. It is "a commingling of the dolomitic Lockport sediments with the argillaceous Rochester sediments." Above the DeCew waterlime in Niagara peninsula there is a member called the Gasport by Kindle.[1] According to this author "the section on the Canadian side at Niagara falls shows 7 feet of hard, grey, subcrystalline, crinoidal limestone, sharply differentiated from the saccharoidal dolomite above and the 9 feet of argillaceous limestone below." According to Williams this member westward from Niagara is 5 to 28 feet thick and at Thorold is composed largely of coral reefs. The DeCew and Gasport members of the Lockport are local developments and are not recognized in Ontario outside of Niagara peninsula. In the vicinity of Hamilton at the top of the Lockport there are 80 to 90 feet of argillaceous limestones and some shales and these have been called the Barton beds. Also, in the western peninsula of Ontario, even-bedded, argillaceous, arenaceous, or bituminous dolomites occur at the top of the Lockport and these are known as the Eramosa beds. According to Williams[2] these beds are 40 feet thick at Wiarton in Bruce peninsula, 30 or more feet thick at Guelph, and 35 feet thick at Spencer creek, 7 miles west of Hamilton. South of Hamilton the highest of the dark, slaty strata, known locally as the Barton beds, are probably the equivalent of the Eramosa. The Eramosa beds are quite bituminous and are transitional with the overlying Guelph formation.

The Lockport dolomite along Niagara river disappears above the falls beneath the Guelph formation, consisting for the most part of a light grey or cream-coloured dolomite generally having a porous, saccharoidal texture. The Guelph underlies a belt of country from 5 to 13 miles wide extending from Niagara river westward and then northward to Bruce peninsula. In Niagara peninsula the estimated thickness of the Guelph is 140 feet, farther north the thickness appears to be only about 90 feet, the decrease in thickness according to Williams suggests erosion prior to the deposition of the next succeeding formation. The Guelph dolomite continues west beneath younger beds and may underlie the whole peninsula of southern Ontario where many wells penetrate it and in some cases give a thickness of as much as 240 feet for the combined Guelph and Lockport formations.

It is generally assumed that after the deposition of the Guelph beds, the Silurian sea withdrew from the southern Ontario and adjoining regions, but left a large, nearly isolated basin of water covering southern Ontario and the neighbouring part of United States. In this basin were deposited the somewhat abnormal, youngest Silurian sediments. The earliest of these are the beds of the Salina formation of which the lowest member is the Camillus, consisting of grey or green shale with beds of dolomite and gypsum. These beds occupy a broad belt trending west from Niagara river and then north to the shores of lake Huron north of Southampton. The Camillus at Niagara has a thickness of 387 feet, at Delhi in Norfolk county 310 feet, at London 750 feet, including 170 feet of salt, and in Dover township near lake St. Clair the thickness varies between 550 and 745 feet.[3]

[1]Kindle, E. M.: U.S. Geol. Surv., Folio 190, p. 7.

[2]Williams, M. Y.: "An Eurypterid Horizon in the Niagara Formation of Ontario"; Geol. Surv., Canada, Mus. Bull. No. 21, p. 1.

[3]Williams, M. Y.: Geol. Surv., Canada, Mem. 111, p. 84 (1919).

The Camillus member is overlain along its west edge by the Bertie member, consisting of beds of dolomite, waterlime, and shale varying in thickness up to 40 feet. Overlying the Bertie is the youngest member of the Salina, the Akron dolomite, less than 10 feet thick. The Salina beds disappear to the west under younger strata and with varying thicknesses underlie the whole of the peninsula bounded by lakes Huron and Erie. In the district bordering Detroit river a group of strata named Bass Island or Lower Monroe series is known mainly from drill records. These beds lie above the equivalents of the Camillus shale and below a sandstone termed the Sylvania. The thickness of the series is 330 to 375 feet and it consists largely of dolomites with one thin shale horizon. It seems probable that the Bass Island series is about equivalent to the combined Bertie and Akron, that is to the upper part of the Salina. The Sylvania sandstone of the Detroit River area varies much in thickness and appears to be an æolian deposit formed after the withdrawal of the sea in which the Bass Island strata had been deposited. Above the Sylvania lie 300 to nearly 400 feet of dolomites and limestones known as the Detroit River or Upper Monroe series. Their contained fossils have been variously interpreted as indicating the strata to be of late Silurian or early Devonian age. It seems probable that the period of erosion represented by the Sylvania sandstone includes latest Silurian time and that the Detroit River series is thus of very early Devonian age. If so this series was deposited in a sea that did not reach far eastward into Ontario and which withdrew from the area in early Devonian time. Later in Oriskany and Onondaga time, after a period of erosion, a sea advanced over southern Ontario and in it were laid down Devonian strata.

The eastern edge of the area occupied by Devonian beds follows a curving, westerly course from the head of Niagara river to the vicinity of Woodstock and from there strikes northerly to the shore of lake Huron near Port Elgin. Westward from this edge as far as the head of lake St. Clair, higher and higher members of the Devonian occur in successive bands or irregular areas stretching north and south. The youngest Devonian in Ontario borders the north shore of lake St. Clair, whereas south of this, as a result of gentle folding, successively lower horizons come to the surface until in the southwest part of Essex county the Onondaga appears resting on the Detroit River series. Along the eastern edge, the Devonian rests on late Silurian strata, but on horizons that differ from place to place, since during late Silurian and early Devonian time the region was a land area undergoing erosion. The earliest Devonian beds along the eastern edge of the Devonian area are the Oriskany sandstones, usually a massive, coarse-grained, white to yellowish rock probably nowhere more than 20 feet thick and occurring only in a stretch from Niagara river west to the west boundary of Haldimand county, beyond which the overlying Onondanga rests directly on Silurian strata.

Everywhere in the southwest peninsula of Ontario the Onondaga limestones occur either at the surface or underlying younger Devonian strata. These overlie the Oriskany in Niagara peninsula, and the Detroit River series in Essex peninsula. The Onondaga is the large productive oil horizon of Ontario. According to Stauffer[1]

[1]Stauffer, C. R.: Geol. Surv., Canada, Mem. 34, p. 6 (1915).

"The Onondaga limestone is a most variable formation as it is traced westward across the province. Near Fort Erie and Port Colborne the lower portion is a compact, cherty, grey limestone . . . . . These beds pass upward into an argillaceous, brownish limestone in which the fossils occur chiefly in semi-crystalline streaks. This portion is gradually succeeded by a highly calcareous, semi-crystalline, grey limestone in massive beds which are separated by thin partings of a greenish shale . . . . These beds are overlaid at places unconformably, by cherty, bluish black, compact limestone . . . . . These beds in turn pass upward into very cherty, grey limestone . . . . . constituting the uppermost portion of the Onondaga in the vicinity of Windmill point. As the formation is traced westward the lower and upper portions either thin out entirely or become more like the middle part and are inseparable from it . . . . . At Springvale the bottom layers of the Onondaga contain such quantities of coarse sand that they resemble very closely the true Oriskany sandstone except that they contain the Onondaga fauna. The supply of sand for these beds undoubtedly came from a nearby deposit of the Oriskany which was worked over by the advancing Onondaga sea and the resulting material incorporated into the basal layers of the deposit from that sea . . . . The Springvale sandstone has a thickness of about 8 or 10 feet and is found outcropping along the edge of the Devonian westward from Hagersville for a distance of nearly 6 miles."

The thickness of the Onondaga is variable, but as given by well logs reaches as much as 150 feet.

In New York the Marcellus shale overlies the Onondaga, but is found at only a few localities in Ontario. It is a brownish black shale which outcrops in the vicinity of Port Burwell[1] and occurs in the drift near Port Stanley. It grades upwards into dark limestones and shales which on account of lithological and faunal resemblance to the Delaware limestone of Ohio are known by the name of Delaware. In many well logs of Ontario the Delaware seems to lie directly on the Onondaga and a division between them is impossible; its thickness is, presumably, 60 feet or more.

Above the Delaware is a soft blue shale known as the "lower soap" of drillers. This is the Olentangy shale and in the Petrolia field it is said to be 40 to 70 feet thick. Above it occurs a limestone known to the drillers as the "middle lime" and called the Widder beds. These are 10 to 15 feet thick. They are followed by the Petrolia shale or "upper soap" of drillers. These are soft, blue shales which at Petrolia are 100 to 130 feet thick, but at Sarnia are stated to be as much as 260 feet thick.[2] Above the Petrolia shale is the Ipperwash limestone or the "upper lime" of drillers. It is 20 to 50 feet thick. The Olentangy shale, the Widder beds, Petrolia shale, and Ipperwash limestone constitute what is known as the Hamilton formation.

Overlying the Hamilton of Ontario is a black shale which has been called the Huron shale.[3] The Huron shale is very bituminous and is said by Kindle to contain more than 10 per cent of combustible matter. At Kettle point, lake Huron, the Huron shale is characterized by the presence of spherical concretions, many of large size. Only about 10 feet of this black shale is exposed at Kettle point; in the vicinity of Sarnia it is more than 35 feet thick. Overlying it are arenaceous green and black shales thought to belong to the Portage-Chemung group and which because they occur in wells near Port Lambton have been called the Port Lambton shales.[4] The Port Lambton shales are 30 or more feet thick and are the youngest consolidated rocks in southwestern Ontario. No Mesozoic or Tertiary formations are known and the surface materials are for the most part Glacial or Recent.

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[1]Stauffer, C. R.: Op. cit., p. 7.
[2]Williams, M. Y.: "Oil Fields of Southwestern Ontario"; Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 33.
[3]Kindle, E. M.: Geol. Surv., Canada, Sum. Rept. 1912.
[4]Stauffer, C. R.: Op. cit., p. 13.

STRUCTURAL GEOLOGY

The Palæozoic beds of southwestern Ontario dip toward the southwest away from the Canadian Shield. As stated by Malcolm[1] the dip

"does not exceed a few feet per mile, but results in the exposure of the different formations in long belts with a northwest trend across the province, so that in travelling from Kingston to Sarnia, one passes over the bevelled edges of successive younger formations from the Black River group to the Port Lambton beds. The southwesterly dip of the strata continues to that part of the province lying between lake Erie and the south end of lake Huron. From this section there is a gradual rise of the strata towards the southwest and the Onondaga formation which has disappeared beneath the eastern edge of the Delaware reappears in Essex county."

Thus there is a broad syncline extending from the southern end of lake Huron in a southeasterly direction to lake Erie and in this syncline the youngest Devonian rocks in Ontario occur.

Early geologists[2] were of the opinion

"that the Cincinnati and Nashville anticline, on the flanks or near the crest of which the great oil and gas fields of Ohio occur, extended northeastward from Ohio through the western end of lake Erie into western Ontario. This now appears to be true only in part . . . . . The Trenton along the supposed axis of the anticline, which in Ohio is only 350 feet below sea-level at Findlay and 800 feet near lake Erie, is 1,500 feet below sea-level in Colchester township, Ontario, 1,860 feet at Leamington and 2,543 feet at Petrolia. Continuing northeastward from Petrolia the Trenton begins to rise, as it is 2,310 feet below sea-level near Inwood, 1,166 feet at Stratford, 572 feet at Glen Allen, 310 near Alma, and 350 in Osprey township, Grey county."

Thus it is apparent that the Trenton in Petrolia area occupies a position on a downwarp which as already stated is indicated by the late Devonian beds at the surface and extends from the south end of lake Huron south to lake Erie. To the northwest of Petrolia, west of Saginaw in the centre of the Michigan basin between lakes Huron and Michigan, the Trenton is more than 2,500 feet lower than at Petrolia. As already stated there is a regional rise northeast of Petrolia of a few feet to the mile. The downwarp appears to be a cross-fold on the Cincinnati anticline which crosses the west end of lake Erie in a northeast direction, passes through Essex county into Lambton and Kent counties, and is apparent[3] as a very broad warp as far as Woodstock in Oxford county. The Cincinnati anticline was inaugurated in the Ordovician and by the close of the Silurian was a broad, but very flat, arch in southwestern Ohio. The movement continued to the close of the Carboniferous period when the Appalachian mountains were uplifted. In the Ohio region the shales overlying the Trenton are thicker on the flanks than on the crest of the Cincinnati anticline. In the Ontario area there is also much variation in the thickness of the shales between the top of the Trenton and the base of the Queenston; thus, at Beachville, Oxford county, the thickness[4] is approximately 720 feet and in Tilbury East in Kent county it is 600 and 650 feet, whereas at Petrolia[5] it is only 370 feet, but is 585 feet[6] in Colchester South township,

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[1]Malclom, W.: "The Oil and Gas Fields of Ontario and Quebec"; Geol. Surv., Canada, Mem. 81, p. 45 (1915).
[2]Smith, R. A.: "The Occurrence of Oil and Gas in Michigan"; Mich. Geol. and Biol. Ser., Pub. 14, Geol. Ser. 11, p. 52 (1912).
[3]Logan, Sir William: "Geology of Canada, 1863,", p. 378.
[4]Williams, M. Y.: Geol. Surv., Canada, Mem. 111, fig. 4 (1919).
[5]Knight, C. W.: Ont. Bureau of Mines, Ann. Rept., vol. XXIV, pt. II, p. 86 (1915).
[6]Knight, C. W.: Op. cit., p. 75.

Essex county. There is also much variation in the thickness of the upper Silurian, especially in the case of the salt and gypsum beds of the Salina formation. The Detroit River series is also a local development and is followed by an erosional unconformity, so that the first formation of the middle Devonian in southwestern Ontario rests on different members of the underlying formations at different localities. Due to these facts the Onondaga limestone, which is the great oil-bearing member in Ontario, does not follow the minor folding of the Trenton, but does follow in a general way the regional southwest dip as far southwest as the east part of Kent county, although the amount of dip of the Trenton and of the Onondaga is not the same. From this it is inferred that the folding that affected the Devonian also affected the Ordovician, but that there was some deformation of the Ordovician prior to the deposition of the Devonian sediments. The local folding in the Devonian, which casued the concentration of oil into fields of limited extent, has been fairly well outlined by drilling, but from the information available it is not possible to determine to what extent, if any, this same local folding occurs in the Trenton or intermediate formations and it is suspected that each oil and gas horizon presents a separate problem as far as the occurrence of oil and gas in it is concerned.

The oil fields of southwestern Ontario thus occupy local folds within a basin structure in which occurs the youngest Devonian strata known in Ontario.

CHAPTER III

HISTORY OF THE DEVELOPMENT OF THE OIL AND GAS FIELDS OF SOUTHERN ONTARIO

Oil springs and asphalt in Ontario were known to the earliest settlers and Indians. Logan[1] gives a detailed account of occurrences.

"Two oil-bearing beds are here [Bertie township, Welland county] visible, the one 3 and the other 8 inches in thickness, while others are said to be concealed by the water in the quarry (lot 13, range 2). When the rock is recently broken, the oil is seen to be confined to the cells of corals which belong to the genera Heliophyllum and Favosites and make up a great part of the beds in question. The corals are surrounded by a solid crystalline encrinal limestone which is free from oil, but as the limestone dries by exposure to the air, the oil spreads and colours the portions around the corals, giving rise to the appearance of a continuous band of the dark, oil-stained rock which is limited both above and below by the solid and light coloured limestone. This appears to be not only destitute of petroleum, but impermeable to it. In some of the beds were found large Heliophylli where pores were open but contained no oil. A thin and continuous bed of Favosites was white, porous, and destitute of petroleum, while beds above and below were filled with it. One of these, 3 inches in thickness, was seen to be twice interrupted in a distance of a few feet giving rise to the appearance of lenticular masses of dark, oil-stained coralline limestone embedded in a lighter coloured and compact rock. . . . . The beds of limestone are here somewhat inclined, they are very massive and the oil-bearing layers show no disposition to separate from the contiguous portions.

A similar coralline bed impregnated with petroleum and lying immediately beneath a layer of chert, occurs a mile to the west of the village of Jarvis; and the quarries in the limestone of the Corniferous (Onondaga) formation at Gravelly bay in Wainfleet (Welland county) present petroleum under similar conditions to those described in Bertie. In the township of Rainham (Haldimand county) shells of *Pentamerous ovatus* in the same limestone are found having an interior cavity lined with crystals of calcite and filled with petroleum.

In other localities the bitumen in this formation is solid and takes the form of asphaltum or mineral pitch. On the 6th and 7th lots on the south line of Kincardine, is a quarry where about 20 feet of the Corniferous (Onondaga) limestone is exposed. The lower beds are yellowish grey, massive, finely granular, fitted for building and holding a few corals. In the upper part of the section are thinner, slaty beds, some of them of a dark chocolate colour, alternating with pale yellowish earthy layers. Specimens from one thin bed in the upper part of the section contained no less than 12·8 per cent of bitumen soluble in benzole. In others, which were much less coloured, the combustible matter, which gave a smoky flame when the stone was placed on the fire, was in a great part insoluble in the same liquid. . . . . .

The districts yielding oil in western Canada [southwestern peninsula of Ontario] were made known by natural oil springs, small quantities of petroleum being found floating upon the surface of the water, or as in Enniskillen, forming, by its drying up, beds of tarry bitumen. On sinking through the clay which in Enniskillen covers the surface of the rock with a thickness of from 40 to 60 feet, a bed of gravel is generally met with, from which considerable supplies of petroleum are obtained . . . . . The areas within which natural oil springs have been observed in western Canada, besides the one found on Grand Manitoulin island [presumably from the Utica formation], are four in number. Two of these are in Enniskillen, one in the southern part of the township on Oil creek, and another in the northern part. A third locality is in the townships of Mosa and Oxford on the Thames, and a fourth on Big Otter creek in Dereham near Tilsonburg . . . . . In Enniskillen . . . . the shales of the Hamilton formation are found beneath the clay; while in Dereham, the Corniferous [Onondaga] limestone is covered only by about 40 feet of drift clay.

The modifications which petroleum undergoes by exposure to the air are very instructive. Partly by volatilization and partly by oxidation it becomes less fluid and eventually is changed to a solid form. Thus near Oil creek in Enniskillen the thickened oil forms two

[1]Logan, Sir Wm.: "Geology of Canada, 1863." p. 522.

layers, known as gum beds, of a viscous, tarry consistency and covering together two or three acres, with a thickness varying from a few inches to 2 feet. At Petrolia in the northern part of Enniskillen, in sinking a well near a natural oil spring, a bed of mineral pitch or asphaltum similar to that just described but more solid was met with at a depth of 10 feet in the clay and reposing upon a layer of gravel of 4 feet. This bed of bitumen is from 2 to 4 inches in thickness and is readily separable into thin layers, which are so soft as to be flexible and show upon their surfaces the remains of leaves and insects which had become embedded in the bitumen during its slow accumulation and solidification . . . . . In some instances the hardened bitumen is found in the cavities of the bituminous rocks themselves. Thus at Kincardine a black, hard, brilliant form of mineral pitch occurs in small quantities in the fissures of the bituminous limestone."

The evidences of petroleum in southwestern Ontario being so abundant, the development of the oil fields only awaited the finding of a use for the oil. This began in 1857 when Mr. W. H. Williams of Hamilton undertook the distillation of the tarry bitumen occurring in Enniskillen township at the present site of Oil Springs and thus began the refining industry. This came about as the result of the successful introduction of oils both for illuminating and lubricating purposes. Mr. Williams realized that the asphalt occurring in Enniskillen could be used as a substitute for coal in the manufacture of such oils and had the advantage over coal of containing 80 per cent of volatile materials. It was soon discovered that on penetrating below the asphalt the material became more fluid and hence nearer the condition needed for manufacture.[1] The first well drilled by Williams in 1858 reached the gravel above the bedrock. This was in reality the first oil well drilled in America, although it did not penetrate the rock as did the Drake well of Pennsylvania drilled in the following year. The success of the Drake well encouraged drilling into the rock at Oil Springs and Shaw[2] drilled the first well in 1861 striking oil at 160 feet in a gusher that flowed uncontrolled for several days. Great drilling activity followed and Oil Springs became a town. The wells came in with a flow of oil that could not be controlled and much oil was wasted. Robert Bell visited the area in the spring of 1862 and reports[3] that at the time of his visit, "the trunks of the trees over a considerable extent of low ground were blackened to a height of several feet by the oil which had temporarily flooded the neighbourhood." Commenting on the drilling boom Winchell[4] states:

"There was no use for the oil at that time. The price had fallen to 10 cents per barrel. The unsophisticated settlers of that wild and wooded region seemed inspired by an infatuation. Without an object save the gratification of their curiosity at the unwonted sight of a combustible fluid pouring out of the bosom of the earth, they seemed to vie with each other in plying their hastily and rudely erected "spring poles" to work the drill that was almost sure to burst, at a depth of a hundred feet, into a prison of petroleum. Some of these wells flowed three hundred and six hundred barrels per day. Others flowed a thousand, two thousand, and three thousand barrels per day. Three flowed severally six thousand barrels per day and the "Black and Mathewson" well flowed seven thousand five hundred barrels per day. Three years later the oil would have brought ten dollars per barrel in gold. . . . . It floated on the water of black creek to the depth of 6 inches, and formed a film upon the surface of lake Erie. At length the stream of oil became ignited and the column of flame raged down the windings of the creek. . . . . From detailed determinations I have ascertained that during the spring and summer of 1862,[5] no less than 5,000,000 barrels of oil floated off upon the water of Black Creek."

[1]Robb, Chas.: "On the Petroleum Springs of Western Canada"; Can. Jour., vol. VI, new ser., p. 315 (1861)
[2]Harkness, R. B.: "Oil and Gas in Ontario"; Bull. Can. Inst. of Min. and Met., No. 143, March, 1924.
[3]Bell, Robert: "The Petroleum Fields of Ontario"; Can. Min. Rev., vol. VI, p. 124 (1888).
[4]Winchell, Alexander: "Sketches of Creation", p. 286, 1870.
[5]This probably is a mistake and should be 1861. *See* Harkness, R. B.: "Oil and Gas in Ontario"; 2nd (Triennial) Empire Mining and Metallurgical Congress, 1927.

The success in obtaining petroleum at Oil Springs encouraged exploratory drilling and the Petrolia field (For situations of these and other oil or gas fields in Ontario, *See* Figure 9) was discovered about 1862 or 1863, but flowing wells were not obtained until 1865. There were no methods for controlling the wells and consequently much oil was lost in this field as at Oil Springs. A portion of the Bothwell field along Thames river was also discovered in 1862, but the main part of this field was not developed until about 1895. The Oil Springs, Petrolia, and Bothwell Springs fields have been the large producers of oil in Ontario, although subsequent to the development of these fields much exploratory drilling was done and several smaller fields were discovered. This development, according to Harkness,[1] was due to better refining methods. The Ontario crude oil contains an appreciable quantity of sulphur which gives it an offensive odour and consequently it suffered from competition with the Ohio and Pennsylvanian crude oil which is practically sulphur free. After 1885 better redistillation methods to remove the sulphur brought a better price for crude oil, with the consequent revival of interest in finding new sources of oil. Part of the success in Ontario, however, should be attributed to the development of the science of petroleum geology. The enunciation of the anticlinal theory of oil accumulation had a tremendous influence in the location of wells with the consequent successful results. Robert Bell[2] states

"The anticlinal theory in connexion with the accumulation of gas and petroleum was first mentioned to the writer by the late Sir W. E. Logan in the autumn of 1860 . . . . But this idea seems to have originated with his colleague, Dr. T. Sterry Hunt[2] who mentioned it in a lecture delivered in Montreal and published in the *Gazette* of that city on March 1, 1861."

The effect of an anticline on accumulation was discussed by Logan[3] in "Geology of Canada, 1863," but boring in Ontario on the theory that the Cincinnati anticline extended into Ontario from Ohio followed the publication of the report of Edward Orton[4] on the "Geology of Ohio" in 1888. Professor Orton was no doubt greatly influenced by the re-statement of the anticlinal theory by I. C. White and his success in applying it. Orton's statements that the gas in Ohio was related to the Cincinnati anticline led to the location by Eugene Coste of a well near Ruthven between Kingsville and Leamington in Essex county. This well was completed in 1889 with a gas flow of 10,000,000 cubic feet a day. This was the beginning of the Essex gas field. In the same year drilling 7 miles east of Port Colborne opened up a well of 1,700,000 cubic feet in what later developed into the Welland-Haldimand gas field. This success led to much drilling, and gas was exported to Buffalo and Detroit, a condition that continued until the gas field began to show exhaustion. The export of gas to Detroit was stopped in 1901 and to Buffalo in 1908. It is interesting to note that drilling for gas in the Caledonia area in 1894 led to the discovery of the gypsum which has subsequently been mined in that locality. An increase in the price of oil in 1895 led to a large increase in the number of wells in the Petrolia and Oil Springs areas and to considerable exploratory drilling. Several wells were drilled on Pelee

[1]Harkness, R. B.: "Oil and Gas in Ontario"; 2nd (Triennial) Emp. and Min. Cong., 1927, pp. 23-24.
[2]Bell, Robert: "The Petroleum Fields of Ontario"; Can. Min. Rev., vol. VI, p. 124 (1888).
[3]Logan, Sir Wm.: "Geology of Canada, 1863," p. 379.
[4]Orton, Edward: "Geology of Ohio," vol. VI (1888).

island and two of these reported oil, but no field developed. The better price of oil led to the opening up of the Bothwell field which had been abandoned in 1866 owing to water troubles and because of the better results being obtained at Petrolia and Oil Springs. By 1899 a number of small oil fields had been found in Sarnia township, in Zone township near Thamesville, and in Euphemia and Dawn townships, and in 1899, a small field was opened up in Dunwich township, Elgin county. In 1909 a gas strike was made in Amabel township, Bruce county, in the Trenton formation. This strike led to the development of a small gas field. In 1902 a well struck oil in Raleigh township, Kent county, and by January, 1903, twenty-five wells were being drilled. In April, sixty wells had been completed and ten were being drilled. The first well produced 1,000 barrels a day while it flowed and by April was pumping 25 barrels a day.

The year 1905 witnessed the finding of the Moore Township field in Lambton county and the Leamington field in Mersea township, Essex county. Some large wells were obtained in this latter field from the Guelph formation, the largest one flowing initially 1,200 barrels a day. In December of 1905 the first strike of oil was made in the Tilbury field[1] and the second producing well was drilled in March, 1906. The first well after being shot flowed 40 barrels a day, but the second was rather small. The third well was somewhat better and flowed 60 barrels a day. Many wells were subsequently drilled, the largest well flowing 1,500 barrels of fluid, 1,200 of which were salt water and 300 oil.

An oil well in Romney township was drilled at the close of 1906 and by the beginning of 1907 there were seven producing wells, several of which came in with over 1,000 barrels a day. In July, 1907, the Tilbury and Romney wells[2] were producing 35,000 barrels of oil a day, whereas in November, 1908, the production had fallen to 12,000 barrels. The Tilbury field, like the Leamington field, produced the oil from the Guelph formation.

In 1910 another small field was discovered in Onondaga township, Brant county, about 5 miles from Brantford. The best well in this field is reported[3] to have yielded 40 barrels a day for twenty days. The area containing oil covers about 5 square miles. This field also yielded considerable volumes of gas.

In 1910 a new gas field was opened up in the township of Bayham, Elgin county, near Vienna, and this supplied Tilsonburg and Aylmer. This field extended over about 10 square miles, but the gas-bearing strata were thin and the field never developed into one of major importance.

During the summer of 1913 several wells were drilled[4] at Oil Springs and a moderate flow of gas secured. In 1914 a well with larger yield was drilled and much activity followed. The results, however, were disappointing and during the two years following the discovery, eleven out of twenty-one wells drilled were abandoned. The gas flow came from the Guelph formation at a depth of 1,910 to 2,000 feet. In 1913, also, the Belle River oil field was opened up, but the production was very small.

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[1]Coste, Eugene: The New Tilbury and Romney Oil Fields of Kent county, Ont.; Jour. Can. Min. Inst., 1907, p. 27.
[2]Ont. Bureau of Mines, vol. XVIII (1909).
[3]Ont. Bureau of Mines, vol. XIX (1910).
[4]Ont. Bureau of Mines, 23rd Ann. Rept., pt. I, and pt. II, p. 36 (1914).

No new discoveries of importance were made until 1917 when an oil field in Mosa township, Middlesex county, was found. The oil was found at a depth of 390 to 450 feet in the Onondaga limestone. In 1917 also a deep well drilled in Dover West, Kent county, near lake St. Clair, found oil in the Trenton formation at 3,183 feet depth. This led to the development of a small field.

Due mainly to work[1] done for the Geological Survey by M. Y. Williams, the Raleigh field was discovered in 1919. Oil was found in the Onondaga formation at a shallow depth. No new discoveries were made until 1923 when oil was struck[2] at 3,560 feet in Shanks No. 6 well in Romney township. The well began flowing 150 barrels a day and it is thought the production came from the sandstone at the base of the Trenton limestone. Further drilling in this field gave very discouraging results.

Recent drilling in Ontario has not opened up any new fields, but there is no doubt that with the adequate supervision now in force, the gas and oil fields will continue to produce for many more years. The older oil fields have had a remarkable record of long-continued production and although the yield per well is now very small and many wells are yearly being abandoned, the older fields still continue to be the largest producers (*See* Figure 7).

The gas fields have produced a very large quantity of natural gas, reaching a maximum production of nearly 20,000,000 thousand cubic feet in 1917. Since that time the production has steadily decreased and with the decrease in volume there has been an increase in price. These relationships are shown in Figure 8.

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[1]Ont. Dept. of Mines, 31st Ann. Rept., pt. V, p. 72 (1922).

[2]Ont. Dept. of Mines, 33rd Ann. Rept., pt. IV, p. 98 (1924).

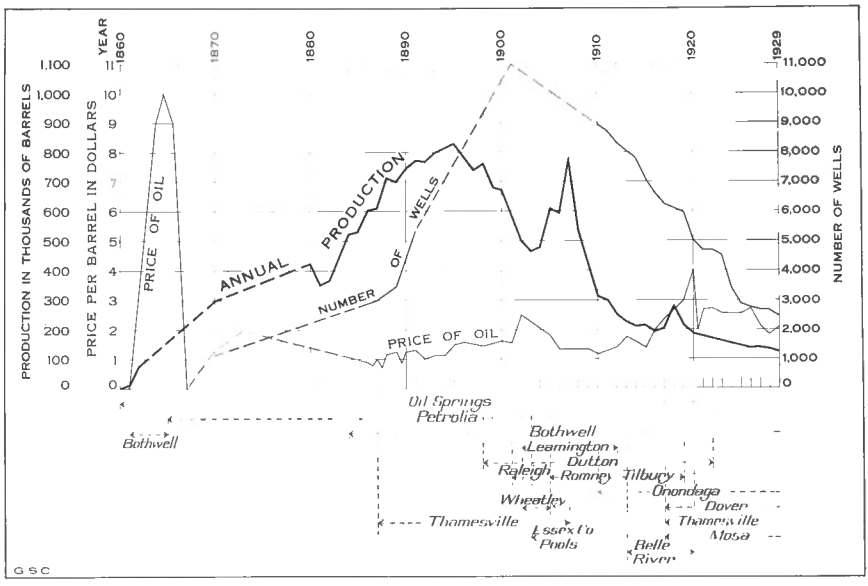

Figure 7. (After R. B. Harkness). Graph showing annual production of oil, number of producing wells, etc., oil fields of southern Ontario.

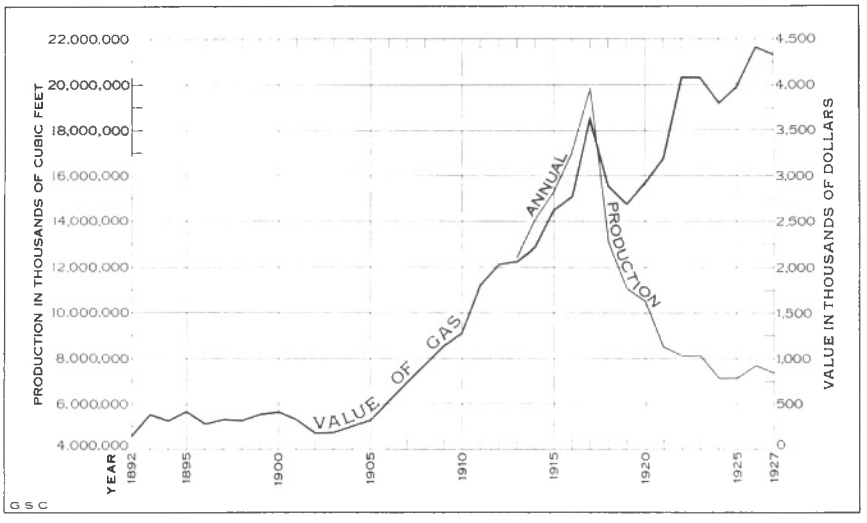

Figure 8. Graph showing annual production of natural gas, gas fields of southern Ontario.

CHAPTER IV

DESCRIPTION OF OIL AND GAS FIELDS OF SOUTHERN ONTARIO

OIL FIELDS

LAMBTON COUNTY

Oil Springs

Owing to seepages of a tarry or asphaltum-like material, drilling was undertaken in 1858, at Oil Springs, Enniskillen township, Lambton county, but the first wells only reached the gravel above the bedrock. In 1861, however, a well was drilled into the rock and at 160 feet an oil gusher that flowed for some time was struck. Great drilling activity followed this discovery and many wells of large capacity were drilled, the largest recorded being that of "Black and Mathewson" which had an initial flow of 7,500 barrels a day. Several other wells had a flow of from 2,000 to 5,000 barrels a day.

The geological section as given by wells in the field is as follows:[1]

East Side of Field

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	60	60
Ipperwash (upper lime)	Limestone	35	95
Petrolia (upper soap)	Shale	101	196
Widder (middle lime)	Limestone	27	223
Olentangy (lower soap)	Shale	17	240
Delaware and Onondaga (lower lime)	Limestone	130	370

West Side of Field

Surface	Glacial drift, etc	80	80
Petrolia (upper soap)	Shale	116	196
Widder (middle lime)	Limestone	27	223
Olentangy (lower soap)	Shale	17	240
Delaware and Onondaga (lower lime)	Limestone	130	370

The "lower lime" of these well logs belongs to the Delaware and Onondaga formations; the shales and limestones lying above it are part of the Hamilton group. In Oil Springs area it is difficult in the case of well

[1]Geol. Surv., Canada, vol. V, pt. II, pt. Q, p. 62 (1890-91).

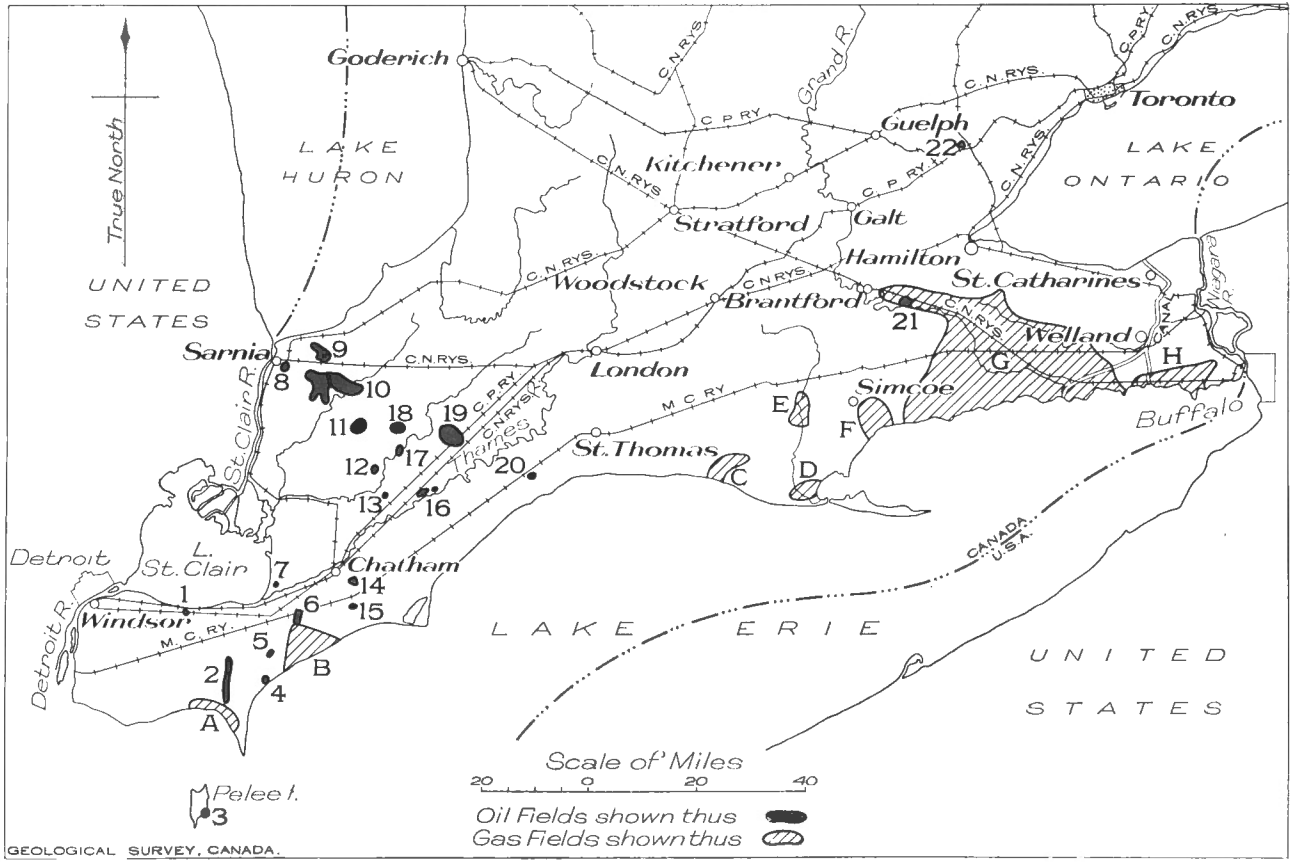

Figure 9. Oil and gas fields of southern Ontario. Oil fields: 1, Belle River; 2, Leamington; 3, Pelee Island; 4, Wheatley; 5, Romney; 6, Tilbury; 7, Dover West; 8, Sarnia; 9, Plympton; 10, Petrolia; 11, Oil Springs; 12, Dawn; 13, Thamesville; 14, Kipp; 15, Raleigh; 16, Bothwell; 17, Euphemia; 18, Brooke; 19, Mosa; 20, Dutton; 21, Onondaga; 22, Milton. Gas fields: A, Leamington; B, Kent; C. Bayham; D, Port Rowan; E, Middleton; F. Simcoe; G, Haldimand county; H, Welland.

samples to distinguish the Delaware from the Onondaga. According to Stauffer,[1] in certain parts of Ontario underlain by Devonian rocks, Marcellus black shales intervene "between the Onondaga and the usual basal limestone of the Hamilton." The Marcellus shales are not shown to be present in the well records from Oil Springs and their place is taken by the Delaware limestone. Brumell[2] says of the two well logs recorded: "Oil is found in both of these wells at 370 feet from the surface or about 60 feet below the summit of the Corniferous [Onondaga] limestone." In Huron county, in a number of sections, Stauffer[3] records a "rough and uneven" contact between the Delaware and Onondaga. This has not been taken as evidence of a disconformable contact. Some differences are recorded concerning the character of the limestones above and below the contact.

The Oil Springs field occupies a dome-like structure, the total closure of which, according to Harkness,[4] is 50 feet. Williams[5] describes the structure as a "typical, excentric dome with the apex close to the northeast margin." He says that "production is fairly even over the dome except on the northwest side, which appears to be barren of oil at elevations that are productive elesewhere."

Oil has been produced from three horizons, namely: oil due to seepages at the surface; lubricating oil from the unconsolidated gravels overlying the bedrock; and from the Delaware-Onondago limestones. The production in the early days, according to Williams,[6] came from a porous stratum in the Delaware limestone about 7 to 11 feet below its top. The production secured at a later date came from porous limestone 100 to 120 feet below the top of the Delaware or presumably 30 to 50 feet within the Onondaga formation. Harkness[4] states that the thickness of the oil-bearing stratum is from 5 to 10 feet. The main pool at Oil Springs is about three-quarters of a mile wide. A small pool west of the main pool, opened about 1917, is about $\frac{3}{10}$ mile north and south and $\frac{3}{5}$ mile east and west. The two pools have a combined area of about $1\frac{1}{3}$ square miles. It is estimated[4] that this field up to the end of 1925 produced 7,400,000 barrels of oil; production for 1926 to end of 1929 added 142,000 barrels to this already large total. This represents a recovery of over 9,000 barrels an acre. During 1927 there were one thousand and sixty wells in operation in the Oil Springs field.

In 1913 several wells were drilled in the Oil Springs field to deeper horizons than the Onondaga and some gas was secured in the Guelph formation. In 1914 a much larger well was drilled and considerable other drilling was undertaken, but with discouraging results as a whole. According to Williams[7] two of the wells had "initial flows of 20,000,000 cubic feet of gas a day, but this decreased rapidly. No. 2 well drilled by the Oil Springs Gas Company struck gas from 1,840 to 1,960 feet from the surface or 15 to 135 feet below the top of the Guelph formation." Several wells drilled to the Trenton in Oil Springs and vicinity have met with no success.

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[1]Stauffer, C. R.: "The Devonian of Southwestern Ontario"; Geol. Surv., Canada, Mem. 34, p. 7 (1915).

[2]Brumell, H. P. H.: Geol. Surv., Canada, Ann. Rept., vol. V, pt. Q, p. 63 (1893).

[3]Stauffer, C. R.: Geol. Surv., Canada, Mem. 34, p. 120 (1915).

[4]Harkness, R. B.: Second (Triennial) Empire Mining and Metallurgical Congress, Canada, 1927.

[5]Williams, M. Y.: "Oil Fields of Southwestern Ontario"; Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 34.

[6]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 34.

[7]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 35.

Petrolia

The Petrolia field occupies parts of Enniskillen, Moore, Sarnia, and Plympton townships, Lambton county. The first flowing well was obtained in 1865 and development proceeded rapidly with much waste of oil due to poor recovery methods. The owners, according to Harkness,[1] sold their oil rights in very small plots, scarcely large enough to erect a drilling rig and consequently more wells were drilled per acre than in any other field. This field has been the largest producer of oil of any field in Ontario and still continues to lead all other Ontario fields in production.

The geological section is much the same as at Oil Springs and is shown by the following log[2] of a well on the south part of lot 14, con. XII, Enniskillen tp.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	100	100
Ipperwash ("top rock")	Limestone	50	150
Petrolia (upper soap)	Shale	134	284
Widder (middle lime)	Limestone	15	299
Olentangy (lower soap)	Shale	45	344
Delaware (lower or big lime)	Limestone	50	394
Onondaga	Limestone	82	476

The oil-bearing rock in this well is reported to be 462 to 471 feet in depth, or 68 to 77 feet below the top of the Onondaga limestone.

The structure in the central and eastern part of the field is a dome with a closure of 40 feet. An extension to the west of the main dome structure extends 120 feet down the dip in a distance of approximately 6½ miles from the centre of the dome. As might be anticipated on the basis of structure the most productive[3] parts of the field are the central and eastern parts where the oil stratum is 5 to 13 feet thick and consists of porous, cavernous limestone. According to Harkness "in the northwestern part of the field, which is the least productive, the oil is reported by the drillers to occur in 'fissures' or 'crevices' in the rock. Wells along a certain strike will be found to be productive, while others within the same area give little or no oil. These 'crevice' wells have not a long life, but when closed down for a short time they appear to accumlate oil, for, when again pumped, the production is restored for a time." Williams thinks these "crevices" or "fissures" are porous bands in a stratum of rock and hence are nearly horizontal, i.e. follow the bedding and are not fissures in the ordinary meaning of that word. It would appear, therefore, that the extension of the field down the dip in a westerly direction is in reality dependent on the presence of a porous horizon suitable to contain oil, although in the southwest part of the field, according to a map by Williams,[4] there is a tendency toward some doming. Harkness states[5] that at its maximum the Petrolia

[1]Harkness, R. B.: 2nd (Triennial) Empire Mining and Metallurgical Congress, Canada, 1927.
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 31.
[3]Harkness, R. B.: Op. cit., p. 20.
[4]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E.
[5]Harkness, R. B.: Op. cit., p. 20.

field had an area of about 20,000 acres and the total estimated production up to the end of 1925 was 15,090,700 barrels. The production of this field for 1926 to end of 1929 was slightly more than 233,000 barrels.

Although the first oil refinery in Canada was located at Oil Springs, Petrolia presently took the lead in the refining industry. Harkness states[1] that J. H. Williams, of Hamilton, who erected the first refinery and who had had some experience distilling the oil-shales of Scotland, "Was attracted to the seepage of heavy petroleum at Oil Springs, known locally as 'gum beds,' by a desire to obtain a supply of raw material which would give a greater yield of 'coal oil,' as illuminating oil was then termed, than the raw material then obtainable." The first refinery in Ontario to operate on a commercial basis was built in Petrolia about 1861 or 1862. In 1887 and 1890 there were nine refineries in Petrolia; in 1891 eight; in 1894 five; and in 1898 only one. At present there is still one refinery at Petrolia—the Canadian Oil Companies Limited—and it has a capacity of 1,200 barrels of oil a day.

Moore

The Moore oil field is in Moore township, Lambton county, west of Petrolia. This field was discovered in 1904, on lot 3, concession X, and was developed to comprise lots 1 to 5, concessions IX, X, and XI.

The stratigraphy is much the same as at Petrolia and is illustrated by the following log[2] of a well on lot 3, concession XI, Moore township.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc.	164	164
Surface	Gravel	7	171
Ipperwash (top rock)	Limestone	52	223
Petrolia (upper soap)	Shale	120	343
Widder (middle lime)	Limestone	15	358
Olentangy (lower soap)	Shale	40	398
Delaware and Onondaga (lower lime)	Limestone	140	502

Some gas was found at 415 feet and oil at 430 to 463 feet. According to Williams

"the general elevation of the oil formation is about 80 feet lower than in the main Petrolia field, but this difference of elevation is partly offset by the oil occurring . . . . . higher up in the formation. Thus, the top of the oil stratum at Petrolia is about 118 feet below the top of the Delaware limestone and the top of the oil stratum in the Moore field is only from 57 to 83 feet below it. The top of the oil is thus from 20 to 45 feet below the oil in the main Petrolia field."

The oil-bearing rock in the Moore field is not thick.

The initial production of some of the best wells was 40 to 100 barrels a day and all wells were pumped. Oil is still being produced from the Moore field, the yearly production for the last few years having been slightly more than 2,000 barrels (*See* Figure 10).

[1]Harkness, R. B.: Ont. Dept. of Mines, vol.XXXIV, pt. V, p. 62 (1925).
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 32.

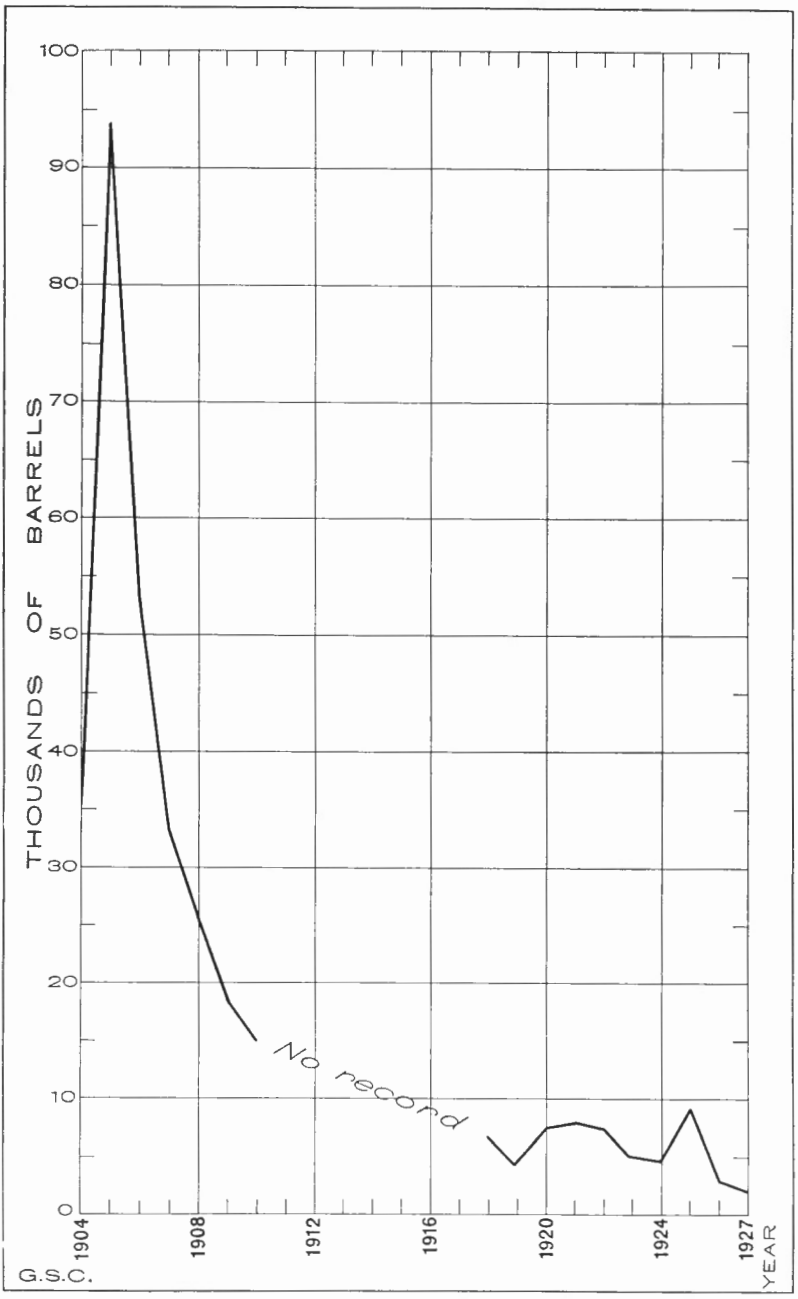

Figure 10. Graph showing annual production of Moore oil field, Moore township, Lambton county, Ontario.

Plympton

This field is mainly in Plympton township, but extends northwest into Sarnia township, Lambton county. It is north of the Petrolia field, the nearest parts of the two fields being separated by only about one mile.

The stratigraphical succession in this field is illustrated by the following log.[1] Oil was struck at a depth of 440 feet in this well.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial material, etc	106	106
Ipperwash (top rock)	Limestone	47	153
Petrolia (upper soap)	Shale	123	276
Widder (middle lime)	Limestone	10	286
Olentangy (lower soap)	Shale	52	338
Delaware and Onondaga	Limestone	132	470

The field occupies a low anticline extending in a northwest by west direction[2] and the closure seems to be about 20 feet. The elevation of the oil formation, according to Williams, is about the same as in the Moore field, but it is apparent that the oil in the Plympton field, like that of the Petrolia field, occurs in the Onondaga formation instead of in the overlying Delaware.

Sarnia

The Sarnia oil field is on the Indian Reserve about one mile south of Sarnia Tunnel station, in Sarnia township, Lambton county.

The stratigraphic succession is given by the log of a well on lot 16, concession III, Sarnia township. Gas and oil were found in this well at 480 feet and oil at 518 feet.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	120	120
Huron	Black shale	30	150
Ipperwash (top rock)	Limestone	20	170
Petrolia (upper soap)	Shale	260	430
Widder (middle lime) Olentangy (lower soap)	Limestone Shale	45	475
Delaware and Onondaga	Limestone	55	530

In the Petrolia field the highest point on the top of the Delaware limestone is 350 feet above sea-level, whereas in the Sarnia field the elevation of this horizon is about 150 feet and since the distance between the crests of the two fields is about 11 miles, the dip is about 18 feet to the mile in a westerly direction. It is not apparent from the information available whether the Sarnia field is a closed dome, but if closure exists it is very small. Since the oil occurs only 43 feet below the top of the Delaware limestone, it evidently occurs in the Delaware rather than in the Onondaga limestone as at Petrolia.

[1]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 33.
[2]Williams, M. Y.: Op. cit.

Euphemia

The Euphemia Township field in Lambton county is sometimes called the Shetland field because it lies 2 miles northeast of the village of Shetland. This field, as early as 1896, had a few wells and produced 150 to 200 barrels a month, mainly from lots 26, 27, and 28, concession IV, Euphemia. The stratigraphy of the field is given by the following log.[1]

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	58	58
Hamilton	Shales and limestone	264	322
Delaware and Onondaga	Limestone	100	422

The oil is reported[2] to have occurred 100 feet below the top of the Delaware limestone and thus is presumably in the Onondaga formation.

The structure of the field is a small anticline which, according to Williams,[3] can be seen "at the ford in Sydenham river at the north end of the field where the Ipperwash (Hamilton) limestone is exposed. The fold pitches to the north and the production of oil is almost entirely confined to the area south of the river."

The initial production[4] of some of the wells was 20 to 30 barrels a day and one on Mr. Richard Dobby's farm yielded 100 barrels a day for a few days only. The decline was rapid and the yield soon fell off to less than half a barrel a day per well.

According to Williams[5]

"during the autumn of 1918 and the summer of 1919 the Castle Oil Company prospected the area south of the shallow oil field at Smiths Falls [Euphemia oil field], Lambton county. Drilling was carried on there a few years ago and a good gas well was struck on the east end of lot 26, concession IV. The production was estimated at about 250,000 cubic feet of gas per day of 24 hours, and the well has been supplying the village of Shetland and the neighbouring farms with gas for more than three years. The first well drilled by the Castle Company is situated on the Palmer farm, on the east end of lot 25, concession IV, and was completed and closed in on March 1, 1919. Gas was struck at 1,585 to 1,590 feet from the surface and a little oil was struck at 1,690 feet. This well is said to promise a fair production of gas. In No. 2 well on the Moorhouse farm near the middle of the west half of lot 25, concession I, oil and gas were struck at 1,605 to 1,611 feet and, after shooting, the well was reported to have an open flow of about 1,000,000 cubic feet of gas, the closed pressure being about 750 pounds per square inch. In well No. 3, situated on the Tanner farm in the northwest corner of the east half of lot 24, concession V, the drill penetrated 15 feet of black shale; and on the assumption that the shale indicated unfavourable structure the well was abandoned.

In well No. 4, on the Leng farm, in the southwest corner of the east half of lot 27, concession V, about one foot of black shale was penetrated by the drill, but the well was completed and is reported by the company to have an open flow of approximately 350,000 cubic feet of gas a day, the rock pressure being 780 pounds a square inch. Two additional wells are reported to be in progress, one on the Smith farm in the northeast quarter of lot

[1]Clapp, F. G.: "Petroleum and Natural Gas Resources of Canada"; Mines Branch, Dept. of Mines, Canada, Pub. 291, p. 183.

[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 36.

[3]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 36.

[4]Ont. Bureau of Mines, vol. V, p. 25 (1895).

[5]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 9.

26, concession IV, and one on the Tully farm in the southwest corner of the northwest quarter of lot 27, concession V. The anticline on which the shallow oil field is situated pitches to the north, and deep drilling at a previous date found no oil or gas in the Salina to the north of Sydenham river. The Moorhouse well, above described, is the best well in the field, the available information thus indicating the probable location of the extension of the oil pool to the south rather than to the north. Reducing the reported occurrences of oil and gas to sea-level, the gas horizon in the original well supplying Shetland is 1,034 feet below sea-level; the horizon in No. 1 well of the Castle Oil Company is 932 feet below sea-level, the lower oil horizon being 1,033 feet below; in No. 2 well the gas horizon is 945 feet below sea-level. This would suggest that there may be a still higher structure in the gas horizon on lot 24, concession IV."

The Castle Oil Company continued drilling operations through 1919 and 1920, at the end of which time they had six producing gas wells.

No production of oil has been reported from the Euphemia field since 1925 when only 23 barrels were produced.

Dawn

In 1897 a new field was opened up about midway between Landbank and Florence in Dawn township, Lambton county. This field is sometimes known as the Florence field to distinguish it from a small producing area in the northeast part of Dawn township on lots 30 and 31, concessions XIII and XIV.

The Dawn field was very small, being less than a half mile long or wide. The stratigraphy of the field is shown in the following log[1] of a well in which oil was found at a depth of 318 to 325 feet.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	22	22
Ipperwash (top rock)	Limestone	6	28
Petrolia (upper soap)	Shale	172	200
Widder (middle lime)	Limestone	15	215
Olentangy (lower soap)	Shale	21	236
Delaware and Onondaga	Limestone	113	349

The oil zone is probably in the Onondaga rather than in the Delaware. According to Williams[2] the structure is a small dome.

The first or discovery well[3] was drilled in 1897, on lot 17, concession XIII, Dawn, to a depth of 342 feet, where salt water pumping 2 barrels a day was struck.

"The second well, located 300 feet southeast of the first was bored to 317 feet and yielded at first at the rate of 30 barrels (of oil) per day. The flow fell off gradually to 1 barrel when the bore-hole was deepened to 356 feet and it was shot at 290 feet. The pump was again put in and the yield was found to be 10 barrels per day at which rate it continued. Eleven wells were drilled before the close of the year and all these were producers. These were subsequently sold to Mr. Fairbanks of Petrolia who developed the field."

[1]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 35.

[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 35.

[3] Ont. Bureau of Mines, vol. XVII, p. 19 (1897).

A small oil field was discovered at the northwest corner of lot 30, concession XIII, Dawn township, but according to Williams the accumulation of oil was very insignificant. The structure of the field is a small dome, but there is little closure on the west side and a terrace extends from the field to the Oil Springs dome about 4 miles to the northwest. The top of the Delaware limestone in this field is 308 feet above sea-level and rises to 430 feet in the Oil Springs field.

In 1921 a new gas field[1] was discovered in Dawn township by a well on lot 24, concession VII. The well came in with 177,000 cubic feet of gas from 1,615 and 1,750 feet in depth, from what appears to be the top of the Guelph formation. A number of wells, of which five were productive, were drilled. The stratigraphy of the field is shown by the following log of a well drilled by Eugene Coste and Company on lot 30, concession IX, Dawn. This well was outside the productive area.

Formation	Description	Thickness in feet	Depth in feet
Surface	Drift	100	100
Huron	Black shale	100	200
Hamilton	Shale and limestone	220	420
Delaware and Onondaga	Limestone	60	
	Shale	20	
	Limestone	50	
	Shale	20	570
Sylvania (?)	Sandy limestone	30	600
Detroit River (?)	Dolomite	50	650
Salina	Dolomite and gypsum	150	800
	Dolomite	230	1,030
	Dark grey dolomite	80	1,110
	Shale with streaks of dolomite. Gypsum toward bottom	395	1,505
	Salt	70	1,575
	Shale	185	1,760
Guelph and Lockport	Dolomite	220	1,980
Medina-Cataract	Shale	150	2,130
	Dolomite	20	2,150
	Shale	20	2,170
Queenston	Red shale	330	2,500
Richmond and Lorraine	Dark grey shale	330	2,830
Utica	Black shale	100	2,930
Trenton and Black River	Limestone	930	3,860
	Basal arkose	40	3,900
Precambrian	Granite	.....	3,913

The structure of the gas field is not known. Production from five wells amounted in 1923 to 74,414 thousand cubic feet, in 1924 to 57,400 thousand cubic feet, and in 1925 to 35,561 thousand cubic feet.

Brooke

According to Williams[2]

"a small oil field on lots 6, 7, and 8, concession II, Brooke township (Lambton county), was producing oil from two or three wells in 1918 and it seems probable that other wells may still be brought in. The dome appears to be of considerable size, but its maximum elevation is low and only the extreme top contains oil."

[1]Ont. Dept. of Mines, vol. XXXI, pt. V, p. 49 (1922), and vol. XXXII, pt. V, p. 12 (1923).
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E, p. 35.

The following log of a well on NW. ¼ lot 8, concession II, Brooke township, illustrates the stratigraphy of the field. Oil was found at 66 feet and at the bottom of the well.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	55	55
Ohio	Shale	4	59
Ipperwash (top rock)	Limestone	5	64
Petrolia (upper soap)	Shale	184	248
Widder (middle lime)	Limestone	18	266
Olentangy (lower soap)	Shale	22	288
Delaware and Onondaga		60	348

According to Stauffer[1]

"the thickness of the Delaware limestone in the province is difficult to determine, because the full amount of it is nowhere exposed; and also because in well sections it is often impossible to separate it from the underlying Onondaga limestone. It is quite probable that it does not lack much of 50 feet, while at Petrolia and vicinity the interpretation of well records has assigned 70 feet or more to it."

A log of a deep well, which did not yield oil or gas, on lot 5, concession IV, Brooke township, at Inwood, is given by Clapp[2] as follows.

Formation	Description	Thickness in feet	Depth in feet
Pleistocene	Clay		0–60
	Boulder	65	60–65
Hamilton	Shales	85	65–150
	Upper limestone	15	150–165
	Upper "soapstone"	205	165–370
	Middle limestone	25	370–395
	Lower "soapstone"	25	395–420
Onondaga	Limestone	115	420–535
Salina	Dolomites, limestone, and marls with gypsum and salt	1,300	535–1,835
Guelph and Niagara	Limestones and dolomites	225	1,835–2,060
	Dark shales	15	2,060–2,075
Clinton (?)	Limestone	35	2,075–2,110
Medina	Red shale	440	2,110–2,550
Lorraine	Light grey shales with limestone	285	2,550–2,835
Utica	Dark shales	165	2,835–3,000
Trenton	Limestone	380	3,000–3,380

According to present knowledge of the stratigraphy some modification of the record of this well log is required. The Hamilton of the log presumably consists of Ipperwash limestone ("upper lime") depth from 150 to 165 feet; the Petrolia shale ("upper soap") depth from 165 to 370 feet; The Widder beds ("middle lime") depth from 370 to 595 feet; and the Olentangy shale ("lower soap") depth from 395 to 420 feet. The shales from 65 to 150 feet presumably are Huron in age. The limestone from 420 to 535 feet, called Onondaga in the well log, undoubtedly consists of Delaware and Onondaga and may include some or all of the

[1]Stauffer, C. R.: Geol. Surv., Canada, Mem. 34, p. 9 (1915).
[2]Clapp, F. G.: Mines Branch, Dept. of Mines, Ottawa, Pub. 291, p. 185 (1915).

Detroit River series if such is present in this area. It is possible, though, that Detroit River beds, if present, are included in the Salina of the well record, from 535 to 1,835 feet. The limestone and dolomites from 1,835 to 2,060 feet undoubtedly represent the Guelph and Lockport. The dark shales from 2,060 to 2,075 feet, may represent the Rochester. The limestones from 2,075 to 2,110 feet have, in other logs, been interpreted as the Manitoulin beds rather than Clinton. The red shale from 2,110 to 2,550 feet are probably Queenston. The remainder of the well log would, in the light of present knowledge, be interpreted as given.

In 1917 and 1918 ten wells were being pumped in the Brooke field. Two further wells were drilled in 1920, but both were dry. In 1924 only one well was operating.

KENT COUNTY

Bothwell-Thamesville

The Bothwell and Thamesville fields are so alike in many respects that they are here treated together. The Bothwell field was discovered in 1862 and in the following three years many wells were drilled, almost all of which were in Mosa township north of Thames river. Most of the wells were drilled under contracts so favourable to the contractor that he drilled the well to contract depth regardless of whether he had encountered oil or not. Underlying the Onondaga from which the oil was produced in this field is a water-bearing sand, only 20 to 30 feet deeper than the productive oil horizon. As a result of the contract drilling many wells were drilled into this water horizon and when the United States operators abandoned their wells in 1866 at the time of the Fenian raid, their wells were flooded and this part of the field was ruined.

The Bothwell field was re-opened in 1895 and as the anticlinal theory of oil accumulation had gained credence by this time, a search was made for the highest part of the structure, the datum plane being the top of the Delaware limestone. This led to the discovery of the field as now known and which lies principally in Zone township.

In the Bothwell field the geological section is given by the following log:

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift	167	167
	Limestone (middle lime)	10	177
	Shale	16	193
Hamilton	Limestone	8	201
	Shale	2	203
Delaware and Onondaga	Limestone	178	381

The Middle lime is the Widder beds and the remainder of the Hamilton above the Delaware consists of Olentangy shale. The results of drilling in this well gave:

"Some water and oil at 210 feet; began to show oil at 345 to 350 feet, but from 365 to 376 feet the limestone is quite coarse . . . . Oil is, therefore, found in the Corniferous (Onondaga) . . . . The Hamilton formation in this field has been greatly eroded, being about 200 feet less in thickness than at Petrolia or Thamesville."[1]

[1]Ont. Bureau of Mines, vol. XIV, p. 110 (1905).

In a well about a mile north of Thamesville railway station, 240 feet of Hamilton shales, etc., were reported[1] under 60 feet of clay.

The structure[2] in the Bothwell-Thamesville field is an east and west ridge on which there are several long, narrow oil fields. The ridge continues westward from Thames river south of Bothwell to north of Thamesville and is, in all, about 20 miles long with a closure of 80 to 120 feet. On the eastern end, the top of the Delaware at the summit of the oil fields has an elevation of 450 to 460 feet, but at the western or Thamesville end the elevation is 380 to 390 feet. This accounts for the greater thickness of Hamilton in the Thamesville area than at Bothwell. It may, also, be in part the explanation why the Bothwell field, since it is higher structurally, has been more productive of oil than the Thamesville field. In these fields the oil extends 10 to 20 feet down the dip from the crest of the structure. The thickness of the oil-bearing stratum averages about 8 feet.

The Bothwell field never gave such large wells as at Petrolia or Oil Springs and the production of the Thamesville fields has been much smaller than at Bothwell.

According to Harkness[3] the production of the Bothwell field was not reported separately from other fields until 1898 and for the years 1885 to 1898 is, therefore, an estimated portion of the total production for the province based on the number of wells recorded and the history of the development of each field. This estimated and recorded production from 1885 to 1927 totals 2,213,876 barrels. Production is still at the rate of 23,000 to 24,000 barrels a year.

Tilbury

Two fields, namely Fletcher and Glenwood, have produced oil and gas in Tilbury East township, Kent county, and an area of 34·6 square miles[4] adjoining the shore of lake Erie constitutes what is known as the Kent gas field.

Oil was struck in the Fletcher field in 1905 on the northwest part of lot 10, North range of the township of Tilbury East. According to Coste,[5] at a depth of 1,360 feet this well struck

"a rather strong gas vein. . . . . Then another at 1,375 feet; then the first oil pay with more gas at 1,385; then a second oil pay at 1,410 feet and a third one at 1,430 feet. A little below that some salt water was found and the drilling was stopped at 1,450 feet. The well after being shot started to flow at the rate of 40 barrels of oil per day, with a gas flow of about half a million cubic feet per day."

These results were the cause of much activity and many wells were drilled. The field, as finally developed, covered 5,000 acres in Tilbury East township and 600 acres in the adjoining Raleigh township.

The stratigraphy of the field is given by the following log[6] of a well on the south half of lot 1, concession VI, Raleigh tp., north of the town of Fletcher.

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[1]Geol. Surv., Canada, Ann. Rept., vol. V, pt. II, pt. Q, p. 72 (1893).
[2]Harkness, R. B.: 2nd (Triennial) Empire Mining and Metallurgical Congress, Canada, p. 22, 1927.
[3]Harkness, R. B.: Ont. Dept. of Mines, vol. XXXVII, pt. V, p. 58 (1928).
[4]Ont. Bureau of Mines, vol. XIX, p. 150.
[5]Coste, E.: "The New Tilbury and Romney Oil Fields of Kent County"; Jour. Can. Min. Inst., vol. X, p. 77 (1907).
[6]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E., p. 12.

Formation	Description	Thickness in feet	Depth in feet	Remarks
Surface	Blue clay	85	85	
	Gravel	5	90	Fresh water
Huron	Black shale	20	110	
Hamilton	Shale			
	Limestone	170	280	
	Shale			
Delaware	Limestone	50	330	
Onondaga	Limestone (chert at 395 feet)	110	440	
Oriskany (?)	Sandstone	5	445	Contains brine and sulphur water
	Dolomite	30	475	
	Sandstone	5	480	
Detroit River series	Dark buff dolomite	150	630	
	Chert beds	20	650	
	Buff dolomite	50	700	
	Chert beds	60	760	
	Buff dolomite	10	770	
Sylvania (?)	Fine sand in dolomite	20	790	
Bass Island	Brown and buff dolomite	110	900	
Salina	Grey shale	120	1,020	
	Brown dolomite	70	1,090	
	Dark grey shale	20	1,110	
	Shale and dolomite	70	1,180	
	Black shale	40	1,220	
	Buff dolomite	40	1,260	
	Dark shale	30	1,290	
	Buff dolomite	70	1,360	
	Grey shale	20	1,380	
	Light buff dolomite	70	1,450	Oil and gas
Guelph and Lockport	Light buff and grey dolomite	10	1,460	Brine
	Cream dolomite	60	1,520	
	Brown and grey dolomite	160	1,680	
Rochester, Clinton, Medina-Cataract	No record	70	1,750	
Manitoulin	Dolomite	50	1,800	
Queenston	Grey shale	15	1,815	
	Red shale	85	1,900	
	Grey shale	10	1,910	
	Red shale with grey streaks	90	2,000	
Richmond	Grey shale and dolomite			
Lorraine, Utica	Principally shale	.....	2,780	
Trenton and lower formations	.....	387	3,167	Bottom of well

The log of this well was prepared by M. Y. Williams from cuttings furnished by the driller. The well was slightly east of the producing oil field. The log[1] of another well drilled within the oil field, on lot 6, concession IX, Tilbury East township, showed the following stratigraphic succession.

Formation	Description	Thickness in feet	Depth in feet
Surface	Boulder clay	95	95
	Grey sand	5	100
	Clay and gravel	28	128
	Blue, clay shale "upper soap"	37	165
Hamilton	Middle lime	10	175
	Blue, clay shale "lower soap"	67	242
Delaware and Onondaga	Yellow limestone	158	400
Salina	Grey, drab, brown, and blue dolomites with gypsum and flint Shaly series with darker shaly dolomites and more gypsum from 835 to 1,185	1,020	1,420
Guelph	Blue-white dolomitic limestone	9	1,429

Gas at 1,250, 1,362, 1,370, 1,376, 1,382 feet.
Oil at 1,392 to 1,400 and at 1,416 and 1,426 feet.
A little surface gas.

In this log the Detroit River, Sylvania, and Bass Island strata are obviously included in the Salina.

According to Williams[2]

"the structure of the oil-bearing formations cannot readily be determined owing to lack of data. The top of the Guelph formation is not easily distinguished in drill cuttings and it is not well established that the oil and gas are confined to a well-defined stratum, as there is no definite, impervious covering formation. From the general study of the region, however, it seems probable that the lower formations have a structure nearly parallel to the Corniferous (Delaware and Onondaga limestones) limestone. In that case the gas occurring so plentifully to the west of the oil field occupied the top of the dome and the oil occupies its east side and the adjoining terraces."

The production of the first well, as already stated, was 40 barrels a day after being shot. This production came from the bottom of the Salina and the top of the Guelph. The largest well[3] in the northwest part of the field started to flow, naturally, 1,500 barrels a day of fluid of which 1,200 barrels were salt water and 300 barrels were oil. The largest gas well was on lot 1, concession VI, Raleigh tp. This well measured 7,000,000 cubic feet of gas a day from 1,417 to 1,421 feet in depth. The natural gas contained sulphuretted hydrogen. An analysis of the gas as given by Coste is as follows:

	Per cent
Hydrocarbons, principally methane	92·20
Carbon dioxide	1·40
Oxygen	trace
Carbon monoxide	0·21
Hydrogen	0·40
Nitrogen	5·59
Sulphuretted hydrogen	0·20
	100·00

[1]Ont. Bureau of Mines, vol. XVI, p. 103 (1907).
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 11.
[3]Coste, E.: Jour. of the Can. Min. Inst., vol. X, p. 78 (1907).

The oil from this field also contains some sulphur. It has a dark green colour and a gravity of 38 to 41 degrees A.P.I. According to Williams about ten wells per 100 acres were drilled.

The Glenwood field is in lot 10, concession IV, Tilbury East township, and oil and gas are found in the same horizon as in the Fletcher field. According to Williams[1]

"the records of four of the wells indicate that the productive horizon varies from 1,385 to 1,408 feet below the surface, or 752 to 775 feet below sea-level, the dip being to the north. The structure of the Onondaga limestone in this area appears to be a narrow terrace or nose extending to the northeast from the higher structure to the south and west; but sufficient data are not available to indicate the structure of the oil-bearing strata. The area around the oil pool has been extensively drilled, and the pool is, in consequence, clearly outlined."

In 1928 production in the Tilbury East fields had declined to 736 barrels and in 1929 to 139 barrels.

Wheatley

The Wheatley field in Romney township, Kent county, was opened up between 1902 and 1904. According to Williams[2]

"in 1904 four wells on lot 11, con. II, Romney tp., were producing 40 barrels per day . . . The four wells mentioned appear to have been the principal producers, the oil being found in the Guelph formation at a depth of 1,290 to 1,300 feet from the surface or 690 feet below sea-level."

No reliable log of any well in this field is available, but Malcolm[3] reports that 400 feet of salt is said to have been passed through in the drilling. "The structure of the Guelph formation here is not known. The Onondaga limestone rises to the southwest and may be represented in this field by a nose or terrace." The production of the field amounted to 4,490 barrels in 1904, but had dropped to 775 barrels in 1906.

Romney

The Romney field is in the township of Romney, Kent county. It was opened up in 1906 and was abandoned in 1910.

The oil was obtained from the top of the "Corniferous" limestone, that is, presumably, from the Delaware formation. The top of the limestone is about 170 feet below the surface of the ground and the oil came from 30 feet below the top of the limestone. Williams thinks[4] the oil was contained in crevices rather than in a porous rock. The oil was described as dead and heavy, which usually is taken to mean it contains no dissolved gas. The percentage of sulphur in the oil was high and the density about 28 to 30 degrees A.P.I. The production of this field amounted to 11,165 barrels in 1908 and 1,082 barrels in 1909: the field was abandoned in 1910. The structure is not definitely known. Several of the wells[5] had an initial production of over 1,000 barrels a day.

In November, 1923, at a depth of 3,560 feet, oil was struck by the Southern Ontario Gas Company on lot 188, Talbot Road Survey, Romney township, in the No. 6 Shanks well. This oil came from the basal arkose. Further drilling yielded negative results and in this area the Trenton was found to be unproductive.

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[1]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 13.
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 14.
[3]Malcolm, W.: Geol. Surv., Canada, Mem. 81, p. 76 (1915).
[4]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 10.
[5]Coste, E.: Jour. Can. Min. Inst., vol. X, p. 84 (1907).

Raleigh

In November 1902 oil was discovered on lot 18, concession XII, Raleigh township, Kent county. The well flowed for a time at the rate of 1,000 barrels a day and in a few months was pumping 25 barrels a day. This well became known as the Gurd gusher and although considerable drilling was subsequently done no wells were found which equalled this first one.

The following log[1] of a well on lot 15, concession XII, Raleigh, shows the stratigraphy as encountered in drilling in the Raleigh field. Oil was encountered at 360 feet, in the Onondaga limestone.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	110	110
Petrolia	Shale	75	185
Widder (middle lime)	Limestone	5	190
Olentangy (lower soap)	Shale	46	236
Delaware and Onondaga	Limestone	124	360

It is reported[2] that the dip in the Raleigh field is 30 feet in a half mile on the northern side and about the same on the south. These dips, however, may not be very accurate as Williams[3] shows a structural high, to the north of the Raleigh field, although no oil was apparently encountered in the highest part of the structure.

The Raleigh field did not prove to be of much importance in spite of the promising results encountered in the Gurd well. Many wells were drilled, but from most of them the production was very small and the field had been abandoned in 1905.

Kipp

The Kipp field[4] is in Raleigh township, Kent county, about 2 miles southeast of Chatham. The field was very small and is now abandoned. It was mostly confined to lots 22 to 25, concession VIII, but extended slightly to the north of this.

The stratigraphic sequence is illustrated by the following log. The oil was in the Onondaga at 360 feet.

Formation	Description	Thickness in feet	Depth in feet
Surface	Drift, etc	110	110
Petrolia (upper soap)	Shale	75	185
Widder (middle lime)	Limestone	5	190
Olentangy (lower soap)	Shale	46	236
Delaware and Onondaga	Limestone	124	360

[1]Ont. Bureau of Mines, vol. XVI, pt. I, p. 104.
[2]Ont. Bureau of Mines, vol. XII (1903).
[3]Williams, M. Y.: Map No. 1826, Geol. Surv., Canada, 1920.
[4]Ont. Bureau of Mines, vol. XVI, p. 104 (1907).

The production of this field, according to Williams,[1] came from a small dome in which the maximum elevation of the top of the Delaware limestone is approximately 350 feet.

Dover West

The Dover West field, Kent county, was discovered in 1917 by a well bored, on lot 3, concession III, Dover West township, by the Union Gas Company. This well, at a depth of 3,165 feet or 282 feet within the Trenton formation, yielded gas with light oil and the flow, together with smaller flows from depths between 3,010 and 3,040 feet, gave an initial pressure of 1,250 pounds and an estimated flow of 6,000,000 cublic feet of gas a day. This strike was important in that it was the first large production from the Trenton formation in Ontario.

The stratigraphy of the Dover West field is given by the following log[2] of a well on lot 2, concession III.

Formation	Description	Thickness in feet	Depth in feet
.....	Missing.....	185	185
Widder.....	Limestone.....	10	195
.....	Missing, probably shale in part..	72	267
Delaware.....	Limestone.....	45	312
Onondaga.....	Limestone.....	88	400
Sylvania.....	Fine sand.....	20	420
Bass Island.....	Dolomite.....	605	1,025
Salina.....	Shale.....	15	1,040
	Dolomite.....	35	1,075
	Shale and gypsum.....	185	1,260
	Dolomite.....	90	1,350
	Shale.....	280	1,630
	Dolomite.....	205	1,835
Guelph and Lockport.....	Dolomite.....	120	1,955
Rochester.....	Shale.....	35	1,990
Medina-Cataract.....	Red shale.....	120	2,110
	Green shale.....	15	2,125
	Dolomite.....	20	2,145
Queenston.....	Red and purple shale.....	185	2,330
Richmond and Lorraine.....	Shale.....	482	2,812
Utica.....	Shale.....	80	2,892
Trenton and Black River.....	Limestone.....	413	3,305

A small showing of oil was found at 3,295 feet. The well was shot with 100 pounds of nitroglycerine and the flow was increased to about 20 barrels a day.

The Dover West oil field is unusual in that the production comes from a syncline or a faulted zone in the Trenton formation. The conclusions of M. Y. Williams[3] are as follows:

"The Trenton contains little water and varies greatly in porosity from place to place, or is 'pockety'; the finding of oil in the lowest structure prospected suggests that in the absence of saturation by water and consequent hydrostatic pressure, the oil and gas have gravitated to the rock basins."

[1]Williams, M. Y.: Geol. Surv., Canada, Map No. 1750.
[2]Interpretation of log by M. Y. Williams.
[3]Williams. M.Y.: Geol. Surv., Canada, Sum. Rept. 1917, pt. E, p. 25.

Although a number of wells have struck water, yet, according to Williams,[1] the water "is not definitely associated with oil or gas and as it was not struck in nearby wells, it appears to have been confined to rock channels which are not connected with the oil accumulation." Williams also states that the structure of the Dover West field is

"a well-defined, although rather gentle syncline with the oil and gas pool limited to its axial area. . . . . Gas and oil occur at different horizons, neighbouring wells being quite unlike, although the occurrences may be roughly grouped . . . . The initial pressure in well No. 1 was 1,250 pounds per square inch. This unusual pressure might be expected to drive gas long distances into the rock adjoining the pool and yet No. 2 well, one-quarter mile to the east of the axis, had only a showing of gas and No. 3 well one-half mile to the west was totally dry. It appears that only the lack of continuous rock porosity can account for this."

Harkness[2] is of the opinion that the field owes its porosity to sharp folding or faulting in the Trenton formation. The Union Gas Company's well on lot 2, concession III, Dover West township, gave an initial oil production of 200 barrels of oil and 3,500,000 cubic feet of gas a day at a depth of 3,277 feet. Other wells produced as much as 7,500,000 cubic feet a day initially, but production did not hold up very well. The gas was practically free from sulphur.

MIDDLESEX COUNTY

Mosa

The Mosa field is in Mosa township, Middlesex county, about 4 miles northwest of Glencoe. The field was discovered in 1917 and rapidly came into production. The stratigraphic succession does not differ much from other oil fields of Kent and Lambton counties and is illustrated by the following log[3] of a well on lot 6, concession VI, Mosa township.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	77	77
Petrolia	Shale	58	135
	Limestone	6	141
	Shale	73	214
Widder (middle lime)	Limestone	19	233
Olentangy (lower soap)	Shale	20	253
	Limestone	4	257
	Shale	2	259
Delaware and Onondaga	Limestone	55	314

According to Williams[4]

"oil in this field generally occurs in the upper 20 feet of the Delaware limestone, but it also occurs in a few wells in the "middle lime" or Widder beds. In a deep well on lot 6, con. VI, Mosa tp., the following conditions were found. The Delaware limestone and the Onondaga limestones are 97 feet thick and are underlain by white sandstone, consisting of fine, rounded quartz grains. The sandstone is almost pure for 10 feet in depth and overlies 21 feet of

[1]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 17.
[2]Harkness, R. B.: Ont. Dept. of Mines, vol. XXXVII, pt. V, p. 74 (1928).
[3]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1918, pt. E. p. 37.
[4]Williams, M. Y.: Op. cit.

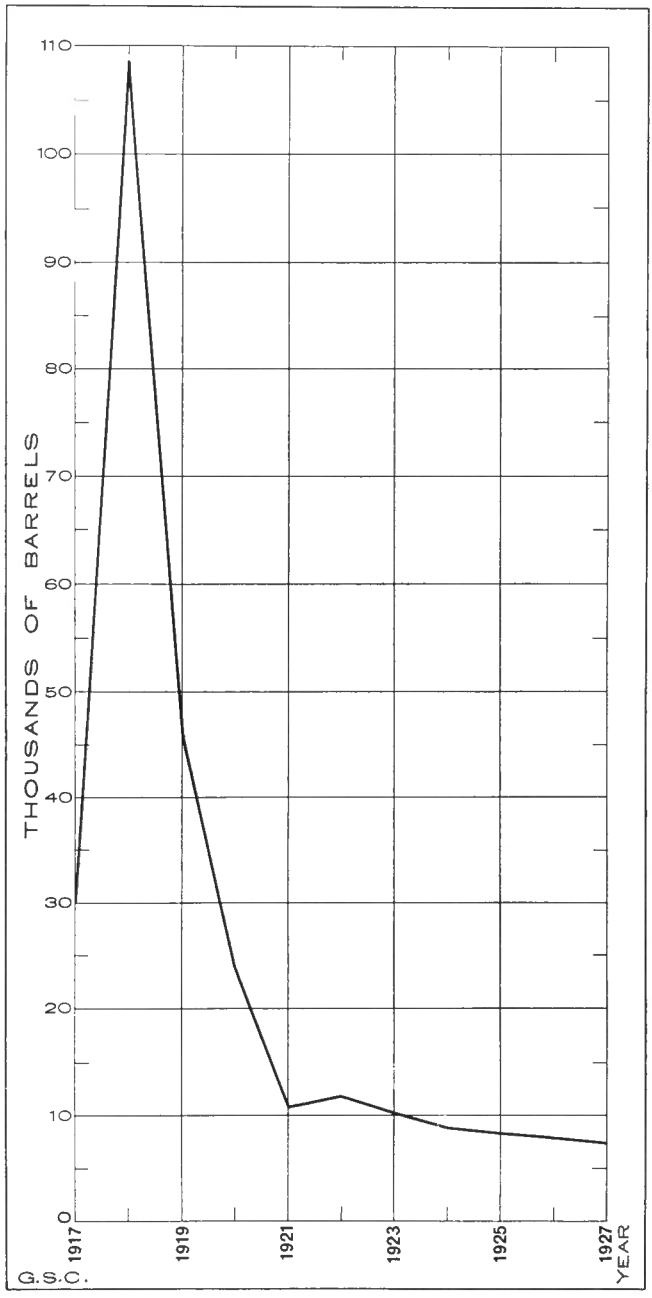

Figure 11. Graph showing annual production of Mosa oil field, Mosa township, Middlesex county, Ontario.

grey limestone containing considerable sand. The sandstone generally carries black water containing much hydrogen sulphide and probably a small amount of salt. The dolomite below the sandstone does not carry oil.

The general practice in the Mosa field has been to drill only about 50 feet into the 'lower lime' or just to the bottom of this Delaware limestone, as it is delimited. By this practice no water troubles have been met. Some companies, however, operating around the edge of the dome, have persisted in drilling into the sandstone mentioned above. Although this sandstone appears close grained in many places and so does not always give immediate trouble with water it has generally been found that water sooner or later became troublesome."

The top of the dome, however, produced some oil from this sandstone.

The Mosa field, according to Harkness,[1] covers about 4,000 acres. The field is roughly oval in shape with the long axis northwest and southeast and the closure on top of the Delaware limestone is about 70 feet with the maximum elevation on this horizon at 450 feet. The production of this field up to the end of 1927 amounted to 264,500 barrels. This represents a very small recovery per acre. The yearly production of this field is now 7,000 to 8,000 barrels.

ELGIN COUNTY

Dutton

The Dutton oil field is in Dunwich township, Elgin county. The field was opened in 1898. The stratigraphic succession in this field is shown by the following log[2] of a well drilled near the centre of the field, on lot 13, concession X, Dunwich township.

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift	200	200
	Shale	7	207
Hamilton	Blue, clay shale	25	232
Delaware and Onondaga	Limestone	170	402

The shales of Hamilton age probably belong to the Olentangy. Oil was struck in this well at a depth of 392 feet or 160 feet below the top of the Delaware. The thickness of the Delaware at this locality is not definitely known, but presumably the oil zone is within the Onondaga formation.

According to Williams[3] the oil occurred in a dome, but oil was found much lower on the west side than on the east side of the field. The average yield of the wells a day was low. The first well drilled[3] penetrated 505 feet into the limestone or to a depth of 687 feet. A bed of oil-bearing rock 10 feet in thickness was encountered at 332 to 342 feet and a second one of the same thickness at 400 to 410 feet in depth. From the first of these beds 500 barrels of oil was pumped. It was then shut off and the second yielded one barrel a day during a 20-hour test. A small flow of gas was struck at 550 feet and the rock from 650 to 687 feet yielded artesian water. In other wells the oil-bearing stratum was as much as 20 feet in thickness. In certain parts of the field the drift lies directly on the limestone, but

[1]Harkness, R. B.: Second Triennial Empire Mining and Metallurgical Congress.
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 10.
[3]Ont. Bureau of Mines, vol. VIII (1899).

in other parts 25 to 30 feet of shale overlies the limestone. The best wells[1] were those that encounter shale overlying the limestone. The field at its maximum comprised about 400 acres. The oil produced was of excellent quality, having a gravity of 42 degrees A.P.I. and a dark green colour. The production in 1929 was only 148 barrels, so that the field is approaching exhaustion; the maximum production, according to Williams,[2] was in 1906 when 19,376 barrels were produced. According to Harkness[3] the Dutton field produced 186,651 barrels of oil from 1889 to 1927.

The Dunwich Oil Company[4] drilling in 1923 on lot 24, concession V, north of Dunwich, opened up a small gas field in the Onondaga formation. In this area only glacial drift overlies the Delaware-Onondaga limestone.

ESSEX COUNTY

Leamington or Mersea

The Leamington or Mersea Oil field is in Mersea township, Essex county, northeast of the town of Leamington. The field has a north and south trend and a small part of it extends into Tilbury West township, north of Mersea township. The length of the field is approximately 8 miles and the width a quarter of a mile to 2 miles, the greater part of the field being in lots 10, concessions 4 to 9, and lot 238, Talbot road. There were, also, two small areas on lots 8, concessions 5 and 6, which were productive. A small amount of production was also obtained near Comber, in Tilbury West township, directly north of the Leamington field. To the south and west of the Leamington oil field is the Leamington gas field. The Leamington gas field was discovered in 1888, but the Leamington oil field was not discovered until 1904 and was short lived.

The stratigraphy of the Leamington field is shown by the following log of Roslyn No. 1 well, lot 5, concession X, Tilbury West. This well is north of the Leamington field and south of Comber.

Formation	Description	Thickness in feet	Depth in feet
Onondaga and Monroe	Limestone	650	650
Salina	Dark shale-gypsum	130	780
	Grey dolomite—some shale	100	880
	Dark shale—gypsum	240	1,120
Guelph and Lockport (?)	Dolomite	530	1,650
Rochester (?)	Shale	10	1,660
Clinton	Limestone	20	1,680
Cabot Head	Red shale at top followed by dark shale	130	1,810
Manitoulin	Dolomite	20	1,830
Queenston	Red shale	260	2,090
Richmond and Lorraine	Dark shale	360	2,450?
Utica	Dark shale	120	2,570
Trenton and Black River	Limestone	848	3,418
	Arkose	5	3,423

[1]Malcolm, W.: Geol. Surv., Canada, Mem. 80, p. 63 (1915).
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 10.
[3]Harkness, R. B.: Ont. Dept. of Mines, vol. XXXVII, pt. V, p. 59 (1928).
[4]Ont. Dept. of Mines, vol. XXXIII, pt. V, p. 97.

In this well angular quartz grains in a calcareous cement occur at 410 feet in depth. The sample from 400 feet in depth contains a considerable amount of white sand; chert occurs in more or less amount from 400 to 450 feet. It is, therefore, possible that the stratum at 400 feet represents the horizon of the Sylvania sandstone, as Williams[1] has recognized much chert from samples of the Lower Monroe or Bass Island series from other wells in Essex county. The presence of chert, however, is not by any means a diagnostic feature, as it occurs in samples above the horizon of the supposed Sylvania in this well and is known to occur elsewhere at the base of the Detroit River series and in certain parts of the Onondaga. In the samples from this well it is not possible to tell whether or not any of the Upper Monroe or Detroit River series is present, or if present where to draw the division between the Detroit River series and the Onondaga.

The structure of the field is a long, narrow anticline or possibly a fault of small throw. Data are not at hand to determine the exact structure, but apparently there is a downward plunge northward and the gas field to the west of the south end of the oil field is structurally higher than the oil field.

According to Williams[2] the oil-bearing horizon of this field is probably in the lower Salina. It lies at a depth of 1,068 feet in concession IV, 1,107 feet in concession VIII, 1,109 feet in concession IX, and 1,307 feet north of Comber. In Roslyn No. 1 well from lot 5, concession X, there are dolomitic bands interbedded with shales from a depth of 980 to 1,080 feet. At 1,110 feet considerable gypsum occurs and for this reason the top of the Guelph is thought to be at 1,120 feet. It is not known whether this gypsum bed is a uniform feature throughout the field or whether the oil production was secured from above or below it. If the production comes from above it then the producing zone would be assigned to the Salina. From a study of the samples from Roslyn No. 1 well, however, it seems probable that the oil-producing zone was in the top of the Guelph, since the samples show a small trace of oil. The initial production of some of the wells was fairly large. According to Malcolm[3] "the Jackson well started with a flow of 400 barrels a day after it was shot, but fell off in a few days to 100 barrels per day and the Hickey No. 4 started with a flow of 1,200 barrels and fell off to about 200 barrels per day."

The production of the Leamington field was as follows:

1904	25,241
1905	No record
1906	39,652
1907	6,133
1908	9,334
1909	5,929
1910	141

Belle River

In Essex county, south of lake St. Clair, the Belle River field with twenty-five wells produced 2,200 barrels of oil from the Onondaga limestone[4] between the years 1913 and 1918.

[1]Williams, M. Y.: Geol. Surv., Canada, Mem. 111, Fig. 5, op. p. 88.
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 14.
[3]Malcolm, W.: Geol. Surv., Canada, Mem. 81, p. 66 (1915).
[4]Harkness, R. B.: Ont. Dept. of Mines, vol. XXXVII, pt. V, p. 59 (1928).

In this area the Onondaga limestone lies immediately below the surface drift. The oil produced from this field was heavy and "dead" and brought a price considerably less than the Oil Springs and Petrolia oil.

Pelee Island

According to Williams[1]

"Pelee island was first prospected about 1895 when seven wells were drilled on Grove avenue, near the eastern side of the island, for the Kingsville Oil and Gas Company of Canada. The first two produced some oil, the third flowed 400 barrels, and the last four were dry. The total estimated production was 450 barrels. In 1907 seven more wells were drilled in the same locality by the New York, Lake Erie Oil and Gas Company. Mr. Wm. J. Hussey, who drilled the wells, reports that they started with a production of four to twelve barrels per day and held up well for the twelve months during which they were pumped. He estimates the production for this time at from 3,000 to 4,000 barrels. Shipping was expensive and difficult and with unduly large operating expenses the field was forced to close down. The field suffered little from water troubles and the gas supply was sufficient for drilling and operating purposes. There was little production before shooting, but a steady production afterwards".

The oil rock lies about 742 to 762 feet below the surface which is here about 575 feet above sea-level. According to a log given in the Fourteenth Report of the Bureau of Mines, Ontario, the section is as follows.

Formation	Description	Thickness in feet	Depth in feet
Surface	Drift, etc	58	58
Delaware and Onondaga	Limestone	222	280
Oriskany (?)	Sandstone (?)	44	324
Bass River and Salina	Dolomites, etc., with gypsum	458	782

Unless the formations, as shown in the log, are about 300 feet thinner on Pelee island than on the mainland in the vicinity of Leamington, this well did not reach the Guelph. As already stated the oil was struck at from 742 to 762 feet from the surface and so must occur in the Salina.

"Another small oil field was opened up near Pelee island south, about one mile west of Mill point. Little could be learned of this field, but the production is said to have been obtained from an horizon 780 feet below the surface. This would suggest that possibly there are two producing horizons. The Corniferous (Onondaga) limestone outcrops at the shore west of Mill point, whereas it was struck in the oil field to the north at a depth of 58 feet. However, the difference in elevation of the surface of the Corniferous (Onondaga) may be due to glacial erosion. The Corniferous (Onondaga) limestone outcrops on the north side of the island about one mile west of Scudder, where notable glacial erosion is evident, and also near the oil pier at the northwest part of the island, where considerable quarrying was formerly carried on. In the northern outcrop the limestone lies in a horizontal position, but on the shore at Pelee island south, the strike is parallel to the shore, the dip being several degrees to the southeast. Other wells have been drilled on the island, but large areas have not been explored. The Pelee Island oil field was never troubled with water and as little drilling has been done, the field may be considered pretty much as new territory, the past development indicating that fair quantities of oil and gas may be found. The attitude of the rock at Pelee island south, taken together with that on the northwest corner of the island, indicates that a dome, or at least a terrace, exists somewhere between the two localities. The structure will probably continue downward to the oil-bearing strata.[2]

Pelee island produced 1,023 barrels[3] of oil in 1904 and 378 in 1906. The quality of the oil is reported to have been good."

[1]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1919, pt. E, p. 14.
[2]Williams, M. Y.: Op. cit., p. 15.
[3]Information from Ont. Bureau of Mines, vol. XIV, p. 20 (1905).

BRANT COUNTY

Brantford

During 1888 a well was drilled[1] 1,118 feet deep by the Waterous Engine Company in the yard of their works on Dalhousie street, Brantford. Small shows of gas of no commercial importance were obtained. The well probably penetrated to about the base of the Queenston shales.

In the same year another well was sunk on lot 16, concession XV, Brantford township. In this well only small flows of gas of no significance were encountered. The well reached a depth of 2,160 feet or 210 feet below the top of the Trenton. Flows of water accompanied by a little gas were found between 200 and 300 feet in depth and a small flow of gas at 1,950 feet, undoubtedly from the top of the Trenton.

According to the Bureau of Mines[2], Ontario,

"In the latter part of 1903 drilling was begun for gas in the city of Brantford. From two or three wells put down at the Cockshutt plough works a strong flow of gas was obtained. This gas was used in the furnaces at the works for a short time when the pressure began to lessen and the supply soon became too small to keep the furnaces going. It was then found, however, that two of these wells contained oil which appears to have gradually oozed in as the gas disappeared . . . . With a hand pump used for only a short time daily three or four barrels of oil have been taken from one well from day to day . . . . Six or seven wells have been drilled in the city, four of which are on the Cockshutt property and only one of the seven is said to contain neither gas nor oil. Four wells have been drilled on the Bow Park farm which is distant about 2 miles southeast of the Cockshutt wells. Gas and oil have been found in these wells. In the last one drilled it is stated that oil began to come almost immediately after the bottom of the well was reached and kept rising in the pipe until now it has come to the top and the gas pressure will force it out, the same as it did in the two wells on the Cockshutt property."

The log of No. 2 well, Bow Park, drilled in 1903, is as follows:

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	88	88
Guelph and Lockport	Limestone	252	340
Rochester	Shale	50	390
Clinton	Limestone	20	410
Cataract-Medina	Red shale	40	450
	Grey shale	40	490
Whirlpool	White sandstone	15	505
Queenston	Red shale	77	582

Gas was found at 395, 505, and 508 feet with a pressure of 265 pounds. This gas evidently comes from the Clinton and Whirlpool formations. Williams[3] interpreted the red shale between 410 and 450 feet and the 40 feet of underlying grey shale as belonging to the Cabot Head formation. The upper 40 feet of this, that is the red shale, was formerly called the Red Medina, whereas the 15 feet of white sandstone between 490 and 505 feet was formerly called the White Medina.

[1]Brumell, H. P. H.: Geol. Surv., Canada, vol. V, pt. II, pt. Q, p. 44 (1890-1).

[2]Ont. Bureau of Mines, vol. XIII, pt. 1, p. 25 (1904).

[3]Williams, M. Y.: Geol. Surv., Canada, Mem. 111, fig. 4.

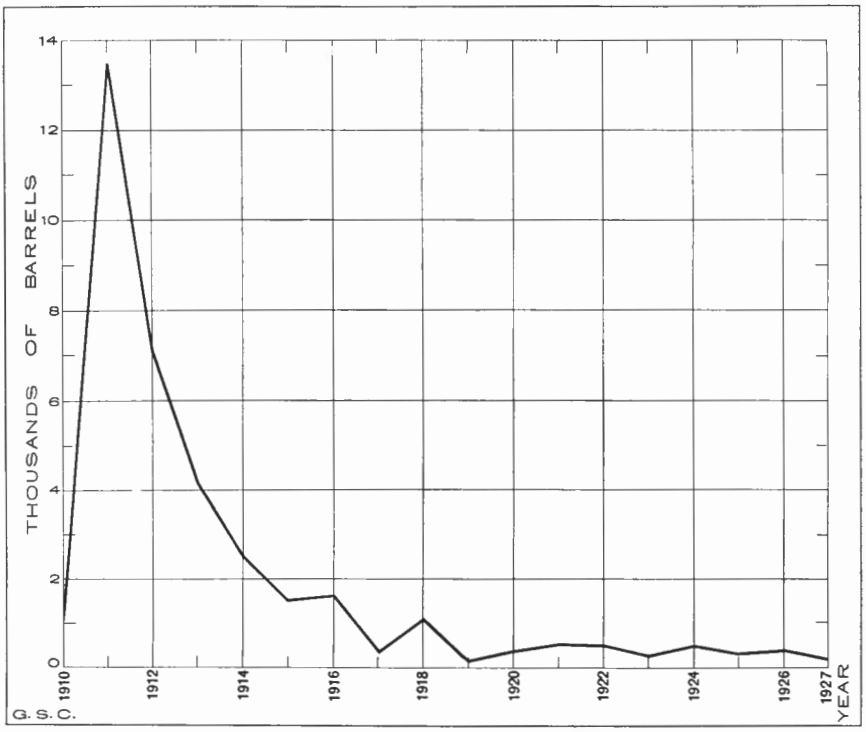

Figure 12. Graph showing annual production of Onondaga oil field, Onondaga township, Brant county, Ontario.

The log of Cockshutt No. 3 well in Brantford is interpreted as follows:

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	82	82
Guelph and Lockport	Dolomites	283	365
Rochester	Black shales	45	410
Clinton	Limestone	12	422
Cabot Head	Red shale	45	467
	Grey shale	45	512
Whirlpool	Sandstone	20	532
Queenston	Red shales	88	620

Gas and oil were found in the Whirlpool sandstone at 512 feet.

In the record[1] of a well drilled by Gould, Shapley, and Muir Company on Wellington street, Brantford, the Whirlpool (White Medina) was reported to occur at a depth of 505 to 515 feet and red shales (Queenston) from 515 to 670 feet. Gas was struck at 610 feet and evidently must have come from the Queenston shales. Such an occurrence is unusual.

Nine wells were drilled on the Bow Park farm and one of these struck the Trenton formation at a depth of 1,930 feet. The production from these wells was relatively small and unimportant from a commercial standpoint.

Onondaga

An oil-producing territory[2] was opened up in Onondaga township in 1910, the discovery well being drilled on the farm of Mr. Harold Howell on lot 16, concession III, west of Fairchilds creek. The oil was found in the Whirlpool sandstone (White Medina) at a depth of 550 feet. In some of the wells subsequently drilled sufficient gas was associated with the oil to flow the wells for a few months.

The best well is said to have produced forty barrels of oil a day for twenty days. The oil had a gravity of about 39 degrees baumé and was found over an area of about 3 square miles. Territory producing natural gas adjoins the oil area to the south.

MANITOULIN ISLAND

[3]"An oil spring was early discovered on Smith bay near the Indian village of Wekwemikong by the Jesuit missionaries, the pioneer among them being Father Poncet who spent the winter of 1648-49 on some part of the island.

In the early sixties, following the oil development at Titusville, Pa., and in southwestern Ontario, a Montreal company drilled five wells on Manitoulin island, the location being near the Smith Bay oil spring as indicated by tradition and field evidence.

This enterprise was abandoned on account of trouble between the drillers and the Indians.

[4]In 1905 the Northern Oil and Gas Company drilled several holes about 2 miles southeast of Wekwemikong and about 500 barrels of petroleum were produced. About the same time the Benedum-Trees Oil Company of Pittsburgh, Pa., were drilling in the vicinity of Manitowaning, several wells west of the town starting with considerable flows of oil. Drilling was also carried on near Gore bay, and one unfinished well was drilled at Providence bay. The hard times of 1907 caused a cessation of drilling and no new development was undertaken until 1912 when Senator Pascal Poirier leased property south of

[1]Ont. Bureau of Mines, vol. XIV, p. 106 (1905).
[2]Ont. Bureau of Mines, vol. XX, p. 36 (1911).
[3]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1920, pt. D, pp. 26-32.
[4]Malcolm, W.: Geol. Surv., Canada, Mem. 81, p. 85 (1915).

Pike lake (about 3 miles southwest of Sheguiandah) and started to drill. Conditions arising from the Great War resulted in the closing down of these operations. The anxiety regarding oil supply at the close of the war once more focused attention on Manitoulin island where several thousands of acres of oil leases were taken up in 1919 and 1920. The Kyto Oil Company re-leased the Poirier and adjacent properties and drilled three wells during the summer of 1920, and H. C. Gordon drilled two wells within the west margin of the property tested previously by Benedum-Trees. Results of the drilling during 1920 verified the previous reports from the same areas, viz., that oil occurred but not in commercial quantities. Valuable data were, however, obtained from the well records.

The oil spring which attracted the Jesuit's attention is located on the south side of Smith bay about 4 miles from Wekwemikong. It is at the level of the water of the bay and is only about 10 feet from the shore, the waves washing into it in rough weather. A thick scum of oil covers the surface of the spring, which shows no visible flow.

Of the five wells drilled by the Montreal company in the early sixties,[1] two were located near the oil spring mentioned, the caved-in pits being still visible. According to Hunt, the greatest depth reached was 524 feet, the log being as follows:

Description	Thickness in feet	Depth in feet
Soil	32	32
Black shale	100	132
Limestone	340	472
Red sandstone	150	524

Saline water was struck at 192, and oil at 193, 248, and 270 feet, about one hundred and twenty barrels of "Excellent petroleum" being produced before the supply failed. A few barrels were obtained from another well, and two wells were not complete when the report was made.

Of the 1905 operations, the only evidence seen by the writer is an abandoned well located about 1¼ miles south of Wekwemikong. The ground around the well is saturated with oil for a radius of several yards, this evidence corroborating the statement of one of the Indians that the oil gushed for some time—or, until the well was shot. This was probably the well that produced most of the 500 barrels of oil mentioned by Malcolm.

A number of abandoned wells mark the area tested by Benedum-Trees and others in the vicinity of Manitowaning.

About 1½ miles west of Manitowaning, five old wells are located on lot 45 and one on lot 46, con. II, Assiginack tp. Of these three have oil in the casings at the present time and one was dipped for local use by means of a tripod and sand pump until some time after 1912 when the tripod was blown down. Gas is bubbling up in three of these wells. Other wells noted are located as follows: one near the middle of the east side of lot 51, con. I, Assiginack; one in the northeast corner of the same lot; one near the middle of the east line of lot 20, con. I, Sheguiandah; and one 1¼ miles south of Manitowaning at the top of the hill above the bay. A well flowed gas for some years on the Tucker farm, lot 35, con. II, Assiginack, and a show of oil is reported from a well on lot 30, con. II, of the same township. There were other wells, of which no record is available, drilled in this vicinity.

The following logs were furnished by the Benedum-Trees Oil Company.

Well on James A. Watson farm, lot 46, con. I, Assiginack tp.

	Top	Bottom
Richmond limestone	6	130
Lorraine and Utica shale	130	305
Trenton limestone	455	566
Oil	464	474

Well on Lehman farm, lot 45, con. I, Assiginack tp., drilled in 1907

	Top	Bottom
Richmond limestone	14	130
Lorraine shale	130	410
Utica shale	410	430
Trenton limestone	430	.....
Oil and gas	442	477

NOTE. This well is said to have produced forty-five barrels of oil in 15 minutes.

[1]Hunt, T. S.: Geol. Surv., Canada, 1863-66, pp. 252-253.

Several wells were drilled during this period in the vicinity of Gore Bay [west of Kagawong], and several produced some oil. A well located near the wharf (now covered by a stable) at Providence bay is said by the driller, H. F. Slater of Toronto, to have struck the Trenton at about 960 feet, and to have penetrated about 100 feet when the tools were lost. This is the only record of a well drilled on the south side of the island.

The operations started by Senator Poirier about 1912 were principally centred about lots 3 and 4, cons. VIII and IX, Bidwell tp. At least twenty wells were drilled at this locality, of which eleven are said to have produced oil, and three to have had traces of oil. The drilling contractor stated that some of these wells produced as much as twenty-seven barrels a day for a short time. Four are reported as "dry". Following is analysis of a sample of oil from Renny Byers' farm, lot 3, con. IX, Bidwell tp., Green bay, Manitoulin island.

Specific gravity at 15·5° C.—0·864

Distillation—continuous method

First drop	100°C.
Up to 150° C	10%
150°–200° C	7%
200°–250° C	8%
250°–300° C	11%
300°–350° C	18%
Residue (by difference)	46%

Calorific value:

Calories per gramme gross	10,600
B.T.U. per lb. gross	19,080

Sulphur:

0·2%

Poirier also drilled a well on the south end of lot 34, con. I, Howland tp., and another on the north end of lot 24, con. XI, Bidwell tp. Both of these wells are reported by local observers to have stopped in the Utica shale. A well which flows salt water is located near the road on lot 25, con. XI, Bidwell tp., but the data regarding the well or the source of the water are not at hand. During 1920, three wells were drilled on the old Poirier leases, No. 1 being dry, No. 2 producing some oil with a small amount of salty, sulphur water, and No. 3 not being reported on. The top of the Trenton in No. 2 is 9 feet higher than in No. 1. The log of No. 1 as determined by the writer from samples is as follows:

Well Drilled by Kyto Oil Company, Near Southeast Corner of Lot 4, Con. IX, Bidwell Tp.

Formation	Description	Thickness in feet	Depth in feet
Surface	Clay, etc	5	5
Richmond	Limestone	11	16
Lorraine	Grey shale	356	372
Utica	Black shale	28	400
Trenton	Light-coloured, hard, semi-crystalline limestone	9	409
	Show of oil at		418

Of the two wells drilled by H. C. Gordon, west of Manitowaning, No. 1 is situated about 70 yards from the east line and 90 yards from the north line of lot 50, con. II, Assiginack tp. The top of the well is about 10 feet below the base of the Manitoulin dolomite, of the Cataract formation, as exposed a few rods away, and the log, taken by the writer, from the samples, is as follows:

Formation	Description	Thickness in feet	Depth in feet
Surface	Drift, etc	5	5
Richmond and Lorraine	Hard, dark grey limestone and shale	360	365
Utica	Grey shale	20	385
	Brown shale	65	450
	Black shale	15	465
Trenton	Grey, semi-crystalline limestone	15	480
	Calcareous shale	5	485
	Grey, semi-crystalline limestone	65	550

This well was dry except for a small show of gas.

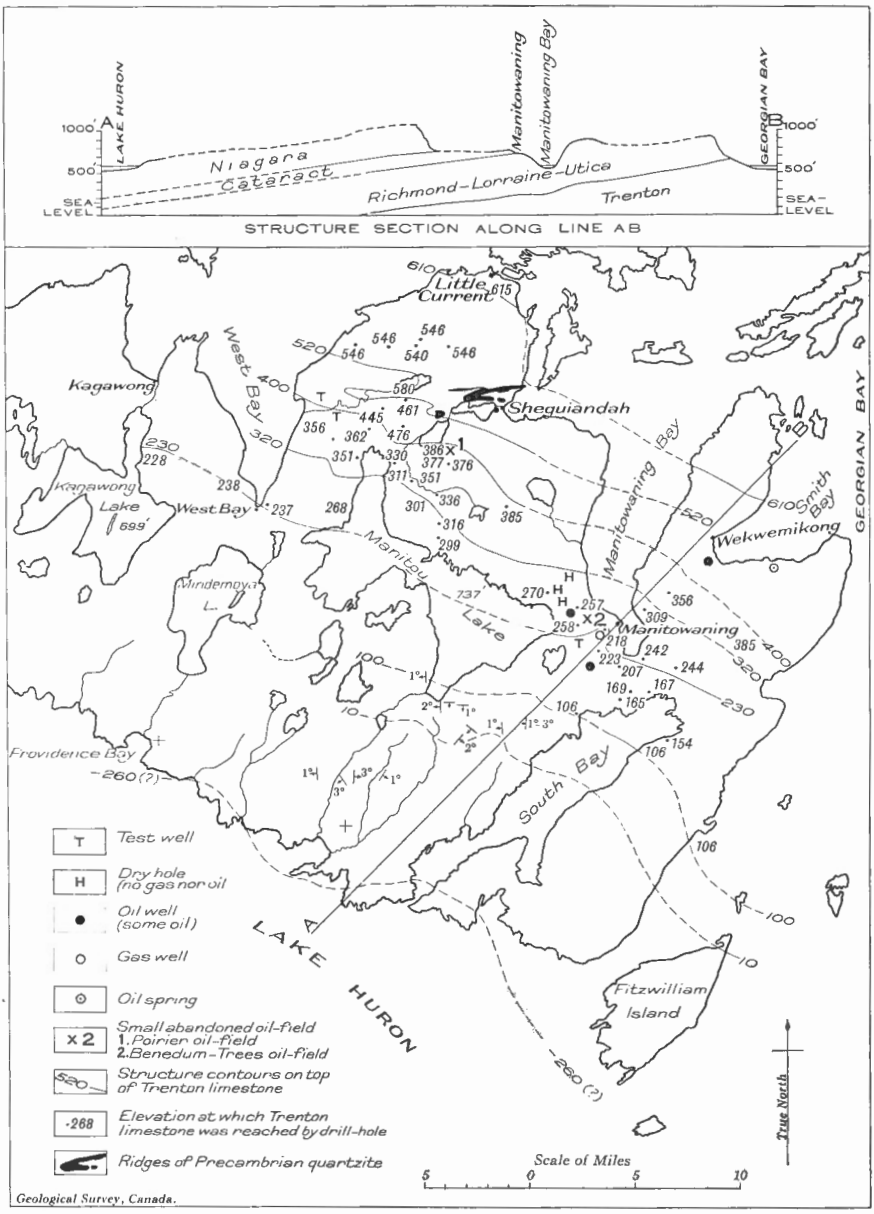

Figure 13. East part of Manitoulin island, Ontario.

No. 2 well is located on lot 45, con. II, Assiginack tp., a short distance north of the main road and about 130 yards from the west side of the lot. The Trenton is reported to have been struck at about 445 feet from the surface. At about 17 feet in the Trenton limestone, considerable gas and a little oil were obtained. After shooting with dynamite there was little change, but considerable salt water was reported. Following is an analysis of oil from: A—lot 44, con. II, Assiginack tp.; B—M. W. Brett's farm, lot 6, north side of Hall street, Gore Bay.

——	A	B
Specific gravity—		
At 15·5° C.	0·877	0·881
Distillation—continuous		
First drop	220° C.	180° C.
Up to 250° C.	10%	9%
250°–300°.	20%	19%
300°–350°.	18%	18%
Residue (by difference)	52%	54%
Calorific value		
Calories per gramme gross	10,790	10,800
B.T.U. per pound gross	19,430	19,440
Sulphur	0·2%	0·2%

NOTE. The yield obtained between 300 degrees C. and 350 degrees C. is uncertain owing to the tube of the condenser being clogged with the wax formed. This holds for both samples.

As seen on Figure 3 (*See* Figure 13, this volume) the best oil wells are located well within the syncline the conditions being similar to those prevailing in the Trenton oil fields of Dover township, Kent county, Ont. Some water occurs in the wells of Manitoulin island, but it is not a normal flow such as is found in the shallow fields of southwestern Ontario. It has not been definitely established, either, that the water and oil occur in the same beds, although that is probably the case.

The oil appears to be confined to the upper 20 feet of the Trenton limestone, suggesting the Utica shale as its source. The water present may have entered the formation through the relatively nearby outcropping of the limestone beneath the water of North channel. The salt and sulphur content might readily be obtained from substances in the limestone such as entrapped sea salt and the oxidation products of iron pyrites.

Large areas of Manitoulin island have never been tested for oil, particularly in the southern half of the island. Here, the complications arising from bay and surface water are minimized, and as water does not appear to have controlled oil accumulation, the lower structural areas are probably at least as promising as the higher areas. In but few cases has drilling been continued deep into the Trenton formation, and it is possible that oil may occur at lower horizons than those tested."

HALTON COUNTY

Milton

According to Williams[1] "A number of wells have been bored into the Trenton formation in the vicinity of Milton, one of which produced some oil and two of which are producing small quantities of gas for domestic purposes." The following logs illustrate the stratigraphy.

[1]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1917, pt. E, p. 21.

Log of Well, Brandon Brickyard on East Half of Lot 14, Con. I, Trafalgar Township

Formation	Description	Thickness in feet	Depth in feet
Surface	Glacial drift, etc	5	5
Queenston	Limestone and shale	305	310
Richmond and Lorraine		753	1,063
Utica (including Collingwood)	Shale	109	1,172
Trenton	Limestone	640	1,812
Sandstone		5	1,817
Precambrian	Granite	3	1,820

A little gas was found at a depth of 300 feet, all of which was gone on the second day.

Log of Greenles Brothers Well North of Canadian Pacific Railway Station, Milton

Formation	Description	Thickness in feet	Depth in feet
Surface	Drift, etc	58	58
Queenston	Shale	177	235
Richmond and Lorraine	Limestone and shale	750	985
Utica (including Collingwood)	Shale	115	1,100
Trenton	Limestone	600	1,700
Precambrian	Red granite at bottom		

A flow of gas which is supplying three families for domestic use was struck at 1,610-1,620 feet depth.

In another well drilled in the Brandon brickyard on lot 15, concession I, Trafalgar township, a little oil was encountered in the Trenton. There was some difference of opinion in regard to the top of the Trenton in this well and the oil was said to be 247 or 302 feet below the top of the formation.

According to Williams, since

"no water has been reported from the Trenton formation, it is probable that such accumulations of oil and gas as occur have been produced by gravitation toward basin structures. This theory is supported by the fact that the two gas-producing wells are located on structure lower than that at the "oil well" of the Brandon brickyard. However, the wells drilled on lower structure to the south and west of the "oil well" produced neither gas nor oil."

GREY COUNTY

A small amount of oil has been found in the Trenton formation in Collingwood and St. Vincent townships, Grey county. The oil occurs in the Trenton formation which in this area is covered only by glacial drift. The amount of oil secured is insignificant.

The location and depth of wells that gave a small amount of oil are as follows, oil occurred at 80, 100, 375, 400, 450, and 500 feet.

Location	Depth
Lot 26, con. VII, Collingwood tp	600
Lot 27, con. VII, Collingwood tp	400
Lot 27, con. VIII, Collingwood tp	500
Lot 25, con. VII, St. Vincent tp	850

GAS FIELDS

ESSEX COUNTY

Leamington

The Leamington or Essex County gas field is said[1] to have been discovered through actions based on the fact that the Cincinnati arch contains gas in Ohio and on the belief that the structure crossed into Ontario. In 1888 the Ontario Natural Gas Company put down a well on the northwest corner lot 7, concession I, Gosfield township, and obtained a supply of gas. A company known as the Kingsville Citizens Natural Gas Association tried to make an arrangement with the Ontario Natural Gas Company to supply Kingsville with gas, but negotiations failed. The Kingsville Citizens Natural Gas Association then drilled a well on the shore of lake Erie in lot 3, concession I, Gosfield township, but this was a dry hole. In the meantime, the Ontario Natural Gas Company had leased all the land in this area and as no agreement could be reached with them by the Kingsville Natural Gas Association, the latter obtained a permit to bore on the public roads and drilled a well on the crossing of the Wigle road and the 2nd concession line 70 yards northwest of the Ontario Natural Gas Company's well. This well was completed in 1890 and obtained gas at a depth of 1,025 feet in what was supposed to be the Clinton limestone. The capacity of the well was about 9,000,000 cubic feet a day and the rock pressure 500 pounds. Gas from this well was piped to Kingsville and Ruthven.

The third well of the Kingsville Natural Gas Association was put down on the northeast corner of lot 4, concession I, Gosfield township, and finished in 1891 at a depth of 1,114 feet with a flow of salt water. A fourth well, drilled on the northwest corner lot 7, concession I, Gosfield township, finished in December, 1891, at a depth of 1,063 feet, obtained gas at 1,030 feet with a flow of 2,231,000 cubic feet under a rock pressure of 400 pounds.

In the township of South Colchester two deep wells were put down at Marshfield station by Hiram Walker of Walkerville. One of these, finished in 1890 at a depth of 1,040 feet, yielded oil which was pumped for some time and gave 6 barrels a day. The second well, about 50 rods east of the first, was sunk to a depth of 1,300 feet and went through 35 feet of rock salt.

In 1893 the gas wells of Essex, eight in number with a capacity of 42,000,000 cubic feet a day, were supplying Kingsville, Ruthven, and Leamington and an 8-inch pipe line was laid to supply Sandwich, Windsor, and Walkerville, about 35 miles distant from the wells. In 1894 the pipe line was extended to Detroit and later also supplied Toledo. A new company,[2] the Natural Gas and Oil Company of Ontario, grew out of the Ontario Natural Gas Company and by 1895 had fourteen producing gas wells in Gosfield and Mersea townships. At this time the gas producing region had been exploited over a width of 2 miles from the lake northward and 12 miles east and west. The best wells were those farthest south near the lake, those farther north suffering from inflow of water. In 1900 the United Gas and Oil Company of Ontario, Limited, was formed and took over

[1]Ont. Bureau of Mines, vol. I, p. 115 (1891).
[2]Ont. Bureau of Mines, vol. V, p. 28 (1895).

the Natural Gas and Oil Company of Ontario, Limited, and the Standard Oil and Gas Company of Essex, Limited. In 1900 the output of gas, exclusive of privately owned and municipally owned wells,[1] amounted to about 3,000,000,000 cubic feet from fifty-two wells. Four years previous to this the production of the field is stated to have been 25,500,000,000 cubic feet a year. This great decrease in capacity caused considerable apprehension regarding the life of the field, and export of gas to Toledo ceased in July, 1900, and to Detroit on December 10, 1909. At this time the export of gas to Detroit amounted[2] to 1,500,000,000 cubic feet a year, or about half of the available supply.

In 1903, after about nine years' production, the Essex field very suddenly ceased[3] to produce. There is in the field a high-pressure, water-bearing formation below the gas and most of the wells were drilled into this water. The result was water flooding of the gas sands and instead of a long period of small production following flush production, the gas flow suddenly ceased. The initial pressure of the field was about 450 pounds and the pressure when the field ceased to produce was reported as 310 pounds.

When the gas was first found it was thought the production was from the Clinton, but in reality the gas came from the top of the Guelph. The stratigraphy of the field is given by the following log of Coste No. 1 well on the northwest corner of lot 7, concession I, Gosfield township. This was the largest well in the field, with an initial flow of 10,000,000 cubic feet a day at a depth of 1,020 feet.

Description	Thickness in feet	Depth in feet
Surface	120	120
Brown and grey, dolomitic limestone with gypsum and with white and black flint	380	500
Grey-blue and shaly dolomites and drab-brown dolomites with a good deal of gypsum	360	860
Dark brown dolomites and gypsum (with gypsum beds from 970-985 feet)	160	1,020
Grey-blue, crystalline, vesicular dolomite	11	1,031

A little gas occurred at 910 and 930 feet and a large quantity was found at 1,020 feet.

It is difficult, in the absence of samples, to state to what formation the rock at 120 feet in this well belongs, but it is probably Onondaga as indicated on the geological map.[4] The remainder of the well down to 1,020 feet undoubtedly is Detroit River series and Salina and the 11 feet of grey-blue, crystalline, vesicular dolomite from 1,020 to 1,031 feet is probably Guelph.

The structure of the Essex gas field has never been fully described. The rock is said[5] to dip north at the rate of about 75 feet to the mile and the area from which the gas was obtained was supposed to be the northern slope of an anticlinal fold. Between Coste No. 1 well on northwest corner

[1]Ont. Bureau of Mines, vol. X, p. 19 (1901).
[2]Ont. Bureau of Mines, vol. XI, pp. 44-5 (1902).
[3]Harkness, R. B.: Second (Triennial) Empire Mining and Metallurgical Congress, 1927, p. 24.
[4]*See* Geol. Surv., Canada, Map No. 1715, accompanying Mem. 111, 1919.
[5]Ont. Bureau of Mines, vol. IX, p. 105 (1900).

of lot 7, concession I, Gosfield township, and well No. 3 of the Ontario Natural Gas Company, Limited, on lot 8, concession II, Gosfield township, in a distance of three-quarters of a mile there was found to be a difference of 80 feet in the height of the producing horizon and Coste accounted for this by a fault trending west-northwest and passing a little to the north of Coste No. 1 well. The downthrow on this fault was on the north side and whereas Coste No. 1 came in with a gas flow of 10,000,000 cubic feet a day the well of the Ontario Natural Gas Company contained only salt water. Another small fault west of Coste No. 1 well and at right angles to the other fault was also described by the same author.[1]

The result of these structural conditions in the Essex field was that the most desirable locations for gas were near lake Erie, whereas inland the wells were unproductive, or at least had a short productive life speedily becoming drowned out by salt water. Even within the best productive territory, there were less productive or non-productive areas. This apparently was due to variations in porosity, the wells that encountered the largest porosity in the gas horizon giving the greatest gas flow, but becoming exhausted sooner than wells drilled in less porous rock.

Several of the wells in the Essex field had initial gas flows of 5,000,000 to 10,000,000 cubic feet a day. The field is estimated[2] to have yielded 22,500,000,000 cubic feet exclusive of waste, which in the early stages of development was enormous. The area that furnished the main production did not exceed 3 square miles and even at 10 cents per thousand cubic feet of gas, this means a value perhaps in excess of $1,000,000 per square mile.

WELLAND COUNTY

Welland Gas Field

The Welland gas field includes parts of Humberstone, Bertie, Crowland, and Willoughby townships.

The first company[3] to bore for natural gas in Canada was the Port Colborne Gas, Light, and Fuel Company of Port Colborne. They commenced operations in 1885. The first well was drilled near the village of Port Colborne and had a capacity of 7,000 cubic feet a day coming from a depth of 763 feet. The success of this well led to considerable drilling and within the next few years a number of gas wells were completed.

The Mutual Natural Gas Company of Port Colborne, organized in 1891, put down a well on lot 29, concession I, Humberstone township, to a depth of 831 feet, obtaining a flow of gas of 100,000 cubic feet at 685 feet. Their second well, on lot 29, concession II, Humberstone township, was bored to a depth of 705 feet and gas was struck at 690 feet with a yield of 1,500,000 to 2,000,000 cubic feet a day at a pressure of 365 pounds. This company laid the pipes in Port Colborne for the use of gas.

In 1889 the Provincial Natural Gas and Fuel Company of Ontario was organized[4] by Eugene Coste and their first well was drilled on lot 35, concession III, Bertie township. This well had a flow of 2,050,000 cubic feet a day from a depth of 846 feet, from the Whirlpool sandstone. Following the completion of this well, many other wells were drilled and in two of

[1]Coste, E.: "Natural Gas in Ontario"; Jour. Can. Min. Inst., vol. III, p. 74 (1900).
[2]Ont. Bureau of Mines, vol. XXV, pt. 1, p. 39 (1916).
[3]Ont. Bureau of Mines, vol. I, p. 129 (1891).
[4]Ont. Bureau of Mines, vol. I, p. 132 (1891).

these north and west of Sherkston (No. 20 well on lot 10, concession III, Humberstone township, and No. 28 well 1,500 feet west and north of the other) a small amount of oil of 44·5 Bé. gravity was reported by Mr. Coste. In one of these wells[1], No. 20, the oil was struck at a depth of 770 feet in the Medina sandstone.

In January, 1891, the Provincial Natural Gas and Fuel Company began the export of gas to Buffalo. The pressure of the wells was 500 to 550 pounds and the flow per well from 300,000 to 12,500,000 cubic feet a day, with the open flow of fifteen wells averaging 2,500,000 cubic feet. Boring had been carried on over an area of 28 square miles, stretching 4 miles north and south and 7 miles east and west. Forty-nine wells were drilled[2] in 1891, of which thirty-six were producers. At the end of 1891 there were sixty-five producing wells in the Welland area.

In 1899 an extension of the field was made into Willoughby township, the gas being obtained in the Medina at 900 feet at a pressure of 250 to 400 pounds. At the end of 1900 there were seventy-five wells in the Welland field attached to the pipe-line, and the capacity of the wells amounted to 700,000,000 cubic feet a year.

The finding of natural gas led to the drilling of a number of wells by independent producers. Caroll Bros., who were burning limestone for lime on the lake shore in Humberstone, drilled their first well for gas to use as fuel, in 1890.[3] This well was a failure, although located within 100 yards of one sunk by the Provincial Natural Gas Company and which yielded 5,000,000 cubic feet a day. Their second well, however, was a success. In 1891 Caroll Bros. united with the Erie County Gas Company of Buffalo and a pipe-line was laid down from their gas wells in Humberstone to Buffalo. In 1901 they had twenty wells producing gas, mostly for fuel in burning lime.

According to Harkness[4] the original rock pressure of the Welland field was 510 pounds in the Medina and 360 pounds in the Clinton. The average pressure in 1890 was 430 pounds. By 1900 this pressure had dropped to 173 pounds with pressures as low as 125 pounds in some parts of the field. The production declined rapidly after 1900. The export of gas ceased in 1908 when distribution was limited to Welland County consumers. The city of Welland had been using gas since 1893 and Niagara Falls since 1904, but in 1920 the service became so poor that consumers in Welland and Niagara Falls were forbidden to use the gas except for heating water and cooking. The decline in pressure is illustrated by a well drilled in 1925 which gave a flow of only 25,000 cubic feet at a pressure of 65 pounds. At this time in certain parts of the field the pressure had dropped to 20 pounds.

In the summer of 1924, according to Harkness,[5] the Provincial Natural Gas and Fuel Company arranged with the Iroquois Gas Company of Buffalo

"for a supply of their gas, which is a mixture of natural gas, some coke oven gas, and a little carburetted water gas. The B.T.U. of the mixture averages 910 and the B.T.U. of the natural gas from the Welland field is 1,009 . . . . The two gases were introduced into the pipe-line near Bridgeburg [now Fort Erie] and mix while travelling through the 8-inch pipe-line to Niagara Falls, a distance of about 18 miles."

[1]Note. For maps of the gas fields of Niagara peninsula *See* Harkness, R. B.: Ont. Dept. of Mines, vol. XXXVII, pt. V (1928).
[2]Ont. Bureau of Mines, vol. II, p. 10 (1892).
[3]Ont. Bureau of Mines, vol. I, p. 134 (1891).
[4]Harkness, R. B.: Ont. Dept. of Mines, vol. XXXIV, pt. V, p. 18 (1925).
[5]Harkness, R. B.: Op. cit., p. 19.

Eugene Coste[1] published four logs of wells of the Provincial Natural Gas and Fuel Company which illustrate the stratigraphy of the Welland County field. These are as follows:

Well No. 1, Lot 35, Con. III, from Lake Erie, Bertie Township. Elevation 618 Feet

Formation	Description	Thickness in feet	Depth in feet	Remarks
Surface	Soil	2	2	
Onondaga[2]	Dark grey limestone	23	25	
Salina[3]	Grey and drab dolomite and black shales with gypsum.	390	415	Fresh water cased off at 284
Guelph and Lockport[4]	Grey dolomites	240	655	Salt water at 548 feet
Rochester[5]	Blue shales	50	705	
Clinton	White crystalline limestones grey and shaly towards bottom	30	735	A little salt water
Medina-Cataract series[6]	Red sandstone	55	790	
	Red shale	10	800	
	Blue shale	8	808	
	White sandstone	5	813	
	Blue shale	20	833	
	White sandstone	13	846	Gas at 836 feet

Well No. 14, Lot 6, Con. XV, from Niagara River, Bertie Township. Elevation 605 Feet

Formation[7]	Description	Thickness in feet	Depth in feet	Remarks
Surface	Clay	38	38	
Salina	Dolomites, grey and drab, black shale, and gypsum	300	338	
Guelph and Lockport	Grey dolomites	230	568	Salt water at 470 feet
Rochester	Blue shales	60	628	
Clinton	White and grey limestones	32	660	
Medina-Cataract	Red sandstone	83	743	A little gas
	Blue shale	15	758	
	White sandstone (Whirlpool)	16	774	
Queenston	Red shales	850	1,624	
Lorraine	Blue shales with lime shells	730	2,354	
Utica	Black shales	.....	.....	
Trenton	White and grey limestones	685	3,210	
"Basal arkose"	Yellowish sandstone	45	3,255	A little salt water
Precambrian	Mica schist	2	3,257	

[1]Coste, Eugene: "Natural Gas in Ontario"; Jour. Can. Min. Inst., vol. III, pp. 75-77 (1900).

[2]Called Corniferous by Coste. [3]The Salina was originally called Onondaga. [4]Called Niagara. [5]Called Niagara shales by Coste. [6]Medina-Cataract here includes Thorold, Grimsby, Cabot Head, Manitoulin, and Whirlpool. *See* M. Y. Williams: Geol. Surv., Canada, Mem. 111, Fig. 4.

(The White sandstone 833-846 is the white Medina of drillers and is the Whirlpool sandstone.)

[7]The formation names are by the author.

Well No. 22, Point Albino, Bertie Township. Elevation 580 Feet

Formation	Description	Thickness in feet	Depth in feet	Remarks
Surface	Sand	10	10	
Onondaga	Grey limestones with flint	82	92	
Salina	Grey and drab limestones, blue shales, and gypsum	388	480	
Guelph and Lockport	Grey dolomites	235	715	
	Gas in large quantity at 500, 530, and 580 feet. Salt water at 600 and 630 feet			
Rochester	Blue shales	55	770	
Clinton	White limestones	30	800	
Medina-Cataract	Red sandstone	80	880	
	Blue shale	13	893	
	White sandstone (Whirlpool)	17	910	Gas at 902 feet

Well No. 61, Lot 2, Con. IV, Willoughby Township. Elevation 610 Feet

Formation	Description	Thickness in feet	Depth in feet	Remarks
Surface	Clay	18	18	
Salina	Dolomite and shales with gypsum	202	220	
Guelph and Lockport	Grey dolomites	220	440	Salt water at 330 feet
Rochester	Blue shales	50	490	
Clinton	White limestones	30	520	A little gas at 495 feet and a little salt water
Medina-Cataract	Red sandstone and shales	73	593	
	White sandstone	10	603	
	Blue shale	12	615	
	White sandstone (Whirlpool)	18	633	
Queenston	Red shales	830	1,463	
Lorraine	Blue shales	717	2,180	
Utica	Black shales	160	2,340	
Trenton	White and grey limestones	670	3,010	Gas at 2,940 feet 1,000 pounds rock pressure
Basal[1] arkose	Grey, coarse sandstone	19	3,029	
Precambrian	White quartz	1	3,030	

[1]Basal arkose called calciferous by Coste.

According to Coste

"These four wells are almost on a north and south line across the field in the following order from north to south: No. 61, No. 14, No. 1, and No. 22 and the distance between the two extreme wells north and south is 10 miles. We may point out from the above logs and from the records of the other wells now drilled in the field, to the number of 142, the following features:

(1) The strata dip to the south and southeast uniformly at the rate of about 35 feet to the mile, except for a small synclinal (about 1 mile wide and 30 feet deep) the axis of which is about 1 mile north of No. 22 well at point Albino.

(2) Salt water was struck in every well in large quantities towards the middle of the Guelph and (Lockport) Niagara formation. A little salt water is also found in the Clinton, in the White Medina (Whirlpool) gas rock and in the Calciferous (basal arkose) at No. 14, but in none of these formations below the Guelph and Niagara (Lockport) is there anything like a continuous body of salt water, which on the contrary lies there in disconnected small bodies of water.

(3) Besides being found in the strata indicated in the above logs gas was also found in some other wells in large quantity, 5 feet in Clinton limestone, 10 feet in the red Medina (Grimsby) sandstone, and in the upper white sandstone of the Medina. Some amber-green colour oil of a gravity of 42½ degrees baumé was also found in the last few feet of the lower white Medina (Whirlpool) sandstone at wells Nos. 20, 28, and 62. The gas in that sandstone is generally found 3 feet in from the top of it, but often also another vein is found 9 to 10 feet in."

According to Harkness[1] "The capacity of the wells appears to bear a greater relation to the character of the rock than to its attitude." In the Welland field "There is one marked fold running slightly east of north through point Albino." This fold, as well as another undulation which obliquely crosses Welland canal in the second concession of Humberstone, was described by Logan,[2] who concluded that the course of both was probably about southwest. These undulations seemed to have had little effect on the distribution of the gas, but since the Clinton and Whirlpool, the two main productive gas horizons, thin to the west and north, the most productive wells[3] were found along the margin of lake Erie where these formations are best developed.

The production of the Welland field to 1927 amounted, according to Harkness, to 37,000,000,000 cubic feet from more than 1,000 wells.

Winger Field

The Winger field,[4] in Wainfleet township, Welland county, was opened up in 1903. The field, as developed, comprised concessions IV and V between lots 25 and 31 and was outlined by dry holes, proving it to be a pool unconnected with other fields. The gas from this field was first used in January, 1904, when it was turned into the gas mains of the Welland field.

The stratigraphy of the field is practically the same as the Welland field and is illustrated by the log of the following well on lot 31, concession V, Wainfleet township.

Formation	Description	Thickness in feet	Depth in feet
Surface		144	144
Salina	Limestone and shale	171	315
Guelph and Lockport	Grey dolomite	160	475
Rochester	Blue shales	45	520
Clinton	White limestone	35	555
Medina-Cataract	Red sandstone	60	615
	Grey shales	25	640
	White sandstone (Whirlpool)	22	662

"Gas found at 640 feet in the white Medina (Whirlpool) sandstone, with 12 feet of gas sand, and at a rock pressure of 260 pounds."

This field was developed by the Provincial Natural Gas and Fuel Company and the Niagara Peninsula Power and Gas Company who piped the gas to St. Catharines. There is about the same regional dip in the Winger field as in the Welland field, i.e., about 35 feet to the mile to the south and southeast.

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[1]Harkness, R. B.: Second (Triennial) Empire Mining and Metallurgical Congress, Canada, 1927, p. 29.
[2]Logan, Sir William: "Geology of Canada, 1863," p. 521.
[3]Harkness, R. B.: Second (Triennial) Empire Mining and Metallurgical Congress, Canada, 1927, p. 29.
[4]Ont. Bureau of Mines, vol. XIV, p. 104 (1905).

HALDIMAND COUNTY

Haldimand County Gas Field

The Haldimand County gas field is very extensive and consists of a number of fields more or less surrounded by unproductive territory. The field includes wells in Walpole, Rainham, Cayuga North, Cayuga South, Dunn, Moulton, Canborough, Seneca, and Oneida townships, Haldimand county, and extends northeast into Gainsborough and Caistor townships in Lincoln, Binbrook, and Glanford townships, Wentworth county, and westward into Brant county where the Onondaga oil field occurs.

The regional dip in the field is to the south and between Caledonia and Dunnville is reported[1] to be 700 feet. Within this field there are a number of gentle folds. The Attercliffe field, about 5 miles northeast of Dunnville in the north part of Moulton and Canborough townships, is an anticline in the gas sand in the Whirlpool sandstone with a closure of 60 to 65 feet in an east-west direction. Another fold, of minor extent, is present in Seneca township and continues north into Binbrook township, Wentworth county. These folds seem to have had little influence on the production of gas, which rather depends on porosity within the productive horizon.

In the Haldimand gas area three horizons, namely the Clinton, the Red Medina (Grimsby) sandstone, and the White Medina (Whirlpool) sandstone, have proved productive of gas. The White Medina yielded some oil in the Onondaga field, Brant county.

The development of the Haldimand field dates from 1891 when the Dunnville Natural Gas Company was organized and the contract let for drilling a well at the eastern end of the village.[2] This well yielded, when finished, a small flow of gas from the Clinton at 612 feet and a larger flow from the Whirlpool sandstone between 740 and 752 feet. The total flow of the well was 150,000 to 200,000 cubic feet a day at a rock pressure of 375 pounds. Following the success of the first well, two others were at once put down and gas in about the same quantity as in the first was found in each. In the autumn of 1891 a well was also put down in the vicinity of Cayuga. Gas was found in the Clinton, in the Red Medina (Grimsby) sandstone, and the White Medina (Whirlpool) sandstone. The top of the Queenston was encountered in this well at 680 feet and the well was finished at 710 feet in depth with an estimated flow of 210,000 cubic feet a day.

Caledonia, Haldimand county, was supplied with gas in 1892, a number of wells being drilled in the vicinity of the town. In the course of drilling for gas the gypsum which later was mined, was discovered.[3] The gas at Caledonia was encountered at a depth of 400 to 500 feet at an original rock pressure of about 190 pounds. The gas is obtained in the Clinton formation.

Further drilling in Haldimand county led to the discovery of a number of fields more or less surrounded by unproductive areas. The Attercliffe field about 5 miles northeast of Dunnville was developed by the Citizens Natural Gas Company of Dunnville and the Dominion Natural Gas Company. The stratigraphy of this field is illustrated by the following log.[4]

[1]Clapp, F. G.: Mines Branch, Dept. of Mines, Pub. 291, 1915, p. 143.
[2]Ont. Bureau of Mines, p. 137 (1891).
[3]Ont. Bureau of Mines, vol. IV, p. 252 (1894).
[4]Corkill, E. T.: Ont. Bureau of Mines, vol. XIV, pt. 1, p. 105 (1905).

Formation	Description	Thickness in feet	Depth in feet
Surface		56	56
Salina	Limestone, shale, and gypsum	290	346
Guelph and Lockport	Grey dolomite	140	506
Rochester	Blue shale	40	546
Clinton	Dolomite and grey shale	33	579
Medina-Cataract	Red sandstone	40	619
	Grey shales	30	649
	White sandstone (Whirlpool)	20	669
Queenston	Red shales	20	725

Gas was found in the White Medina (Whirlpool) at 665 feet, having a flow of 72,000 feet a day.

The initial flow of the wells in the Attercliffe field was only a few thousand up to 100,000 cubic feet a day, except in the case of one well which flowed as much as 1,000,000 cubic feet.

Another field[1] was developed in Rainham and Walpole townships and is known as the Selkirk field. It extends along the lake shore for about 20 miles and back from the shore for 2 or 3 miles, extending north into Cayuga township at the east end. The productive strata reach south beneath the lake and wells have been sunk in the shallow water along the shore.

The gas is found in the White Medina (Whirlpool sandstone), the Clinton and the Red Medina (Grimsby) sandstone, the latter being the main productive horizon. As in the Attercliffe field structure does not seem to play a very important part in the distribution of gas, which depends, rather, on the porosity of the productive horizon. Dry holes occur in territory that would be expected to be productive. The depth of the productive gas horizon in the Selkirk field is 785 to 900 feet, dependent on location. The production of the wells varies from 100,000 to 1,000,000 cubic feet a day. The Selkirk field, as finally developed, included wells in Walpole, Canborough, Rainham, Cayuga South townships, Haldimand county, and Woodhouse township in Norfolk county.

The northern part of the gas area, partly in Haldimand but also including areas in Wentworth and Lincoln counties, has been called the Blackheath field. The stratigraphy of the field is illustrated by the following log from a well in Binbrook township, Wentworth county.

Formation	Description	Thickness in feet	Depth in feet
Surface		54	54
Salina	Limestone, etc	194	248
Guelph and Lockport	Limestone	60	308
Rochester	Shale	18	326
Clinton	Limestone	20	346
Medina-Cataract	Red sandstone	34	380
	Shale	48	428
	White sandstone (Whirlpool)	22	450
Queenston	Red shale	50	500

[1]Malcolm, W.: Geol. Surv., Canada, Mem. 81, p. 68 (1915).

A little gas was found in the Clinton at 334 feet and a little gas in the Red Medina at 361 feet. The main flow of gas of 190,000 cubic feet a day occurred in the White Medina (Whirlpool) sandstone at 438 feet. The initial rock pressure was 160 pounds.

Gas from the Haldimand field was transported by pipe-line to Dundas and Hamilton, as well as to centres of population within the field, such as Dunnville, etc.

ELGIN COUNTY

Bayham

The Bayham gas field in Bayham township, Elgin county, was discovered about 1910. The gas was found over an area having a frontage on lake Erie of about 1½ miles and lying in concessions I, II, and III, on both sides of Big Otter creek. The area of the field is about 5 square miles. The surface formation in this area has been mapped as Delaware limestone.[1] According to Stauffer[2], at certain places in Ontario the Marcellus black shale occurs between "the Onondaga and the usual basal limestone of the Hamilton" that is, in the position of the Delaware. The same author reports that "in the vicinity of Port Burwell and to the westward it (Marcellus shale) lies immediately under the drift and consists of 10 to 30 feet of black shale overlying the Onondaga limestone." The log of a well drilled one mile west of Port Burwell is interpreted by Stauffer as follows:[3]

Formation	Description	Thickness in feet	Depth in feet
Surface	Drift material	287	287
Delaware	Black shale	30	317
Onondaga and probably a portion of the Cayugan series	Cherty limestone reported as flint	280	597
Cayugan	Limestone and shale	490	1,087
Niagara	Limestone	270	1,357
Rochester	Dark shale	60	1,417
Clinton	Shale and limestone	26	1,443
Medina	Red and blue, arenaceous shales including a thin layer of white sandstone	112	1,555

KENT COUNTY

Kent

The Kent gas field, also called the Tilbury field, lies south of Tilbury oil field and is mainly in Tilbury East township, but extends into the adjacent townships of Romney and Raleigh. According to Harkness[4] "the field is rudely triangular in shape with its base extending 9 miles along the shore of lake Erie and its apex situated 7 miles inland." The Kent gas field was discovered in 1906 while drilling for oil. Its area as developed by 1910 consisted of 34·6 square miles[5] and extended under the lake. The stratigraphy of the field is shown by the following log of a well in the southeast corner of lot 6, concession IX, Tilbury East township, Kent county.

[1] *See* Geol. Surv., Canada, Map 1715.
[2] Stauffer, C. R.: Geol. Surv., Canada, Mem. 34 (1915).
[3] Stauffer, C. R.: Op. cit., pp. 107-8.
[4] Harkness, R. B.: Second (Triennial) Empire Mining and Metallurgical Congress, Canada, 1927, p. 26.
[5] Ont. Bureau of Mines, vol. XIX, pt. I, p. 149 (1910).

Formation	Description	Thickness in feet	Depth in feet
Surface	Drift	128	128
Hamilton	Blue shale (upper soap)	37	165
	Middle lime (Widder beds)	10	175
	Blue shale (lower soap)	67	242
Delaware and Onondaga	Limestone	158	400
Salina	Grey, drab, brown, and blue dolomites with gypsum and flint	1,020	1,420
Guelph	Blue-white, dolomitic limestone	9	1,429

Gas at 1,250, 1,362, 1,370, 1,376, 1,382 feet.

Oil at 1,392 to 1,400 feet and at 1,416 feet in the Salina and at 1,426 feet in the Guelph.

According to Harkness, there are, in this field, two to four producing horizons, but the thickness is extremely variable. In some of the wells a little gas is found in the sand and gravel at the bottom of the drift. Also, some gas is commonly encountered in the top of the Corniferous (Delaware and Onondaga). As shown in the log given above, gas occurs at a number of horizons in the Salina and in the Guelph. Below the gas horizon of the Guelph is a water horizon.

The best wells in the field were found close to lake Erie, the wells in some instances giving an initial flow of from 3,000,000 to 10,000,000 cubic feet a day.

Up to the end of 1927 the Kent gas field had produced[1] 135,687,-150,000 cubic feet. This does not include the leakage for the first fifteen years, a waste that, according to Harkness, amounted to 20,000,000,000 cubic feet. The rock pressure of the field was originally 750 pounds, in 1927 it had declined to 300 pounds. The Kent gas field is still a very important gas-producing area.

NORFOLK COUNTY

Middleton

In 1923 the Dominion Natural Gas Company opened up a new gas field at Delhi, Middleton township, Norfolk county. The stratigraphy of the field is illustrated by the following log[2] of well No. 111, Dominion Natural Gas Company, on lot 16, concession II, Middleton South township.

Formation	Thickness in feet	Depth in feet
Surface	245	245
Onondaga	220	465
Bertie-Akron	75	540
Salina	395	935
Guelph and Lockport	250	1,185
Rochester	50	1,235
Clinton	10	1,245
Grimsby	15	1,260
Cabot Head	5	1,265

[1]Harkness, R. B.: Second (Triennial) Empire Mining and Metallurgical Congress, Canada, 1927, p. 26.
[2]Ont. Dept. of Mines, vol. XXXIV, pt. V, p. 56 (1925).

Gas at 1,253 feet with an open flow of 600,000 cubic feet. Rock pressure 640 pounds.

The gas in this area comes from the Clinton formation.

Simcoe or Port Dover

The Simcoe or Port Dover area centres around the town of Simcoe and south to Port Dover in Woodhouse township, but extends west to Port Ryerse in Charlotteville township.

The stratigraphy of the field is shown by the following log[1] of a well by the Dominion Natural Gas Company in lot 8, concession II, Woodhouse township.

Driller's description	Thickness in feet	Depth in feet
Surface	28	28
Flint	57	85
Lime and shale	395	580
Niagara	305	885
Shale	41	926
Clinton	48	974
Shale	60	1,034
White Medina	12	1,046
Red shale	15	1,061

Gas found at 942 to 962 feet.

The top formation in this area, according to geological Map No. 1715, is Delaware limestone. It is impossible, however, to state what thickness belongs to the Delaware and Onondaga limestone and what thickness belongs to the underlying Salina formation. The "Niagara" is the Guelph and Lockport. The underlying shale is the Rochester shale. The shale beneath the Clinton presumably includes the Red Medina (Grimsby) sandstone, since this is known[2] from well records to extend as far west as Port Burwell. The red shale below the White Medina or Whirlpool sandstone is presumably Queenston red shale.

Gas is found in this area in the Clinton, the Red Medina (Grimsby), and in the White Medina (Whirlpool) sandstone. The depth of the Clinton is reported[3] to range from 500 to 1,200 feet, with an average of approximately 960 feet, with the Red Medina and White Medina, respectively, about 30 and 130 feet deeper. In thickness the Clinton is reported to be 25 to 35 feet, the Red Medina 30 to 40 feet, and the White Medina 10 to 30 feet. The original rock pressure was 475 pounds for the Clinton, 500 pounds for the Red Medina, and 700 pounds for the White Medina. The Red Medina is said to have been the most productive.

[1]Ont. Bureau of Mines, vol. XXIV, pt. II, p. 61 (1915).
[2]Williams, M. Y.: Geol. Surv., Canada, Mem. 111, p. 40 (1919).
[3]Clapp, F. G.: Mines Branch, Dept. of Mines, Ottawa, Pub. 291, p. 197 (1915).

Port Rowan

This field includes wells at Port Rowan and in Walsingham township. The stratigraphy is represented by the following log[1] of the Dominion Natural Gas Company on lot 8, concession A, Walsingham South township.

Driller's log	Thickness in feet	Depth in feet
Surface	315	315
Lime—probably Onondaga	175	490
Flint (probably Salina)	110	600
Sharp sand (probably Salina)	45	645
Lime and shale (probably Salina)	355	1,000
Niagara lime	255	1,255
Rochester shale	69	1,324
Clinton	20	1,344
Red Medina	50	1,394
Grey shale	64	1,458
White Medina (Whirlpool)	8	1,466
Red shale (Queenston)	2	1,468

The gas in this area is presumed to come from the Clinton formation. One well in the village of Port Rowan is reported[2] to have had an initial flow of 550,000 cubic feet.

PEEL COUNTY

Caledon

According to Harkness[3]

"one mile north of the village of Inglewood, in Caledon township, Peel county, there are three gas wells. The gas in these wells contains eight-tenths of one per cent helium. These are the only gas wells in the British Empire from which helium may be obtained in commercial quantities with our present knowledge and technique . . . . The gas in the Inglewood field is more suitable for helium extraction than most natural gases, on account of the very small quantity of ethane and higher hydro-carbons in it. The open flow of the three wells now capable of producing natural gas is 385,000 cubic feet per day and the rock pressure is about 50 pounds. The gas is found in the Dundas (Lorraine) shales of Ordovician age at from 400 to 600 feet below the surface. There does not appear to be any particular underground structure that would tend to form a point of accumulation. It is presumed that bands of crystalline limestone or sandy shale form the reservoir, such limestone and sandy shales being known to exist in this formation . . . . There have been only four wells drilled (1926) in this gas field at Inglewood all of which were producers, but of these one has since been abandoned on account of an accident to the casing which allowed water to flood the gas horizon."

Since this was written by Harkness, a well was drilled to test the field and if possible supply gas for research work which was to have been done by the University of Toronto in co-operation with the Research Council. Unfortunately, the new well when drilled gave such a small flow of gas under such low pressure that it was not deemed advisable to proceed with the research work as originally planned.

[1]Ont. Dept. of Mines, vol. XXXV, pt. V, p. 41 (1926).
[2]Clapp, F. G.: Mines Branch, Dept. of Mines, Ottawa, Pub. 291, p. 200 (1915).
[3]Harkness, R. B.: Ont. Dept of Mines, vol. XXXV, pt. V, p. 10 (1926).

BRUCE COUNTY

Hepworth

The Hepworth gas field in Bruce county was discovered in 1900. Gas occurs here in the Trenton formation.

The stratigraphy of the field is illustrated by the following log of the well of the Grey and Bruce Oil and Gas Company, Limited, lot 1, concession X, Amabel tp.

Formation	Thickness in feet	Depth in feet
Soil	4	4
Niagara and Clinton..?	191	195
Medina, Lorraine, and Utica	750	945
Trenton, Black River, etc	625	1,570
Basal arkose (sandstone)	30	1,600
Granite	.....	to 1,650

Gas at 1,405 feet.

The Trenton is indistinguishable from Black River in well samples, so that the age of the gas horizon is not definitely known.

The structure of this gas-producing area is unknown.[1] Two gas wells only are producing, the yearly production[2] for 1927 amounting to about 650,000 cubic feet.

SIMCOE COUNTY

Collingwood

In the town of Collingwood, Simcoe county, four wells[3] were sunk during 1887 and 1888 and although small flows of gas were encountered the supplies were not of commercial importance.

About 1902 there was a renewal[4] of operations in the Collingwood area and sufficient gas was obtained to light some dwellings and drive the machinery in a few industrial establishments.

The log of the following well belonging to Mr. William Carmichael, on Campbell street, Collingwood, illustrates the stratigraphy.

Formation	Thickness in feet	Depth in feet
Surface	33	33
Trenton limestone penetrated	268	301

[1]Ont. Bureau of Mines, vol. I, p. 109 (1906).
[2]Ont. Dept. of Mines, vol. XXXVI, pt. IV, p. 12 (1927).
[3]Brumell, H. P. H.: Geol. Surv., Canada, Ann. Rept., vol. V, pt. II, pt. Q, pp. 26-27 (1893).
[4]Bell, Robert: Geol. Surv., Canada, Ann. Rept., vol. XV, pt. A, p. 272 (1907).

First gas at 135 feet, second at 165 feet, third at 237 feet, and fourth at 288 feet. Pressure 20 to 30 pounds.

The greatest number of wells producing gas were found along a northeast and southwest belt which passes through the town. In 1901

"three wells were put down on the high ground west of the Niagara or Blue Mountain escarpment . . . to test the Trenton and other rocks there for gas, the heavy capping leading the drillers to suppose that the conditions were more favourable for an increased flow than in the valley to the south. One of these wells yielded a trace of gas, but the two others gave neither gas nor oil."

SURFACE GAS

According to Harkness[1]

"an astonishing quantity of gas occurs in the thick mantle of glacial drift which covers southwestern Ontario, and wells with a capacity of 3,000,000 cubic feet a day have been drilled. Seven wells west of Ridgetown (Howard township, Kent county) delivered during the two winters of 1925 and 1926 about 106, 681,000 cubic feet of gas to the town of Ridgetown. Other important occurrences are at Sarnia in Lambton county and at Beeton in the southern part of Simcoe county. The life time of these surface wells is, in many cases, as much as fifty years."

The gas occurs in sand underlying glacial clay.

[1]Harkness, R. B.: Second (Triennial) Empire Mining and Metallurgical Congress, Canada, 1927, p. 31.

CHAPTER V

RELATION OF OIL AND GAS PRODUCTION TO THE STRATIGRAPHY OF THE SOUTHERN ONTARIO FIELDS

The following summary shows the productive oil and gas horizons in the southwestern peninsula of Ontario.

Lambton County

Oil Springs. Small amount of oil 7 to 11 feet below the top of the Delaware limestone. Main flow of oil about 130 feet below the top of the Delaware limestone, that is, approximately 60 feet in the Onondaga limestone. (Note: Delaware supposed to be 70 feet thick in this field.) Gas 15 to 135 feet below the top of the Guelph formation.

Petrolia. Oil 118 to 127 feet below the top of the Delaware limestone, or 68 to 77 feet below the top of the Onondaga formation. (Note: Delaware supposed to be 50 feet thick in this field.)

Moore. Oil 57 to 83 feet below top of the Delaware limestone.

Plympton. Oil 100 feet below top of the Delaware limestone.

Sarnia. Oil 43 feet below top of the Delaware limestone.

Euphemia. Oil 100 feet below top of the Delaware limestone.

Dawn (Florence). Oil 82-89 feet below top of the Delaware limestone.

Dawn Gas Area. Gas in top of the Guelph formation.

Brooke. Oil 60 feet below the top of the Delaware limestone.

Kent County

Bothwell. Oil 142-155 feet below top of the Delaware limestone.

Tilbury (Fletcher). Gas in the bottom of the Salina formation and oil in the base of the Salina and upper 6 feet of the Guelph formation.

Tilbury (Glenwood). Gas and oil at same horizons as in the Fletcher pool.

Romney. Oil from crevices in the Delaware limestone.

Raleigh. Oil from 124 feet below the top of the Delaware.

Kipp. About same as Raleigh field.

Dover West. Gas and oil 282 feet and oil 400 feet below the top of the Trenton formation.

Kent Gas Field. Gas in small amount at top of Delaware limestone. Main flow from several horizons in Salina and top of Guelph formation.

Middlesex County

Mosa. Oil in the upper 20 feet of the Delaware limestone.

Elgin County

Dutton. Oil about 160 feet below top of the Delaware.

ESSEX COUNTY

Leamington or Mersea. Oil probably on top of the Guelph formation.

Belle River. Oil in the Onondaga formation under the drift.

PELEE ISLAND. Oil in the bottom of the Salina.

BRANT COUNTY

Brantford. Gas in the Clinton and Whirlpool formations and a small amount in the top of the Trenton limestones.

Onondaga. Oil in the Whirlpool sandstone.

MANITOULIN ISLAND. Oil about 10 feet below the top of the Trenton formation.

HALTON COUNTY

Milton. A little gas 500 feet in the Trenton.

PEEL COUNTY

Caledon. Small amount of gas in the Dundas formation.

BRUCE COUNTY

Hepworth. Gas at 460 feet in the Trenton formation.

ESSEX COUNTY. Gas from the top of the Guelph and small amount from the base of the Salina formations.

WELLAND COUNTY

Port Colborne. Gas in the Clinton and Red Medina (Grimsby). Oil in small amounts in the Whirlpool sandstone.

Winger. Gas in the Whirlpool sandstone.

HALDIMAND COUNTY

Attercliff and Selkirk. Gas in the Clinton, Grimsby, and Whirlpool formations.

ELGIN COUNTY

Bayham. Gas in the Clinton formation.

NORFOLK COUNTY

Middleton. Gas in the Red Medina (Grimsby) sandstone.

Simcoe (Port Dover). Gas in the Clinton, Red Medina (Grimsby), and Whirlpool formations.

Port Rowan. Gas in the Clinton formation.

SIMCOE COUNTY

Collingwood. Gas 100 to 250 feet in the Trenton formation.

In the above summary the oil occurrences in the Devonian are shown with reference to the top of the Delaware limestone, because it is impossible in well samples to separate the Delaware limestone from the underlying Onondaga limestone. There is very little doubt, however, that the Onondaga rather than the Delaware has yielded the greater part of the oil.

In the early days it was customary to include in the Hamilton formation all beds overlying the Onondaga. Stauffer[1], however, separated the "bottom limestone" formerly included in the Hamilton and called it the Delaware limestone. The reasons for this separation are given as follows:

"Near Selkirk there are occasional developments of Marcellus shale which intervene between the Onondaga and the usual basal limestone of the Hamilton. This calcareous, brown, shaly mass is often thin and soon gives place to limestone, but it carries . . . . Marcellus fossils . . . . which render its Marcellus age rather certain. In the vicinity of Port Burwell and to the westward it lies immediately under the drift and consists of 10 to 30 feet of black shale overlying the Onondaga limestone . . . . Usually the shale of this horizon grades into the overlying limestone or is interbedded with it. In such cases it becomes impossible to separate the two. In addition to the Marcellus forms included in this brown shale and associated brown to bluish limestone, there are numerous others which are identical with, or near relatives to, certain Onondaga fossil forms of the same locality. It is evident that conditions similar to those which obtained during the deposition of the Onondaga limestone were restored after the first invasion of the Marcellus had subsided, and that many of the Onondaga forms which had withstood the interruption resumed their old habitats with few if any important anatomical changes . . . . The introduction of new forms, wholly foreign to the Onondaga and identical with those occurring in the Marcellus and Hamilton deposits of other regions, is the important event and the one which should be regarded as determining the age. The residue of the Onondaga fauna is a diminishing quantity as the later and later Marcellus and eventually the Hamilton beds have been deposited, and thus it is clear that the history of the fauna as a unit had terminated with the change incident to the beginning of the Marcellus. The "bottom limestone" of the Hamilton is thus certainly distinct from the Onondaga and measurably so from the Hamilton. It is identical, both lithologically and faunally, with the Delaware limestone of Ohio and may thus be designated by the same name."

It has been stated by Howard[2] that "fully 95 per cent of the known limestone reservoirs are those in which the porosity has been developed below former erosion surfaces." It is thought that porosity may develop in limestone as a result of solution or leaching during a period of erosion and that the porous horizons so developed are confined within the depth of ground water penetration. According to Murray and Love[3] organic acids may act as solvents for limestone. It is thought that

"solutions containing acids and carbon dioxide may percolate downward through limestone and that the solvent action of these solutions is carried on from the surface of the earth to the water table. At the latter depth the solutions in contact with carbonates become alkaline and reactions between them and the limestone probably cease. Not only do the solutions carry carbon dioxide into the rock, but carbon dioxide is generated within the rock itself and this carbon dioxide being in intimate contact with the rock may well exert more effective action than atmospheric carbon dioxide which has been carried down by rain."

Howard applied this theory to the formation of porosity in the limestones of the Ontario fields. He states[4] that "in Ontario the Onondaga limestone is locally a reservoir rock. It is overlain unconformably by the Delaware limestone. Where post-Marcellus erosion removed the shale completely and attacked the limestone it is porous. Where the shale is present the limestone is not porous." Some modification of this statement by Howard seems necessary to bring it in accord with the Devonian stratigraphy as described by Stauffer.[5] There seems to be no evidence to show that the Onondaga of the Ontario oil fields was once covered by shale which was removed before a further deposition of limestone occurred. In

[1]Stauffer, C. R.: Geol. Surv., Canada, Mem. 34, p. 8 (1915).
[2]Howard, W. V.: Am. Ass. of Pet. Geol., vol. 12, No. 12, p. 1155 (1928).
[3]Murray, A. N., and Love, W. W.: Am. Ass. of Pet. Geol., vol. 13, No. 11, p. 1467 (1929).
[4]Howard, W. V.: Am. Pet. Inst. Research Project No. 23.
[5]Stauffer, C. R.: Geol. Surv., Canada, Mem. 34 (1915).

fact Stauffer states that "usually the shale of this horizon (Marcellus) grades into the overlying limestone or is interbedded with it." It would be concluded from Stauffer's[1] decription of the stratigraphy that the Marcellus and Delaware are but two facies of the same period of sedimentation, in fact he states that "it is evident from much of the fauna that this formation [Delaware] was, in part at least, contemporaneous with the Marcellus beds of New York" (*See* interpretation of Port Burwell well, page 77) and that "the change to western conditions is apparently indicated in the Marcellus beds of western New York where the basal shale becomes more calcareous." In Ontario the shale becomes replaced by limestone which has been called Delaware. This is evident from Stauffer's description[2] of the limestone in the quarries at St. Marys concerning which he states "The outcrop at St. Marys has usually been classed with the Onondaga limestone, but the upper layers contain a preponderance of species which belong to a later formation. These latter show them to be of the same age as those beds from which the Marcellus shale fossils have been collected." It is thus obvious that there is no break or erosion interval between the Marcellus and Delaware as stated by Howard, but the break, if any, came with "the change incident to the beginning of the Marcellus." Stauffer describes[3] the contact between the Onondaga and Delaware as rough and uneven and at Benmiller in Huron county the bottom of the Delaware shows a stylolitic surface. It has been shown[4] that stylolites are evidence of solution in a hardened rock and hence it is possible that the "rough and uneven" contact may be formed in the same way, in fact Stauffer[5] regards the Delaware as "transitional in character and fauna" between the Onondaga and the Hamilton. It thus seems evident that there was continuous sedimentation in Ontario from the Onondaga to the Hamilton and the porosity of the Onondaga could not have developed as the result of solution by ground water during a period of erosion. Production of oil apparently was found in both the Delaware and Onondaga limestone, although as stated previously it is very difficult and in most cases impossible to separate these two formations in well samples. The thickness of both the Delaware and Onondaga is variable and hence as a wide variation exists in the various oil fields in the position of the productive horizon in reference to the top of the Delaware limestone, it is impossible to tell whether the oil occurs in one or in several horizons. In these circumstances it has been found impossible to develop any theory in regard to the origin of the porosity.

Some oil and gas production has been secured from the base of the Salina and the top of the Guelph formation. Grabau thinks[6] that certain parts of the Salina were derived from the erosion of the Niagara beds and Williams[7] states that the Camillus shale, the lowest member of the Salina "rests unconformably on the Guelph dolomite." It is, therefore, possible that the upper part of the Guelph was rendered porous as a result of erosion and that the Salina, which was later deposited on this surface, provided the source materials that yielded oil and gas.

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[1]Stauffer, C. R.: op. cit., p. 137.
[2]Stauffer, C. R.: Op. cit., p. 119.
[3]Stauffer, C. R.: Op. cit., p. 120, p. 122, p. 132, etc.
[4]Stockdale, P. B.: "Stylolites, Their Nature and Origin"; Indiana Univ. Studies No. 55, vol. IX (1922).
[5]Stauffer, C. R.: Op. cit., p. 214.
[6]Grabau, A. W.: Geol. Soc. of Am., vol. XXIV, p. 498 (1913).
[7]Williams, M. Y.: Geol. Surv., Canada, Mem. 111, p. 83 (1919).

The Clinton, Grimsby (Red Medina), and Whirlpool (White Medina) formations have yielded large supplies of gas in Niagara peninsula and some oil has been produced from the Whirlpool sandstone, particularly in the Onondaga field near Brantford. The Whirlpool sandstone is regarded as an aeolian deposit and its character rendered it favourable for a reservoir rock for gas and oil that probably originated in other formations. The Queenston red shales that underlie the Whirlpool would be an improbable source for gas or oil, so that it is assumed the Whirlpool sandstone received its gas and oil by downward migration. The source of the gas and oil is unknown, although possibly it is the same as that which supplied the production for the Clinton and Red Medina (Grimsby) formations. It seems established beyond doubt that the Whirlpool, Grimsby, and Clinton production is related to porosity rather than to structure. For this reason it is impossible to predict new productive areas, although the extensive drilling that has been done has, on the whole, outlined the more porous areas of these formations.

A number of years ago a vigorous drilling campaign was undertaken to test the Trenton formation. The Dover West field was discovered and produced a considerable quantity of gas and oil. The conditions here, however, were found to be rather exceptional, in that the field is in reality a syncline which is practically free of water in the productive zone. There is reason to believe[1] that the Trenton in this field owes its porosity to fracturing which accompanied sharp folding or faulting and hence this field has little bearing on the productive prospects of the Trenton as a whole. According to Williams[2] some oil was produced from wells in Assiginack township, Manitoulin island. The oil occurred in the upper 20 feet of the Trenton and it was suggested that the overlying Utica shales may have been the source. The productive area occurred in a syncline in which very little water was present. A small amount of gas was also produced from the Trenton in Amabel township, Bruce county. In this field the structure has not been definitely determined and the gas zone was about 450 feet below the top of the Trenton formation. A great many wells have been drilled to the Trenton in various parts of the southwestern peninsula of Ontario, but on the whole the results have been disappointing. It is thought that the negative results are due to lack of porosity in the Trenton. This is in marked contrast with the Lima-Indiana field of Ohio and Indiana where a large production of oil and gas has been secured from the Trenton formation. It is, therefore, of interest to compare the stratigraphic conditions of Ontario with those of Ohio and Indiana.

At Cincinnati, Ohio, according to Fenneman,[3]

"the lowest and oldest beds which come to the surface . . . . belong to the Cynthiana formation of Trenton age . . . . The beds here exposed are continuous with the deeply buried oil and gas formation in other parts of the state, but here they are brought to the surface by the Cincinnati anticline . . . . Several of the limestone beds in the upper part of this exposure are noteworthy because composed in large part of broken shells . . . . Large undulations or ripples on the upper surface of these beds are formed by the sweeping up of these shell fragments into ridges by the waves . . . . Incorporated within (the

[1]Harkness, R. B.: Ont. Dept. of Mines, vol. XXXVII, pt. V, p. 74 (1928).
[2]Williams, M. Y.: Geol. Surv., Canada, Sum. Rept. 1920, pt. I.
[3]Fenneman, N. M.: Geol. Surv. of Ohio, Bull. 19, p. 60 (1916).

topmost bed) are balls or fragments of clayey rock, evidently derived from the wasting of a lower bed. With these are irregular slabs of limestone, some of them 2 feet in diameter evidently derived from the breaking up of an older bed . . . . All these features indicate that an old sea bottom had become dry land and that when the land again sank the re-advancing waves broke up and redeposited the topmost beds of the old formation."

It is thus evident that the top of the Trenton in the Cincinnati area was subjected to erosion prior to the deposition of the next succeeding formation, the Utica. The Cincinnati axis had commenced to form in Trenton time and the Utica which overlaps onto it shows a variable thickness and in certain places is entirely absent. It has also been noted[1] that "gas accumulations were found in those parts of the Trenton where the chemical analysis showed the magnesium carbonate content to be at least 25 per cent." It has been pointed out by Howard[2] that in the Ohio and Indiana fields where production comes from the Trenton the

"porosity was developed along a certain bed of lime which lent itself to the development of porosity in those places where it was subjected to the action of downward circulating water. These would be local highs or hills. The outline of certain fields shows that oil was found on both sides of long, narrow depressions which have been interpreted as stream valleys which had cut through the porous bed."

It thus seems evident that the porosity on the Trenton of Ohio may be directly attributed to the results of erosion on an old Trenton land surface.

In Collingwood area, Ontario, Parks[3] has shown that the Cobourg formation of Utica age overlies the Trenton. The Cobourg in this area is largely composed of limestones and was originally considered to be part of the Trenton. It may be, therefore, that in this area there was continuous deposition of limestone without an erosional break between the Trenton and Utica. This condition may be taken as occurring over the southwestern peninsula of Ontario and if so the lack of erosion of the Trenton of this area may be the reason why it is relatively non-porous. Such a condition, if true, precludes the hope of finding the Trenton in Ontario sufficiently porous to act as a large reservoir of oil or gas and explains the lack of results of so many wells drilled into this formation. The Cincinnati axis is not a well-developed structure in Ontario and in fact the top of the Trenton has a relatively low elevation in comparison with the elevation on the same horizon in certain parts of Ohio. It is, therefore, possible that it never reached above sea-level in Ontario and hence porosity did not develop in it to the same degree as is found in the oil and gas fields of Ohio.

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[1]Panytity, L. S.: Bull. of Am. Ass. of Pet. Geol., vol. 5, p. 611 (1921).

[2]Howard, W. V.: Am. Pet. Inst., Research project No. 23.

[3]Parks, W. A.: Roy. Soc. of Canada, vol. XXII, sec. 4, p. 46 (1928).

CHAPTER VI

STRATIGRAPHY AND OIL AND GAS PROSPECTS OF MOOSE RIVER BASIN

BY

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INTRODUCTION

The Devonian section in Moose River basin, according to the log of the deep test hole "A" in the Onakawana lignite field, is 777 feet thick, and the sediments above the Precambrian 1,027 feet. This is a greater thickness than expected, although the sedimentary measures are still thin when compared with those found in most productive oil and gas fields. It is well established that the Devonian formations are similar in lithology to their counterparts in southern Ontario and in the state of New York. Since oil and gas have been found in large quantities in one or more of these formations in southern Ontario and New York it follows that oil or gas may eventually be found in northern Ontario. The chief difficulty is that exploration for oil or gas in Moose River basin and the James Bay slope is usually rendered very difficult by the heavy surface covering of heterogeneous Pleistocene measures, largely consisting of glacial boulder clay, which obscures all the underlying bedrock except along the river courses. Even there the rock exposures are small and scattered. There remains no practical way of locating favourable oil structure except by drilling.

In December, 1930, the first drill hole to penetrate the entire sedimentary section in Moose River basin was completed. This hole was drilled under the direction of the Geological Branch of the Ontario Department of Mines. Diamonds were used and $1\frac{5}{8}$-inch core recovered, the core recovery being about 60 per cent. The object in drilling the hole was, mainly, to obtain data on the thickness and character of the sedimentary formations, and the structure of the region. Although the drill hole was not located on favourable structure it was hoped that some sign of oil or gas would be obtained, but this was a disappointment. The drill hole did, however, yield a great deal of valuable geological information. This information is used as a basis for the present report, which outlines the stratigraphy and structure of Moose River basin, and brings up to date our ideas concerning the prospect for oil or gas in the region.

Log of Drill Hole "A", Onakawana Lignite Field

(Summarized)

Elevation 186·50 feet above level of sea.

Depth feet	Thickness	Description	Formation	Geological subdivision
0–6	6	Muskeg		Recent
6–22		Grey, plastic clay (Marine Champlainian)		
22–80	72	Grey, boulder clay		Pleistocene
80–123		Fire-clay		
123–146		Lignite		
146–148		Fire-clay		
148–151		Lignite		
151–173		Fire-clay and white quartz sand	Mattagami	Lower Cretaceous or Upper Jurassic
173–194	170	Lignite		
194–212		Dark grey, lignitic clay		
212–250		Light grey and green, plastic clay		
250–318		Interbedded, pale, greenish grey clay and grey shale		
318–415	285	Dark grey, bituminous shale with thin bands of greenish grey clay	Long Rapids	Upper Devonian (Portage)
415–535		Pale, greenish grey to grey, shaly clay, with bands of dark, bituminous shale, and hard, concretionary material		
535–655		Interbedded, buff and grey, porous and cavernous limestone and calcareous shale. Brecciation common	Williams Island	Upper and Middle Devonian (Tully - Hamilton)
655–687	301	Red, gypsiferous shale, grey calcareous shales and gypsum		
687–836		Massive, grey shale		
836–873	37	Buff, fossiliferous limestone	Abitibi River	Middle Devonian (Onondaga)
873–936		Interbedded, buff, limestone breccia; buff, porous and cavernous limestone; and grey shale		
936–995	154	Interbedded, grey and buff shale; buff, granular limestone; mostly carrying gypsum or veins of selenite	Moose River	Middle or Lower Devonian
995–1,027		Green, granular, arenaceous limestone and calcarecus sandstone. Reddish sandstone and coarse gritstone. Mostly carrying veins of gypsum and selenite		
1,027–1,057		Weathered, syenitic gneiss, granite gneiss, etc.		
1,057–1,060				Precambrian

DESCRIPTION OF FORMATIONS

PLEISTOCENE

The uppermost Pleistocene formation is the marine (Champlainian) clay which underlies the muskeg. It is a grey, plastic, in some cases silty, clay, with, in places, lenses of sand and fine gravel. At drill hole "A" the thickness of the marine clay was 16 feet, but in Moose River basin in general it varies from 5 to 35 feet.

Underlying the marine clays and forming an erosional contact with the underlying Mattagami formation of Cretaceous age is the Glacial series. In its typical development the series consists of two till sheets separated by an interglacial series of sands, gravels, and stratified clays. In many places, however, the interglacial beds are either missing or poorly defined and it is very difficult or impossible to separate the two till sheets. The upper till sheet is, in general, lighter coloured and sandier than the lower which, especially over the Cretaceous basins, contains a rather large admixture of reworked fire-clay and lignite. Glacially striated and soled pebbles and cobbles are abundant throughout both till sheets, but large boulders are comparatively rare.

Each till sheet varies greatly in thickness, but averages about 30 feet; the interglacial series averages about 15 feet. At drill hole "A" the glacial deposits consist wholly of grey boulder clay 58 feet thick, no interglacial series being distinguishable. In some drill holes, i.e. those on Mattagami river opposite the Onakawana lignite field, there was some evidence of the presence of three till sheets with two interglacial series. Dr. A. P. Coleman states[1] that two interglacial series have actually been found, one of which is marine and the other freshwater.

Mattagami Formation

At drill hole "A" the Mattagami formation holds two seams of lignite, an upper and a lower. The upper is 28 feet thick with 1½ feet of fire-clay near the bottom, and the lower 21 feet thick. The seams are separated by 17 feet of dark grey fire-clay and 5 feet of white, quartz sand. The upper seam is overlain by 43 feet of dark grey fire-clay, and the lower seam is underlain by 16 feet of dark grey, lignitic clay, followed by an alternating series, 38 feet thick, of light grey, cream, and banded grey and cream clay, with a small proportion of lignite particles. The section through the Mattagami formation is rather typical of the better part of the Onakawana lignite field, except that the lignite is usually nearer the surface, between 50 and 100 feet, and is in many cases immediately overlain by boulder clay.

The lignite varies greatly in thickness owing to irregular truncation by the continental ice-sheet. The average thickness is about 23 feet over 5½ square miles, which was the area of the field when drilling was temporarily suspended in April, 1931. The maximum thickness of lignite is 68 feet (drill hole 83). The parting between the two seams, so well shown in drill hole "A", is present at many drill holes, and appears to run continuously through a large part of the field. Other partings were found which do not agree in position with the one noted above. These may be separate, laterally extending lenses, or possibly irregular masses of clay caused by settling and fracturing of the lignite due to the load of the continental ice-sheet.

Although more evidence must be obtained before the origin of the lignite can be definitely determined, most of the data so far obtained point to the same origin for the Onakawana lignite as for most of the great seams of the world, i.e. in situ and under swamp conditions.

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[1]Personal communication.

The Mattagami formation was discovered and first studied on Mattagami river between Long rapids and Grand rapids. Keele, McLearn, and Dyer all found plant remains in the lignite and associated clays and ironstone concretions, which upon identication left no doubt as to the age of the formation. The following species have been identified from the Mattagami formation of Mattagami river by W. A. Bell of the Geological Survey:

Nilssonia cf. *densinerve* (Fontaine)
Brachyophyllum mclearni, Bell
Pityophyllum graminaefolium (Knowlton)
Cladophlebis cf. *albertsii* (Dunker)
Cladophlebis virginiensis Fontaine
Onychiopsis ? sp.
Sphenopteris sp.
Geinitzia reichenbachii (Geinitz)
Elatocladus (Sequoia?) smittiana Heer.

Bell notes, "The age of the deposit, as inferred from this assemblage, is considered to be either Upper Jurassic or Lower Cretaceous, with preference towards the latter on account of the presence of the species *Pityophyllum graminaefolium* that is abundant and widespread in the Kootenay."

One species, *Pityophyllum graminaefolium*, of the above list, has been found in the lignite at Onakawana. The sediments are also so similar in both areas that there is little doubt that it is the same formation that is being described.

The contact of the Mattagami formation with the underlying Long Rapids shales of Devonian age is peculiar. It was expected that this contact would have been clearly marked since the two formations are very far apart in age. Due to the fact, however, that there could have been very little movement between Devonian and Cretaceous time, and that the sediments of the lower part at least of the Mattagami formation must have been derived from the Long Rapids shale, the lower part of the Mattagami and the upper part of the Long Rapids are quite similar lithologically, and the contact between them can only be determined by fairly close examination. The lower part of the Mattagami consists of pale grey and cream clays, whereas the upper part of the Long Rapids formation is made up of pale, greenish grey clay with thin bands of grey shale. The two formations can be distinguished by the slightly different colour of the clays, by the inclusion in the Devonian clays of thin bands of dark shale, and by the fact that the Devonian clays are somewhat more calcareous. The contact, however, is not obvious in drilling and has been missed in those holes which were not cored.

Long Rapids Formation

In drill hole "A" this formation is 285 feet thick. It falls naturally into three subdivisions; an upper, 68 feet thick, consisting of pale greenish clay with interbedded, thin bands of dark grey shale; a middle, 97 feet thick, consisting very largely of dark grey, bituminous shale[1], with thin

[1]The following determinations of the oil content in the Long Rapids shale have been made by the Mines Branch, Ottawa.

1. Drill hole No. 16, Onakawana lignite field, depth of 265 feet, 2 Imperial gallons per ton.
2. Drill hole No. 7, Onakawana lignite field, depth of 225 feet, 4 Imperial gallons per ton.
3. Surface exposure, Long rapids, Abitibi river, 4 Imperial gallons per ton.
4. Long rapids, Abitibi river, 5½ Imperial gallons per ton.
5. Long rapids, Abitibi river (described as weathered bituminous limestone), 1·6 Imperial gallons per ton.

Samples 1 and 2 were submitted by the writer, 3 by M. Y. Williams, and 4 and 5 by J. Keele.

bands of greenish grey clay; and a lower, 120 feet thick, of pale, greenish grey clay to grey, shaly clay with bands of dark, bituminous shale and a few layers of hard, concretionary material and pyrite nodules. An important horizon is the contact between the upper and middle subdivision, i.e., where the greenish grey clay and thin bands of grey shale change to massive, dark grey, bituminous shale. This contact is more clearly marked in some drill holes than others, but in none is it sharp. The dark shale bands in the greenish clay simply become thicker and more numerous downward, until at a certain point the shale becomes more prominent than the green clay. This point is taken as the contact, but its selection is usually arbitrary within an interval of about 10 feet. At drill hole "A" the depth of 318 feet was selected as the contact. The same horizon has also been identified from drill holes 1, 5, 7, 16, 76, 78, and 87. The elevation of this horizon with reference to sea-level becomes progressively lower from east to west in the lignite field, showing a dip toward the west. This agrees with the dip of the lignite seam. In drill holes 1, 16, "A," and 87, the drill passed through both the lignite seam and this Long Rapids horizon, and the interval between them was shown to be similar in all four holes, indicating that the Mesozoic and Palæozoic sediments are separated by nothing more profound than a disconformity, probably an erosional disconformity.

The following fossils from core of drill hole "A" from the middle and lower members have been identified by E. M. Kindle.

Lingula ligea Hall
Lingula n.sp.
Leiorhynchus cf. *laura* Billings
Chonetes cf. *lepida* Hall
Ambocoelia umbonata (Conrad)
Styliolina fissurella Hall
Polygnathellus cf. *curvatus* Ulrich and Bassler
Protosylvania huronensis (Dawson)
Crinoid stems

According to Kindle these fossils represent a fauna frequently met with in Portage horizons.

The Long Rapids formation is well exposed at Long rapids on Abitibi river, from which it derives its name. The maximum observed thickness there is 50 feet, but it is evidently much thicker, as it forms the flanks of a well-developed anticline with dips up to 15 degrees. The dark grey, bituminous shales of the middle division are the most prominent at Long rapids, but the upper and lower members are also seen at that locality. The only other outcrop of the Long Rapids formation is on Mattagami river a short distance above Grand rapids. Here, in a small exposure of grey, fissile shale with concretions, Williams found the brachiopod, *Pugnax pugnus* (Martin), a characteristic fossil of the Portage.

Williams Island Formation

As will be seen from the log of drill hole "A," this formation can also be divided into three members. The upper member is 120 feet thick and is composed of beds of porous and cavernous, buff limestone; and of fine-grained, banded, buff limestone interstratified with grey, shaly limestone and calcareous shale. Brecciation, such as might be caused by

low angle faulting, is a common feature. The middle member consists of: 32 feet of red, gypsiferous shale; grey, calcareous shale carrying gypsum; and 6 feet of pure gypsum. The lower member is 149 feet thick and consists entirely of grey, massive shale. At Williams island, after which the formation was named, the upper member only is present. The middle member outcrops on Mike island on Moose river, but there contains more red shale and less gypsum. It is an interesting fact that this lower member does not outcrop anywhere in the whole Moose River basin, thick as it is at drill hole "A".

In former reports all the beds between the Long Rapids shale and Abitibi River limestone were referred to the Williams Island formation, and this will still be done, although it is questionable if it will ultimately prove the right practice. It may be found that the members are quite different and should be given separate formational names. The fossils found in the exposure at Williams island on Abitibi river[1] contained both Upper and Middle Devonian species, and include *Hypothyris cuboides* a typical Tully brachiopod. It is likely that the upper member will prove to be Tully or near Tully in age, and the lower, Hamilton or Marcellus.

Abitibi River Formation

There is little doubt that the buff limestone with fragmental brachiopods and crinoid columns from 836 to 873 feet in drill-hole "A", is the Abitibi River formation.

This formation is the most commonly outcropping one in Moose River basin, being exposed at numerous places on the rivers in the region. In the best outcrops the formation is about 60 feet thick. It is also the most abundantly fossiliferous in the region—one hundred and ten definitely determined species of invertebrates having been listed from it.[2] These fossils leave little doubt as to the correlation of the formation with the Onondaga of southern Ontario and New York.

Moose River Formation

This formation is 154 feet thick in drill hole "A". The upper 63 feet consists of interbedded, buff, limestone breccia, and buff, porous and cavernous limestone, below which comes 59 feet of interbedded clay and buff shales, and buff, granular limestone, most of which carries gypsum and veins of selenite. There is only one foot of pure gypsum in the whole formation. Apparently the gypsum-forming basin was deeper and better developed farther to the north.

The resemblance of the brecciated and porous and cavernous limestone of the Moose River formation to the limestone beds of the upper part of the Williams Island formation is noteworthy. The Moose River formation with its gypsum is exposed at many points on Moose and French rivers. Beds thought to be correlatable with it also outcrop below Abitibi River limestone at Grand rapids on Mattagami river, and at Long rapids, Coral rapids, and Sextant rapids (above Coral rapids) on the Abitibi. At Sextant rapids the formation is only 33 feet thick, hence there is a rapid increase in thickness of the formation seaward.

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[1] "Geological and Economic Deposits of the Moose River Basin"; Ont. Dept. of Mines, Ann. Rept., vol. XXXVIII, pt. 4 (1928).

[2] Idem, pp 22-26.

The 32 feet of beds at the base of the sedimentary section differ considerably from, and appear older and more recrystallized than, those of the Moose River formation. They are included with the Moose River until evidence of their age is available. These beds are variable, containing green, granular, arenaceous limestone, and calcareous sandstone, reddish sandstone, and coarse gritstone, mostly carrying veins of gypsum and selenite. The gypsum throughout the formation is chiefly selenite and appears secondary as if deposited by percolating underground waters.

These lower beds are somewhat similar in appearance to the Sextant formation, which contains a Lower Devonian flora, and is found only at Sextant rapids. Their origin is probably the same, i.e., from detritus derived directly from the Precambrian and washed into fresh water lakes or rivers, but there is no evidence that they were formed at the same time.

The debated question of the age of the Moose River formation is still not settled definitely, since no definitely determinable fossils have ever been found in it. The opinion of the writer, however, still is that it is Devonian.

PRECAMBRIAN

Drilling in the Precambrian was very difficult and the core recovery was poor. From 1,027 to 1,037 feet some core of a greatly weathered, syenitic gneiss was recovered; between 1,037 and 1,042 feet some fine-grained, weathered granite-gneiss; between 1,042 and 1,057 feet red, sandy material, with the appearance of decomposed Precambrian rock; from 1,057 to 1,060 feet, 18 inches of very good core of weathered, pink granite-gneiss was obtained. It was not until the good core between 1,057 and 1,060 feet was obtained that drilling was definitely known to be in the Precambrian. The rock from 1,027 to 1,057 feet apparently represents weathered residual material composing the ancient Precambrian land surface. Its occurrence is peculiar, since in most exposures the contact between the Precambrian and post-Precambrian is very sharp and very little residual Precambrian material is ever seen.

STRUCTURAL GEOLOGY

It was formerly thought that the Palæozoic rocks of Moose River basin dipped very gradually to the northeast at about the same rate as the gradient of the rivers—3 feet a mile. This is apparently true of the lower part of the basin, near James bay, but nearer the Precambrian escarpment this regional dip is modified by structural basins of considerable extent in which Mesozoic sediments have been preserved from erosion. One prominent anticlinal fold occurs at the lower part of Long rapids, Abitibi river. A flat, but broader, fold occurs at Grand rapids on Mattagami river, and well-defined folding has also taken place near the gypsum deposits on Moose river. Minor folding, not visible at the surface on account of the heavy drift and scarcity of rock exposures, may be present in any part of the area. In the Onakawana lignite field drilling has shown westward dips of 50 to 75 feet a mile, modified by small irregularities. The existence of faulting has not been proved in any part of the area, but a fault of fair size with possibly a few hundred feet of throw is thought to exist at the Precambrian escarpment at the foot of Long rapids on Mattagami river.

STRUCTURAL BASINS ON MATTAGAMI AND ABITIBI RIVERS

There is evidence for assuming the presence of a structural basin of considerable extent along the foot of the Precambrian escarpment and extending between Mattagami and Missinaibi rivers (*See* Figure 14). What may be a separate basin or northeast extension of the same basin has been worked out at Abitibi river, centring about the Onakawana lignite field.

Fossiliferous limestone of Onondaga age rises in a cliff 50 feet above the water-level at Grand rapids on Mattagami river. On the east bank of the river, 4 miles upstream from the head of Grand rapids, a small outcrop of grey shale occurs at water-level. These shales include a bed of soft, grey limestone in which Williams[1] found the brachiopod *Pugnax pugnus*, which is characteristic of the Portage shale of New York state, so these shales might also be regarded as of Portage age. Since the Portage occurs above the Onondaga in the geological time scale, the grey shales lie above the Onondaga limestone of Grand rapids, which means that there must be at this point on the river a dip of at least 50 feet in 4 miles to the southwest. No Palæozoic rock is exposed between the above-mentioned outcrop of Portage shales and the first Precambrian outcrop, a distance of 20 miles to the south, the only outcrops being of the Mattagami formation. This condition, taken in conjunction with the southward dip at Grand rapids, suggests a basin. The fact that no Palæozoic rock has been found on Missinaibi river, but only outcrops of the Mattagami formation, suggests the extension of the basin to the west, at least as far as this river. The southern boundary of the basin may have been formed by steeply dipping Precambrian rocks or by a fault, but the fact that the Cretaceous sediments were found by drilling to extend 128 feet and probably more below the river level at the foot of Long rapids, on Mattagami river, whereas a few hundred feet to the south the Precambrian rocks rise more than 100 feet above river level, suggests a fault.

On Abitibi river the Long Rapids shales form the northwest flank of the anticlinal fold at Long Rapids. These shales dip northward at angles of 10 degrees or more. Northward, down the dip, Cretaceous fire-clay, which must be part of the lignite series, is exposed on the east bank of Abitibi river near the mouth of the Little Abitibi, at an elevation of about 150 feet above sea-level. On Moose river, at the head of Murray island, the Abitibi River limestones outcrop at an elevation of about 120 feet, and a few feet of the Moose River limestones are visible underlying them. To the southwest, at the head of Mike island, 2 miles upstream from the exposure at Murray island, the middle member of the Williams Island formation is exposed at an elevation of about 120 feet, and farther southwest, at the confluence of Mattagami and Missinaibi rivers, fire-clay and lignite of the Mattagami formation outcrop at a slightly higher elevation. At drill-hole "A" the bottom of the lignite seam is at a depth of 194 feet, or 7 feet below sea-level, and the top of the Abitibi River formation was struck at a depth of 836 feet or 649 feet below sea-level. These relationships and the elevations of the assumed contacts between formations with

[1]Williams, M. Y.: Ont. Dept. of Mines, vol. XXIX, pt. 2, p. 26 (1920).

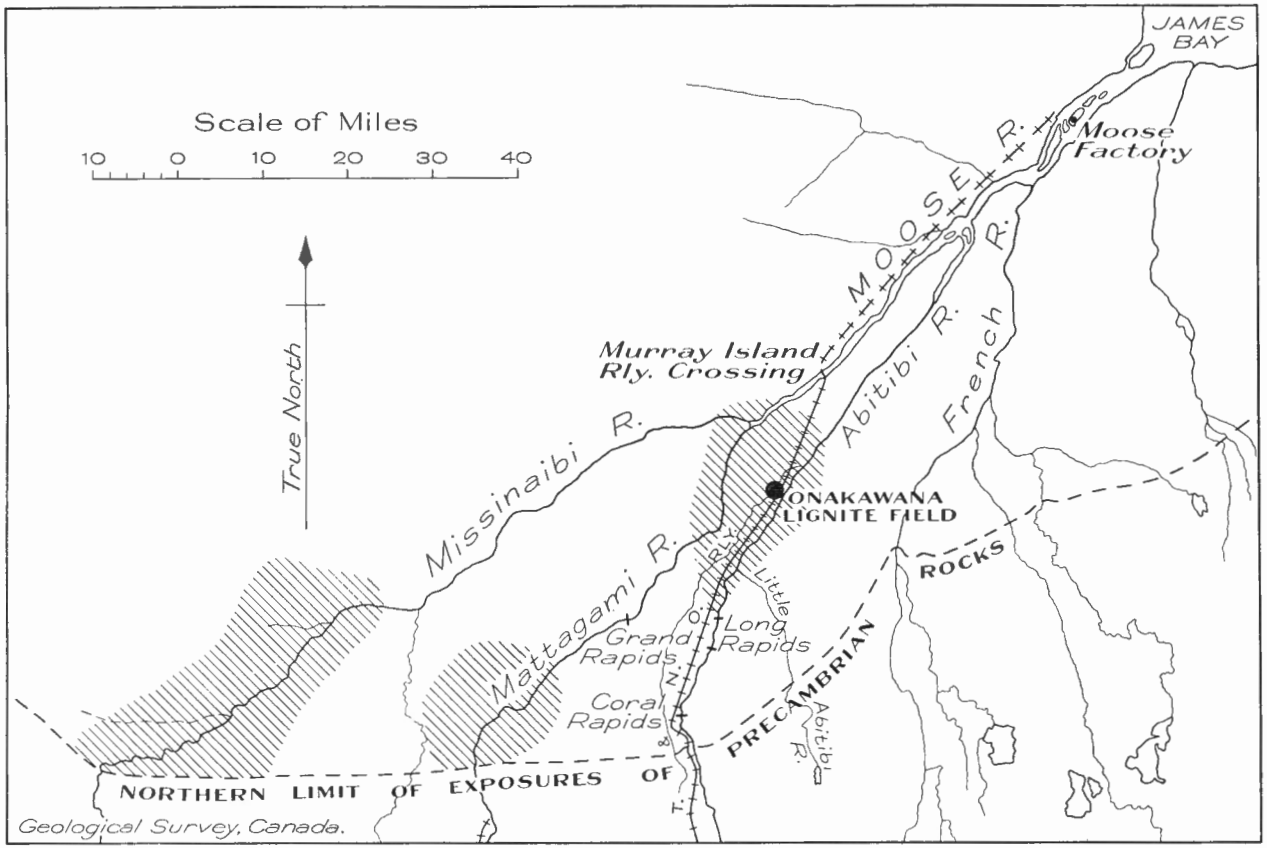

Figure 14. Moose River basin, Ontario (areas underlain by the Mattagami formation are shown by a pattern of ruling).

reference to sea-level are shown in the cross-section, Figure 15. Undoubtedly a well-defined structural basin centres somewhere near the Onakawana lignite field. From Long rapids northward to drill-hole "A", a distance of 15 miles, the Abitibi River formation dips 860 feet. From Murray island southward to drill-hole "A," a distance of 17 miles, the Abitibi River formation dips 806 feet. Due to the thickening of the Williams Island formation, from 100 feet at Long rapids to 300 feet at drill-hole "A," the northward dip of the beds overlying the Williams Island formation at the south side of the basin is not as great as noted above; it is probably more nearly 650 feet. It is known that the beds dip more steeply at the sides of the basin, particularly at the southern side, than in the middle.

Much less information is at hand with regard to the structure along the east-west line through the basin than in a north-south direction. It is known, however, that the Abitibi River formation outcrops 60 miles up French river, near the Precambrian contact. The elevation here must be in the neighbourhood of 150 feet; thus, there must be a dip about 800 feet in 18 miles to the west. Drilling in the Onakawana lignite field has shown westerly dips of about 50 feet to the mile. At the Mattagami, however, this dip appears to flatten out, since the shale-clay marker in the upper part of the Long Rapids formation occurs at about the same elevation in the drill holes near and on Mattagami river.

The extent of this basin is not known. There is now no doubt that it extends west to Mattagami river, probably several miles, but whether it joins up with the basin that occurs between Grand rapids and the foot of Long rapids on the Mattagami is, of course, impossible to say without further drilling. The Abitibi River formation is exposed at Grand rapids and forms an arch, to the north and to the south of which the beds dip down in basins. This arch may reach west or northwest as far as Missinaibi river, dividing the structure into two basins, or it may plunge toward the northwest, allowing the two basins to join.

Anticlinal Folds at Long Rapids, Abitibi River

The lower part of Long rapids, Abitibi river, is formed by the river cutting across an anticlinal fold. Argillaceous limestone and shales of the Williams Island formation are exposed by erosion along the axis of the fold, and Long Rapids shales form the flanks and dip at various angles, from 5 to 35 degrees, away from the axis. The axis of the fold runs nearly northeast. The fold probably continues through to Little Abitibi river, since at a point 4 miles up this river Precambrian gneiss forms an outlier with Devonian sediments dipping away from it on either side. This outlier is northeast of the fold on Long rapids and in the direct line of its axis.

A second fold of similar nature occurs on the upper part of Long rapids with limestones of the Moose River formation exposed by erosion along the axis, and the limestones of the Abitibi River formation composing the flanks. The axis of the fold passes through the island in midstream at the head of the rapids. This fold is not so well defined as the one on the lower part of the rapids, and the direction of its axis could not be determined.

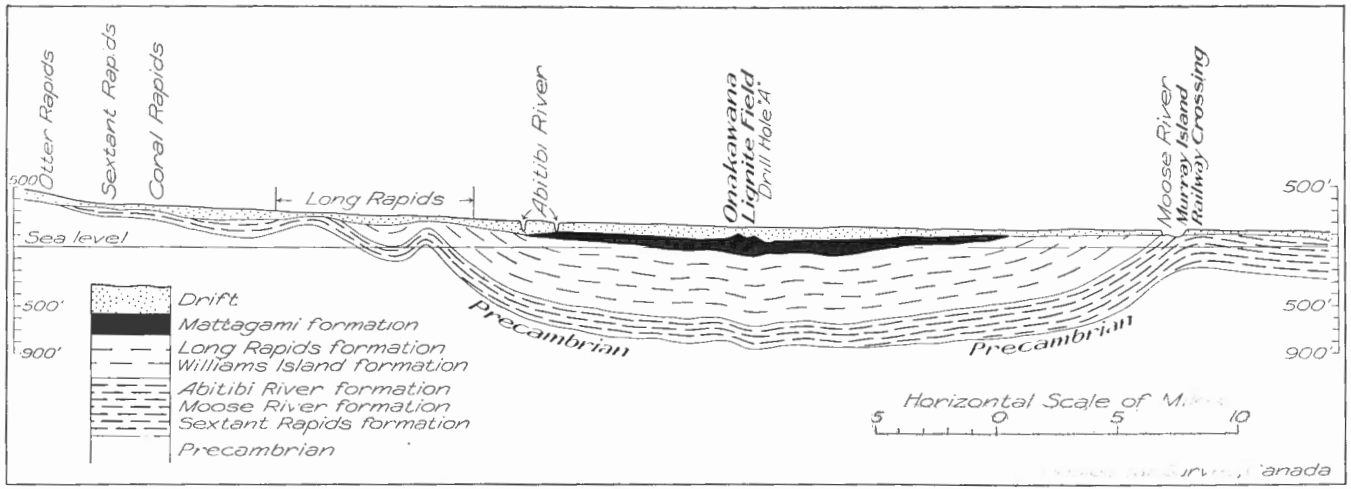

Figure 15. Idealized geological section along the Temiskaming and Northern Ontario railway, north from the Precambrian escarpment.

Folds in the Vicinity of the Gypsum Deposits on Moose River

At several localities in the northern part of Moose River basin, especially in the vicinity of the gypsum deposits, quite steep dips were observed in the Williams Island, the Abitibi River, and the Moose River formations. At the head of Mike island the thick series of red and grey shales dips to the north at an angle of 16 degrees. Half-way down the north side of Mike island a small outcrop of red and grey shales shows a dip of 18 degrees northeast. Toward the foot of the island an outcrop of soft buff limestone or dolomite strikes north 55 degrees and dips northwesterly at 13 degrees. Opposite the head of Murray island on the west shore, a 50-foot series of Abitibi River limestones occurs. At the upper end of the outcrop the strike is north 20 degrees west, and the dip northwesterly at 16 degrees, but on the downstream end within a distance of 500 feet the strike changes to north 45 degrees east, and the dip is southerly at an angle of 20 degrees. The outcrop of Abitibi River limestone at the head of Murray island is distinctly in the form of an arch. At the south end of the outcrop the strike is north 55 degrees east, and the dip 23 degrees southeasterly, and at the north end the strike is south 80 degrees east, and the dip 25 degrees northerly. The distance between the ends of the outcrop is 500 feet. The whole series of strong dips represents probably a series of small, irregular, undulating folds with rather steeply dipping flanks. The same type of folding was found in the drilling and excavation around Mike and Murray islands, carried out in 1930 by the Temiskaming and Northern Ontario railway during the construction of the bridge over Moose river.

Age of the Folding. The problem of determining the time of the folding is more difficult than at first appears. The younger formations are eroded from the edge of the large, structural basin, and hence information can only be obtained in a rather limited area in the middle part of the basin. Also, the contact between the Mesozoic and Palæozoic sediments is rather vague and difficult to establish closely. However, most of the evidence obtained points to a Cretaceous or post-Cretaceous age for an important part of the folding.

In the Onakawana lignite field four holes passed through the lignite seam well into the Long Rapids formation. In these four holes the interval between the lignite and the shale-clay marker of the Long Rapids formation is fairly uniform, and both horizons show a marked dip in the same direction, to the west. This surely suggests that the Cretaceous and the Long Rapids formation are conformable, or separated by nothing more profound than an erosional disconformity.

Elevations with Reference to Sea-levels of Horizon Markers

Drill hole	Bottom of lignite seam	Clay-shale horizon in Long Rapids form	Interval between horizon markers
	Feet	Feet	Feet
1	73	−67	140
16	70	−84	154
"A"	− 7	−131	124
87	39	−150	189
78	.....	−130	134
80	4		

In the following drill holes no lignite was found, but the clay-shale horizon in the Long Rapids formation was penetrated at the stated elevations: No. 5, 7 feet; No. 7, 39 feet; No. 76, 140 feet.

In the Onakawana field the lignite appears to be divided into two seams by a parting of variable thickness, and the lower seam appears to maintain a uniform thickness over most of the field. In another way it may be stated that the parting between the seams roughly parallels the bottom of the seam over any fluctuations that occur. This indicates that the two seams and the clay parting were first deposited on a flat or uniformly dipping plane, and afterwards folded together.

The hypothetical fault at the foot of Long rapids on Mattagami river, if a true fault, must have been formed after the Cretaceous, since Cretaceous clays and sands have been effected by the fault. These lines of evidence indicate that an important part of the folding occurred during or after Cretaceous time.

It is probable that some folding also occurred in pre-Cretaceous time, but of what order this was is not yet known. Lamprophyre dykes have been found at Coral and Sextant rapids, cutting the Sextant and Abitibi River beds, and a small dyke was found in the Long Rapids shale at Long rapids, Abitibi river. No igneous material has yet been found in the Cretaceous. The intrusion of these dykes may have accompanied some pre-Cretaceous folding. Brecciation in the Moose River and Williams Island formations is widespread and has also been found, but to a less extent, in the Abitibi River formation. It has not been noticed in the Long rapids shales, but would naturally be much less noticeable in the shale formation even if it were present. This brecciation has probably been caused by regional folding or by low angle faulting. The cause or time of folding of the series of small folds, or undulations, in the vicinity of the gypsum on Moose river, is not known. They may be related in some way to the brecciation. It is possbile that these two features, the small folds and the brecciation, may have been caused by the expansion of the underlying gypsum when transformed from anhydrite.[1]

PROSPECTS FOR OIL AND GAS

The Devonian section of the Moose River basin has many points of similarity to that of southern Ontario and New York. The Abitibi River formation is lithologically similar and equivalent in age to the Onondaga formation, the Williams Island formation represents the succession from the Onondaga to the Genesee shales, and the Long Rapids formation is correlatable with the Portage of New York state, and probably also in part with the Genesee. Oil and gas occur in these formations in Ontario and New York and in equivalent formations in Pennsylvania, Ohio, Virginia, Kentucky, and other states. It is, therefore, possible that oil or gas may some day be discovered in northern Ontario. The Mesozoic sediments are too thin and too near the surface to contain oil or gas. The most promising horizon is probably the porous and cavernous Williams Island limestone underlying the Long Rapids shale. The Long Rapids

[1]In a hole drilled by the James Bay Basin Oil Company at the head of Mike island, gypsum and selenite were found distributed through 263 feet of the Moose River formation, with 100 feet or more of pure gypsum. In a second hole drilled by the same company at the head of Murray island, there was about 50 feet of pure gypsum.

formation is bituminous in places and is the most promising formation from the standpoint of generation of oil. It is, also, almost wholly shale and is quite thick, 285 feet at drill hole "A," and would, therefore, serve as an efficient impervious cover. The Williams Island limestones are certainly porous and cavernous enough to act as reservoirs for oil. Any oil generated in the Long Rapids shales, however, would have had to find its way downward into the Williams Island formation, for that part that travelled upward would have been dissipated in the erosion interval between the Devonian and the Cretaceous.

Structural anticlines and folds exist in the region, but those that have been worked out either occur too near the Precambrian or have been too intensively eroded to contain oil or gas. It is probable, however, that similar structure exists in the deeper structural basin and has not yet been found. When such structures are found they should be well worth drilling. Such structures can only be located by exploratory drilling on account of the heavy mantle of glacial debris that covers the rocks.

In dry sediments oil will work downward until halted by the first impervious stratum, but in wet rocks oil is forced upwards under hydrostatic pressure into some structurally high place such as an anticline, where if a cap rock is present it will be trapped for an indefinite period, until some period of folding sets in which allows the trap to be flushed of oil by underground waters, or until erosion has removed the cap rock when the oil will be dissipated, or until the structure is drilled upon. The water content of the rocks in Moose River basin is not known with any certainty. In drill hole "A" a cavernous limestone in the upper part of the Williams Island formation at 550 feet was sufficiently dry to cause loss of all drilling water and to drain the sumps, which halted drilling for some weeks, but the lower part of the Williams Island formation and the underlying formations was wet. It is not known at present whether the rocks are sufficiently dry to cause downward migration of oil (synclinal conditions), or whether the more normal wet (anticlinal) conditions prevail; probably the latter.

Certain features appear unfavourable for oil and gas accumulation in Moose River basin. Probably the most unfavourable feature is the entire absence of seepages. No seepages have ever been discovered and the deep test did not encounter any sign of oil or gas other than the bituminous shales. In regions where the sedimentary section is thick and the oil-bearing strata are deeply buried, the absence of seepages is not considered unfavourable, but one would have expected some visible sign of oil in a region such as Moose River basin where the potential oil-bearing rocks are close to the surface.

Although the Long Rapids shales would ordinarily serve as an efficient cover for oil-bearing rocks, it is known that this formation is truncated from some parts of the area and it is just possible that folds exist in the deeper structural basins along which the Long Rapids formation may have been truncated. Such eroded folds would not now be visible, as they would be covered by the much younger Mesozoic clays and lignites. Although this is possible, no sign of it has yet been encountered in drilling. Seven drill holes have been put down to the shales along a length of 10 miles in the Onakawana lignite field, and in every case the previously mentioned marker (between the greenish clays and dark shales) has been

found. There are also quite strong indications that the Mesozoic and Palæozoic sediments are conformable within the structural basin, or at least that they are separated only by an erosional disconformity. In other words, it is thought that the greater part of the movement in the basin took place in post-Cretaceous times.

The limestones of the Williams Island formation, as well as those of the Moose River formation, are in many cases cavernous and brecciated, and a possible explanation of this feature is that it has been formed by a very vigorous ground water movement which may have flushed out any oil that might have been present. This is always a danger, but from what can be learned there is no very vigorous ground water movement now in these rocks. The upper part of the Williams Island formation was even found to be dry at drill hole "A". It is thought that before the rocks assumed their present attitude, i.e. before the structural basin so often mentioned was formed, that there was even less chance of underground water movement, since the sediments probably dipped more uniformly and at lower angles than at present.

If any drilling program for oil or gas is undertaken it is recommended that the holes be drilled through the Long Rapids shales and into the Williams Island limestone. In this way the most definite horizon, that between the shales and limestones, would be penetrated, and an accurate structural map could be built up. Each hole would also stand a chance of obtaining oil or gas. These holes would be about 550 feet deep. A less expensive, but also less satisfactory, method would be to drill into the upper part of the Long Rapids shales. There is a marker in the upper part of this formation that might serve for structural work, i.e., the horizon where greenish clays and thin dark shales change to heavy, dark shales, 318 feet in drill-hole "A". This marker is within the Long Rapids formation, and, therefore, would indicate any structure within the Palæozoic. It is a rather vague marker, however, and can only be defined within 10 or 15 feet. Any hole to this horizon would have much less chance of obtaining oil or gas. Drill holes to this horizon would be about 325 feet deep.

In Albany River region, prospects for oil and gas are not as good as in Moose River basin. No evidence of structure is present, and the beds, which in Moose River basin have the greatest possibilities for oil and gas (the Long Rapids and Williams Island formations), have been completely eroded away, if ever deposited. Even the Abitibi River formation is partly destroyed. All that remains is the uneroded part of the Abitibi River formation and some Silurian beds. Proceeding northwest from the Albany the Devonian soon disappears entirely, leaving only the Silurian and the Ordovician.

CHAPTER VII

EASTERN ST. LAWRENCE REGION, ONTARIO AND QUEBEC

INTRODUCTION

St. Lawrence region embraces an area extending from near the city of Quebec southeast along St. Lawrence river to Brockville and westward along Ottawa river to beyond Ottawa, as well as including the peninsular part of Ontario lying between lakes Ontario, Erie, and Huron. A projection of the Canadian Shield, known as the Frontenac axis, extends southwards across St. Lawrence river between Kingston and Brockville and divides St. Lawrence region into a western part already described, and in which are the oil fields of the southwestern peninsula of Ontario, and an eastern part herein described.

The northern boundary of the eastern part of St. Lawrence region is the southern edge of the Canadian Shield which in places rises abruptly and to a considerable elevation above the adjoining parts of St. Lawrence region. This edge of the Precambrian Shield forms the north shore of St. Lawrence river below Quebec city; but from a short distance below Quebec proceeding westerly, it gradually passes inland and runs north of Montreal and up Ottawa river. Fifty miles above Ottawa the edge of the Precambrian area turns southerly and crosses St. Lawrence river near Brockville. To the southeast of St. Lawrence region lies the elevated country of the Appalachian and Acadian provinces. In the vicinity of Montreal the St. Lawrence region is about 120 miles wide and embraces an area on both sides of St. Lawrence river, which, gradually narrowing, extends northeast to Quebec city. In the opposite direction, in Ontario, the eastern part of St. Lawrence region occupies a triangular area bounded by St. Lawrence river on the southeast, Ottawa river on the north, and the Frontenac axis on the west.

Throughout this whole area, except for a few isolated hills of igneous rocks, mostly in the vicinity of Montreal, the elevation nowhere exceeds 500 feet above sea-level, and below Montreal the area immediately along the St. Lawrence has a general elevation of less than 100 feet and rises to less than 300 feet at the edges of the region.

STRATIGRAPHY

The eastern part of the St. Lawrence physiographic province is underlain by flat-lying Palæozoic rocks. The succession of geological formations is as follows:

—	Formation	Sedimentation	Thickness
Ordovician	Queenston	Red shale	1,000
	Lorraine	Grey shale	3,000
	Utica		
	Gloucester	Dark shale	300–500
	Collingwood	Dark shale	
	Trenton	Limestone and shale	500–600
	Black River		
	Leray	Limestone	60–80
	Lowville	Limestone	
	Pamelia	Limestones and shale	
	Chazy	Limestone and shale	
	Beekmantown	Dolomite	
Cambrian	Potsdam	Sandstone	

The geological history is described by Young[1] as follows:

"During earliest Palæozoic time the southeastern part of the Canadian Shield appears to have been a land area, except possibly in one district in the vicinity of the strait of Belle Isle where early Cambrian beds occur, and although during Cambrian time seas extended southward along the Appalachian area just east of the St. Lawrence region, this region during most of Cambrian time was a land area and formed an eastward and southward projection of the Canadian Shield, with a surface much like that characterizing the Shield today. The first advance of the Palæozoic sea took place in Upper Cambrian time and extended northward from the Adirondack region to New York state to and up the lower Ottawa Valley region. In this sea was deposited the Potsdam sandstone, of Upper Cambrian age, and an overlying dolomitic limestone of early Beekmantown (earliest Ordovician) age. The sea withdrew from these districts in later Beekmantown time, but reoccupied them in late Chazy, when a series of sandstones and shales surmounted by limestone were laid down. In succeeding Black River time a notable expansion of the sea took place, for during this epoch the portion of the St. Lawrence region bordering the lower Great Lakes was first submerged. A further extension of the sea took place in the succeeding Trenton epoch, as indicated in the east in the vicinity of Quebec city and also 100 miles north of this place, where, well within the limits of the Canadian Shield, in the Saguenay River and Lake St. John areas, comparatively small areas of Trenton strata repose directly on the Precambrian. Probably at this time, if not earlier, an open sea-way extended to the Anticosti Island region where, on the Mingan islands on the north shore of the St. Lawrence, late Beekmantown strata rest on the Precambrian and are overlain by Chazy beds. The Chazy beds are inferred to be succeeded by later Ordovician measures now largely concealed beneath the waters of the gulf of St. Lawrence.

The Black River strata, where more fully developed, as in districts adjacent to the lower Ottawa river, consist of, in ascending order, the Pamelia limestone with some shales and sandstone, the Lowville limestone, and the Leray limestone. The Black River beds are overlain by limestones of the Trenton group, consisting of a number of subdivisions, each with a characteristic fauna, but all of which are not known to occur at any one locality. The total thickness of the limestone strata of the Black River and Trenton groups amounts to about 550 feet in the vicinity of Ottawa.

The sea or seas of Trenton time seem to have continued uninterruptedly through the succeeding Utica and Lorraine epochs into Richmond time. In Utica time conditions of sedimentation changed and, instead of limestones, thick deposits of shale accumulated.

[1]Young, G. A.: Geol. Surv., Canada, Ec. Geol., vol. I, p. 70 (1926).

This change commenced in Trenton time in New York state and in Quebec southeast of the St. Lawrence, argillaceous strata of Trenton age also occur. Since limestone-producing, comparatively clear waters characterized the parts of the seas nearer the Canadian Shield, and muddy waters prevailed at the same time to the east and south, the presumption is that the argillaceous material was derived from eastern land areas.

In the vicinity of Ottawa, the Trenton limestones are succeeded by a few score feet of interbedded dark shales and limestones known as the Collingwood formation, above which occur several hundred feet of dark Utica shales. These are followed by the dark grey shales with thin limestones and sandy layers, of the Lorraine. . . . . In Quebec the Lorraine is mainly developed southeast of St. Lawrence river, where in one section there are more than 2,000 feet of such beds, though possibly the lower part of this body of shaly strata may correspond in age to the Utica and even to some part of the Trenton also. The Lorraine beds southeast of the St. Lawrence are succeeded by strata of the Richmond group consisting of several hundred feet of thin-bedded shales and limestones of Waynesville age surmounted by unfossiliferous red shales, in places fully 1,000 feet thick, known as the Queenston formation. These and corresponding beds near Ottawa are, except for certain fragments of Devonian limestone held in an igneous body at Montreal, the youngest Palæozoic strata preserved in the eastern division of the St. Lawrence region. In the outlier of Palæozoic strata at lake St. John, fossiliferous Richmond beds occur and they are also present on Anticosti island, where they consist of more than 1,000 feet of limestones with some shales which pass upwards without break into overlying strata of Silurian age. In the Anticosti Island region, the sea seems to have existed without interruption from Ordovician into Silurian time, but in the St. Lawrence region the presence of the Red Queenston shales in the districts southeast of the St. Lawrence and near Ottawa probably mark, as they do farther west in Ontario, a shallowing of the sea, presaging its withdrawal before the end of the Ordovician period.

The total thickness of the Ordovician strata in the Quebec part of the St. Lawrence region is large. In the neighbourhood of Montreal there are 4,350 feet of strata from the base of the Potsdam to the highest member of the Lorraine there exposed. Making allowance for the remaining part of the Lorraine and the succeeding Richmond, the total thickness is probably more than 6,000 feet. It is possible that Silurian strata once occurred in the eastern section of the St. Lawrence region, and it is known that Devonian beds did occur, for rock fragments, some of which hold a Helderbergian fauna and others an Oriskany fauna, occur near Montreal in a dyke-like igneous body cutting Utica shale. The fossiliferous blocks presumably came from Devonian strata which once lay high above the Utica. The igneous mass is related to rock types forming a series of isolated eminences known as the Monteregian hills.

The Monteregian hills are eight in number and six of them, including mount Royal at Montreal, the most westerly of the group, occur along an approximately east and west line 50 miles long. They form circular or oval hills, each only a few square miles in area, that rise abruptly 600 to 1,200 feet above the surrounding level country. The flanks of the hills are of sediments altered and hardened, whereas the central parts are composed of igneous rocks of alkali types including varieties of alkali syenites, nepheline syenites, essexites, etc. The igneous portions appear to be stock-like bodies or to represent conduits that may have led in some cases to volcanic vents or laccolith-like bodies."

During Pleistocene time, ice covered the eastern St. Lawrence region and the glacial deposits left after the final retreat of the ice mostly belong to the last or Wisconsin stage. Following the retreat of the ice an arm of the sea extended up St. Lawrence and Ottawa valleys and deposited the so-called Champlain clays and sands which in places are nearly 200 feet thick.[1] Remains of beaches belonging to the Champlain submergence are found in many places. With the exception of isolated knobs, the Champlain submergence covered the whole of the triangular area of Ontario between Ottawa and St. Lawrence rivers and east of a line from Ottawa to Brockville. Throughout the whole eastern part of St. Lawrence valley the underlying bedrock is to a large extent concealed by the glacial drift and the deposits of marine clays and sands.

[1]Johnston, W. A.: "Late Pleistocene Oscillations of Sea Level in the Ottawa Valley"; Geol. Surv., Canada, Mus. Bull. No. 24, p. 9.

STRUCTURAL GEOLOGY

In contrast with the area of Palæozoic rocks in Ontario west of the Frontenac axis, where faults are comparatively rare and of minor significance, the area of Palæozoic rocks in the eastern St. Lawrence region is cut by many faults of large throw. An escarpment, 700 to 1,000 feet high, of Precambrian rocks, extends for nearly 300 miles along the northern edge of the fairly flat Palæozoic plain in St. Lawrence and Ottawa valleys. According to Kindle and Burling[1] this escarpment is a normal fault scarp and the Palæozoic sediments are thought originally to have extended far over the Canadian Shield, but have since been removed by erosion. Along the southeast side of the St. Lawrence area of Palæozoic rocks, separating it from the more highly disturbed strata of the Appalachian physiographic province, is the Champlain fault. From lake Champlain the fault proceeds in a gently curving line to Quebec city, crosses the north side of the island of Orleans, and thence follows a northeastward course under the waters of the St. Lawrence to near the extremity of Gaspe peninsula. Thus, the eastern St. Lawrence region lies between two fault systems that closely approach one another in the vicinity of Quebec city. The strata between these two fault systems are, for the most part, very gently inclined. Locally they are traversed by faults, as in the neighbourhood of Ottawa where, for instance, the Hull and Gloucester fault with a maximum throw of 1,850 feet[2] has been traced for many miles. In other districts faults are known or are suspected to be present. Near Quebec a number of strong faults occur, as at Montmorency falls where the displacement along one fault amounts to 600 feet and the downthrow strata are tilted at a fairly high angle.

The structure of the Palæozoic area in eastern Ontario bounded by Ottawa and St. Lawrence rivers, is that of a basin in which the youngest of the gently dipping strata are of Queenston (Medina of Map No. 750, Geological Survey, Canada) age. The Queenston beds, however, occur only in small, isolated patches (Geological Survey, Canada, Map No. 903) surrounded by older sediments. The centre of the basin in Caledonia, Plantagenet, and Cumberland counties is occupied by Utica shales with some Lorraine shales present on the southwest edge of the basin.

In the region extending northeastward from the confluence of St. Lawrence and Ottawa rivers[3] the rocks have, in general, a northeast and southwest trend parallel to the northern edge of the Palæozoic area. The strata north of the St. Lawrence dip to the southeast and as a result successively younger formations outcrop in comparatively narrow belts trending northeast. The youngest strata, which are of Queenston age, occur south of the St. Lawrence where they form three synclinal areas, known, respectively, as the Du Chêne, Nicolet, and Pierreville synclines. These lie east of Yamaska river and a few miles south of the St. Lawrence and are completely surrounded by the underlying Lorraine shales. The Queenston shales are red and their areas may be roughly delimited by the red colour of the soil. The thickness of the Queenston in these areas may be as much as 1,000[4] feet. A large part of the area south of St. Law-

[1]Kindle, E. M., and Burling, L. D.: Geol. Surv., Canada, Mus. Bull. 18 (1915).
[2]Kindle, E. M., and Burling, L. D.: Geol. Surv., Canada, Mus. Bull. 18. p. 10 (1915).
[3]*See* Geological Survey, Canada; Montreal sheet, Map No. 571; Three Rivers sheet, Map No. 655; and Quebec sheet, Map No. 375.
[4]Foerste, A. F.: Geol. Surv., Canada, Mem. 83, p. 174 (1916).

rence river is occupied by Lorraine shales which may be as much as 3,000 feet thick. Undoubtedly this whole area was at one time covered by Devonian strata, as blocks of rock of this age are found as inclusions in intrusions at Montreal. The Devonian, however, has since been completely removed by erosion.

In the area north of the St. Lawrence and extending from about 15 miles below Quebec city to about 35 miles above it, there are, from northeast to southwest, the following anticlines: Chateau Richer, Montmorency, Pointe aux Trembles, Cap Sante, and Deschambault. Of these, the first two, Chateau Richer and Montmorency, lie down river from Quebec city. These anticlines trend, in general, in a northeast and southwest direction with a plunge to the southwest. Their highest parts are on the margin of the Precambrian rocks and hence it would be expected that any oil and gas they may have originally contained would be lost by migration upward to the exposed edge of the reservoir rocks on the northeast end of the anticlines. This would be particularly true in small structures, and of all the anticlines the Deschambault is the only one that has been traced southwest for any considerable distance; according to Logan[1] it extends "from a spur of gneiss which is upwards of 2 miles north of the church of Deschambault to the church of Grondines." The southeast flanks of these anticlines have steeper dips than the northwest flanks and the anticlines show some faulting with the downthrow side to the southeast.

As already mentioned, in the area south of the St. Lawrence there are three synclines,[2] Pierreville, Nicolet, and Du Chêne. The axis of the Pierreville syncline is north of St. Hyacinthe and the syncline is 7 or 8 miles in width. It, like the other two, is occupied by Queenston red shales. The axis of the Nicolet syncline crosses Nicolet river in the vicinity of Ste. Monique and continues for 11 miles southwest. The width of the Nicolet syncline may not exceed 7 miles. According to Foerste, between the Pierreville and Nicolet synclines there is an anticline "whose axis lies about 3 miles southeast of Ste. Monique."

The Du Chêne syncline (*See* Map No. 375 G.S.C.) begins about 2 miles west of Forestdale on Gentilly river and extends northwest for a distance of 21 miles crossing Petite Rivière du Chêne. It, like the others, is occupied by Queenston shales.

Between the Du Chêne and Nicolet synclines is an area of Lorraine shales indicating an anticlinal condition. This anticline may be the southwest extension of the Deschambault anticline as described by Logan. The southwest end of the anticline is said to cross rivière Becançour on range VI, Maddington township.

On Yamaska river, near St. Hughes, two small anticlines are recorded by Foerste.[3] The first of these is north of the ferry landing west of St. Hughes. Dips of 25 to 30 degrees on the southeast flank and dips up to 32 degrees on the northwest flank are recorded. The second small anticline crosses Chibouet river about half a mile from its junction with Yamaska river. These anticlines are on the southwest extension of the anticline that occurs between the Pierreville and Nicolet synclines, but their value as oil and gas structures cannot be determined from data at present available.

[1]Logan, Sir Wm.: "Geology of Canada, 1863," p. 152.
[2]Foerste, A. F.: Geol. Surv., Canada, Mem. 83, p. 61 (1916).
Foerste, A. F.: Geol. Surv., Canada, Mem. 83, pp. 50, 60 (1916).

According to Logan,[1] a flat anticline projects northward from Beauharnois into the county of the Lake of Two Mountains and southward to the International Boundary. This anticline exposes Potsdam in the central part and is flanked by Beekmantown. It has no oil and gas prospects, since the possible productive horizons have been eroded.

Minor undulations on Montreal island and Isle Jesus are described by Logan,[2] but these have no significance as oil and gas structures.

As already mentioned, there are in the St. Lawrence Palæozoic area a number of intrusive bodies now forming abruptly rising "mountains". Dykes associated with these intrusive masses are of common occurrence in many areas. According to the Borings Division of the Geological Survey, dykes were encountered in at least six of the seven wells drilled in St. Hyacinthe area. Dykes are known to occur at many places in the vicinity of Montreal. These dykes would, presumably, act as barriers to the migration of oil or gas and hence may be very important features determining the distribution of oil and gas in any prospective fields in this area. For the most part, the region is covered by drift which conceals the underlying rocks and hence dykes may occur in areas where their presence is not now suspected.

EVIDENCES OF PETROLEUM AND NATURAL GAS

Hardened bitumen, which is supposed to have resulted from the desiccation of petroleum, is described from St. Lawrence area by Sir Wm. Logan[3] as follows:

> "In the Quebec group (Lower Palæozoic strata) in Canada . . . this substance (hardened bitumen) has been observed at Quebec, Orleans Island, Pointe Levis, Sillery, St. Nicholas, Lotbinière, Drummondville, Acton, the vicinity of the Chat river in Gaspe, and many other places. It fills veins and fissures in the limestones, shales, and sandstones and even in the trap rocks which traverse these . . . . At other times it lines fissures, and is seen, as at Drummondville and Sillery, spread over a surface which had been previously encrusted with small crystals of calcite . . . . In other cases it fills fissures several inches in diameter so that it has been mistaken for coal."

The localities mentioned in the above description lie east and south of the Champlain fault, but the former presence of petroleum in these rocks may be taken as indicative of conditions that existed in the less disturbed strata of the same age lying to the west and north of these areas in the relatively flat-lying Palæozoic strata of St. Lawrence region. It is known that the Trenton and Black River limestones in many areas in St. Lawrence area are highly bituminous and in a few places seepages of oil have been reported.[4] Oil is also said[5] to issue from a seepage at Plantagenet from the Chazy formation.

In many areas in the St. Lawrence Palæozoic region gas is reported to occur as seepages. Sir Wm. Logan[6] records natural gas seepages at Caledonia, Varennes, and Caxton in water springs. According to Obalski[7] "in the district about Three Rivers, that is, in the south part of the counties of Champlain, St. Maurice, Maskinonge, Berthier, and Joliette, some very considerable emanations of combustible gas have been noticed ever since the country has been inhabited. The places

[1]Logan, Sir Wm.: "Geology of Canada, 1863," p. 113.
[2]Logan, Sir. Wm.: "Geology of Canada, 1863," p. 141.
[3]Logan, Sir Wm.: "Geology of Canada, 1863," p. 525.
[4]Wilson, M. E.: Geol. Surv., Canada, Sum. Rept. 1920, pt. D, p. 51.
[5]Personal communication from A. E. Wilson, Geol. Surv., Canada.
[6]Logan, Sir Wm.: "Geology of Canada, 1863," pp. 527, 666.
[7]Obalski, J.: Rept. of Com. of Crown Lands, Que., 1884.

where these have been known to occur are at St. Maurice, Pointe du Lac, Louiseville, St. Léon, Epiphanie, St.-Paul-l'Ermite, St. Henri de Mascouche, etc., and on the south shore at St.-Grégoire, county of Nicolet."

Of the above-mentioned places, Pointe du Lac on the north shore and St.-Grégoire on the south shore of the St. Lawrence are on Lorraine shales. The remaining localities are on the Trenton and Utica formations.

The seepages may be taken as indicative of the presence of oil and gas-bearing beds, but it does not follow that commercial supplies of oil and gas are present where a seepage occurs. The requisites for oil and gas fields may be summed up briefly as follows: (1) the presence of an oil and gas supply; (2) porous beds that may act as reservoir rocks; (3) favourable structure that will cause an accumulation of oil and gas into a localized area; and (4) impervious cover over the oil and gas reservoir that will retain the oil and gas when it has been accumulated.

RESULTS OF DRILLING IN QUEBEC

Drilling has been done in several areas in the St.Lawrence Palæozoic region and the following account by Parks[1] gives a general outline of the developments.

"The first serious attempt to bore for gas was made at Louiseville prior to 1880 by Piret and Genest of Trois-Rivières. Then followed an attempt in the cadastre of St. Henri de Mascouche in 1883, by Renaud Frères and Dubois. In 1885 a small company was organized at St.-Grégoire, Nicolet county, primarily to search for oil. This company bored a deep well near St.-Grégoire. The well failed to produce petroleum but voided large quantities of combustible gas. In 1886 a company known as the "Natural Combustible Gas Company", with M. Cyrille Duquet of Quebec as president, secured from the Government the exclusive privilege of boring for natural gas in the province. This company bored at Maisonneuve near Montreal and at Louiseville; the Maisonneuve well was a failure, but four wells at Louiseville yielded gas.

In 1895 a new company was organized, "La Cie de Gaz Naturel de Québec."

In 1899 M. E. Bergeron drilled in the Pointu concession east of St.-Grégoire with indifferent results.

The Canadian Gas and Oil Company was organized in 1904 with J. G. Thibodeau of St.-Grégoire as president. This company operated first in the St.-Grégoire district, but afterwards in the Louiseville district. It supplied natural gas for two years to several villages and piped its product to Trois-Rivières. The company is to be credited as the only producer of natural gas on a commercial scale in the province; unfortunately, it was forced into liquidation and ceased operations in 1908.

The Quebec Fuel Company was organized in 1908 and drilled four wells in Yamaska and Verchères districts without success.

In 1910 a company, "La Cie de Gaz et de Pétrole de St. Barnabé" was formed to exploit the St. Hyacinthe district and drilled a well 6 miles northeast of St. Hyacinthe.

[1]Parks, W. A.: Ann. Rept., Quebec Bureau of Mines, 1929, pt. B, p. 83.

In 1913 the Canadian Natural Gas Corporation, with N. Turcot as president, took over the rights of the St. Barnabé syndicate, and in 1914-15 put down a second well on the same lot. This organization had two subsidiaries: the "Canadian Natural Gas Company," $2,000,000, and the "Natural Gas, Light, Heat, and Power, Limited," $500,000.

The National Gas Company ($125,000) was another organization of about the same date; it acquired rights in adjoining territory and sank a well about 4 miles southeast of that of the Canadian Natural Gas Company.

With the failure of these syndicates the attempts to utilize the natural gas of the province on a commercial scale came to an end.

At the present time gas from shallow wells is actually being used for domestic purposes at Ste.-Geneviève, Yamachiche, St.-Ours, Verchères, and a few other localities.[1]

I. Ste.-Geneviève District, Batiscan Seigniory, Champlain County

The escape of natural gas from crevices in the drift is known at several localities, more particularly a strong flow in the Batiscan river that has attracted attention for more than 30 years. At the present time at least 10 to 15 cubic feet a minute are escaping (opposite lot 588 La Pointe). The region is underlain by Utica shale with Trenton limestone immediately to the north. The drift is about 200 feet thick and no outcrop of rock is seen in the immediate vicinity. Many wells have been bored to the rock, but not into it. A small but steady flow of gas has been obtained from all the wells. The gas is colourless and odourless; it burns with a scarcely perceptible, bluish flame, and gives an intense heat.

The following table gives the information that I have been able to obtain regarding the wells.

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[1]Report of Mining Operations in the Province of Quebec, 1914, pp. 48-68.
Ibid., 1915, pp. 47-48.
Ibid., 1916, pp. 59-60.

Gas Wells of the Ste.-Geneviève District

Owner	Location	Approximate depth	Approximate date	Notes
		Feet		
Cléophas Langlois	Lot 88, village of Ste.-Geneviève	200	1,900	Constant supply for lighting and cooking, private dwelling
Hôtel Ste.-Geneviève	Lot 122, village of Ste.-Geneviève (part of lot 72)	125	1911	Ample supply for cooking, hotel
Mme. Louis Deshaies	Lot 81, village of Ste.-Geneviève (part of lot 63)	.....	1904	Constant supply for heating and cooking, private dwelling
Star Mineral Water Company	Lot 551, parish of Ste.-Geneviève (part of lot 554)	.....	1900	Enough gas for cooking and heating, not all used
Arthur Massicotte, miner's claim on property of Napoléon Trudel	Lot 588, parish of Ste.-Geneviève	70	1929	Rock at 68 feet, gas and water at 40 feet. Very salt water, gas not used
Napoléon Trudel	Lot 588, parish of Ste.-Geneviève	100	1929	Several holes in river near natural gas outlet. Strong flow of gas, no rock at 100 feet
Noel Massicotte	Lot 53, village of Ste.-Geneviève	.....	.....	Lighting all year, partly for cooking
Alfred Moreau	Lot 77, village of Ste.-Geneviève (part of lot 63)	.....	.....	Not used for past ten years
Théo. Brouillat	Lot 116, village of Ste.-Geneviève (part of lot 72)	.....	1909	Constantly used for lighting and cooking, private dwelling
Donat Landry	Lot 557, parish of Ste.-Geneviève	.....	1924	Lights two houses; last well drilled

Literature;
Rept. Com. Crown Lands, 1884, p. 84.
Mining Operations, 1901, p. 35.

II. St.-Grégoire District, Seigniories of Roquetaillade and Bécançour, Nicolet County

According to the maps of the Geological Survey, this region is underlaid by strata of Lorraine age and bordered on the south by the reddish, sandy shales and sandstones of the Queenston.

The county is essentially flat, deeply covered with drift, and with few rock exposures.

(a) Roquetaillade seigniory.

1. Cadastral lots 500 and 501.

The concession road north of the range Beauséjour cuts the northern part of lots 500 and 501. 'About eight arpents southeast of the concession road, and parallel to it, is a patch of land some four arpents in length, from which combustible gas arises. The soil is composed of clay and sand for a depth varying from 50 to 60 feet. From all the borings made down to the hard rock gas escaped in great abundance. At the centre of lot 501 a hole some 15 feet deep had been dug and had become filled with rain water. In this had been placed a barrel, open at one end, with a gun-barrel fitted into the other. The gas escaping from the gun-barrel has been burning since January of this year, with a flame more than a foot high. A small well has also been sunk on No. 500, from which gas escapes incessantly. At other points an ordinary barrel is filled in a very short time. I caused some sounding to be made in my presence with iron rods about half an inch in diameter, and found in great part a bed of clay overlying a thin layer of black sand which in turn rests upon hard rock, which according to the geological map should be the upper schist of the Trenton formation.

The proprietors who have been living for thirty years on these lands assured me that they had always been aware of these emanations of gas.'[1]

In 1885 a well was sunk by a local company (N.P. Poirier) on lot 501 (Hilaire Trudel) to a depth of 1,115 feet, in drift for 75 feet and the rest in rock. Gas was struck at 400 feet and a supply was obtained sufficient for heating and lighting five or six houses, also for cooking. This well is still yielding, but is used at present for only four dwellings.

The log of this well is given below:

Log of Trudel Well

—	Thickness	Depth
	Feet	Feet
Blue loam with thin layers of sand	47	47
White sand; emanations of gas	5	52
Gravel; emanations of gas and water	15	67
Black sand, dense; water, but no gas	7	74
Sandstone, somewhat calcareous, oily oozings	80	154
Same as preceding, but harder and finer-grained	60	214
Red shale	75	289
Red shale, lighter colour	10	299
Shale, nearly black	16	315
Shale, blackish brown, not hard; abundant and sudden flow of gas, having a strong smell of kerosene	54	369

[1]Rept. Com. of Crown Lands, 1884, p. 83.

Log of Trudel Well—Concluded

—	Thickness	Depth
Red shale; emanation of gas	105	474
Red shale, somewhat greyish	50	524
Softer, red shale	55	579
Red shale; another strong flow of gas	60	639
Impure calcareous rock apparently containing magnesia. Another vein of gas	20	659
Calcareous rocks	60	719
Oily, calcareous rock	100	819
Black shale; flow of gas	40	859
Black shale, compact	225	1,084
Depth of well	.....	1,115

Gas yield estimated at 250,000 cubic feet.

A second well was drilled on this property in 1904 by the Canadian Gas and Oil Company. It is located about 200 feet from the old well and reached a depth of about 1,400 feet. Very little gas was obtained and the hole is now plugged.

2. Cadastral lot 516.

On this lot (Archelle Forest) a well was drilled to a depth of 2,900 feet and gave enough gas to supply a house; it was never used and the hole is now plugged.

3. Cadastral lots 517 and 578.

Three wells were sunk on the property of Joseph Guillemette about 12 years ago. They reached depths varying from 2,000 to 3,000 feet and voided some gas and a little oil. The output was insignificant and the holes were plugged.

4. Cadastral lot 237, Grand range, northwest.

North of the previous group, on the property of Adrien Brassard, a well was sunk to a depth of 1,500-1,800 feet, about 30 years ago, in an attempt to obtain oil and gas. The well yielded a quantity of fresh water, but no oil or gas.

(b) Bécançour seigniory.

1. Cadastral lots 420, 421, 422, range St.-Simon (Pointu).

The boring on one of these lots (Ernest Rhéault) is known as the Bergeron well and is described as follows:

'In the course of the year, a boring of 685 feet was made at about 2 miles to the east of the village of St.-Grégoire in the Pointu concession. This work was done by Mr. E. Bergeron, who supplies the following information: After passing through 35 feet of loam and clay, he struck 25 feet of grey limestone underlaid with red schist, to 655 feet, and then 30 feet of grey limestone with more red schist below, at 195 and 240 feet small veins of gas, with an oily exudation at 195. At 600 feet 5 to 6 feet of bluish slate and underneath 50 feet of rock supplying very salt water. The boring was stopped without striking gas in merchantable quantity; the rocks traversed seemed to belong to the Medina formation mentioned by the Geological Survey.'[1]

[1]Report Mining Operations in the Province of Quebec, 1899, p. 41.

Malcolm gives the log of this well as below:

Bergeron Well[1]

—	Thickness	Depth	Formation
	Feet	Feet	
Drift	35	35	
Grey, calcareous, and arenaceous shale	25	60	Medina
Fine-grained, chocolate-coloured shales more or less gritty and calcareous	540	600	"
Bluish shale	5	605	Probably Lorraine
"Salt rock"	20	625	"
Pinkish grey, calcareous shale	30	655	"
Yellowish grey, calcareous shale	30	685	"

III. Louiseville District, Maskinongé County and St. Maurice County

This name is commonly associated with this gas-bearing area which really extends westward from Trois-Rivières to beyond Louiseville. Yamachiche might better be regarded as the centre of production.

The area is underlaid in the eastern part by the rocks of the Lorraine group, and in the west by Utica shale. The drift is thick over the whole region.

The Louiseville district is the best known area in the province and the only one that ever produced gas in commercial quantity. As far back as 1887 four wells were sunk in Louiseville by the Combustible Gas Company, an organization that had secured from the Legislature the exclusive privilege of boring for gas in the province. These wells reached respectively depths of 695, 545, 300, and 295 feet. Three of them were plugged, but the gas from one was used under the boilers of the Water Works Company.

In 1905, The Canadian Gas and Oil Company, J. G. Thibodeau of St.-Grégoire, president, was organized in Buffalo, N.Y., to exploit the gas of the province on a commercial scale. This company operated at first south of the St. Lawrence, but later directed its attention to the Louiseville field. Many wells were drilled and the product at first was piped to Louiseville where it proved ample to meet all demands. In 1907 an 8-inch pipe line was laid to Trois-Rivières. The supply was sufficient for domestic purposes, but failed when industrial plants drew upon it. Financial difficulties forced the company into liquidation and the plant was sold for scrap to E. O. Pequignot for $22,000 in 1907.

The pressure at first was too high and had to be reduced, later it fell off as more demands were made on the supply. Inefficient service resulted, confidence was lost, and the enterprise failed—not on account of an actual decrease of gas but due to the inability of the company to drill more wells in order to meet the increasing demand. Householders complained of injurious effects on chimneys. This fact and the coming of electric light contributed to the failure.

The more important wells in order westward from Trois-Rivières are listed in the following tables.

[1]Geol. Surv., Canada, Mem. 81, p. 236 (1915).

Wells of Louiseville District

Owner	Location and depth	Notes
Jos. Panneton	St. Marguerite road, 1½ miles from Trois-Rivières, 1,200 feet deep	Heat, light, cook, one dwelling. Not now used.
Armand Beaudry	" "	"
Zéphirin Garceau	" "	"
Henri Lacerte	Lot 849, parish of Yamachiche, gas at 180 feet; rock at 265 feet	Since 1908, heat, light, cook, one dwelling
Henri Girardin	Near village of Yamachiche, 280 feet in drift	Since 1910, light, partly for cooking, one dwelling
Crigène Bellemare	Near village of Yamachiche	Light only; one dwelling
Ephrem Bergeron	Near village of Yamachiche	One lamp only, water with gas
Napoléon Bellemare	Near village of Yamachiche	Company drilled deep well. Gave gas for short time. Not now used
Agapit Bellemare	Near village of Yamachiche. Shallow well	Still giving a little gas
Avila Descoteaux	Village of Yamachiche, 200 feet deep	Cook, heat, one dwelling, 20 years. Said to be sufficient for another house
Roméo Isabelle	Parish of Yamachiche, Ricard well. 4½ miles from village	Drilled by company in 1905. Supplied much gas at time. Pipes removed. Too far from house to justify purchase of pipes from wreckers
Nelson Lavergne	Lot 453 (?), parish of St.-Barnabé, 300 feet deep. Thomas Bournival well	This well was the chief producer and supplied gas for two years to Louiseville and Trois-Rivières. Not now used. This well led to formation of the company
Mme. Léon Carbonneau	Lot 706, parish of Yamachiche. 1,500 feet deep	Used at present
Joseph Samson	Lot 450 (?), parish of Yamachiche, 290 feet deep	Bored by company. Heat, light, cook, one dwelling to present time. Purchased pipes from wreckers
Henri Garceau	Lot 468, parish of Yamachiche, 280 feet deep	Bored by company, but not connected to pipe line. Heat, light, cook, one dwelling constantly

Alphonse Bourassa	Parish of Yamachiche	Enough to heat and light, but not used
Arthur Ferron	Lot 460, parish of Yamachiche. 160 feet deep	Bored by owner. Light, cook, heat, one house, for 17-18 years
Albini Milot	4 miles northeast of Yamachiche. 375 feet deep to rock	Light, heat, cook, one dwelling. Three years ago, two dwellings. Very salt water
Lucien Milot	One mile northeast of Yamachiche	Light, heat, cook, one dwelling
Thomas Trahan	Lot 1102, Yamachiche, one mile west of range Grande-Acadie	Light, heat, cook, one dwelling
Josaphat Trahan	Lot 1103, Yamachiche	Light, one house
Edmond Trahan	Lot 1110, Yamachiche	Light, one house
Clovis Héroux	Lot 1112, parish of Yamachiche	Supplied gas to company. Light, heat, cook, one dwelling now
Rodolphe Trahan	Three-fourths mile west of Héroux	No other fuel used in large house for past eight years
Several owners	Range Vide Poche	Privately drilled wells in drift; giving gas for all purposes
Gustave Bellemare	Lot 770, Ville de Louiseville, 125 feet deep	Heat, light, cook, one dwelling. Abandoned last year on account of corrosion of pipes by salt water
Edouard Beland	Lot 795, parish of Louiseville	Abandoned three years ago
About ten other owners	Parish of Louiseville	Drilled prior to 1904, gave a little gas

It is apparent that the area between and northward of Yamachiche and Louiseville is capable of yielding gas, at almost any point, in sufficient quantity to supply a dwelling. The wells require only a moderate depth in the drift, but are capable of yielding a steady supply almost indefinitely. The value of a small well of this kind is estimated by the owners at from $50 to $300 a year; perhaps $200 a year would be a fair average.

With regard to commercial development it is to be noted that for two years an adequate supply was produced for the communities of Louiseville, St.-Barnabé, St.-Sevère, and Yamachiche. There is no reason for doubting a similar capability for the future.

Abbé Laflamme gives the following log of a typical well at Louiseville:

Well at Louiseville

—	Thickness	Depth
	Feet	Feet
Drift	160	160
Shale	190	350
Limestone	295	654
Sandstone		

At 350 to 480 feet the limestone was coarse grained; at 515 feet it became darker and less crystalline; at 545 to 575 feet it enclosed crystals of pyrite. At the bottom of the well a fine, yellowish sandstone was struck which the drillers claim to have penetrated for a distance of 8 feet (Potsdam). Gas was struck at 216, 260, and 342 feet, salt water at 216, 261, and 290 feet, and mineral water at 644 feet.

Literature, Louiseville district:

Rept. Com. Crown Lands, 1883, p. 105.
Trans. Royal Soc. Canada, vol. VI (1888), sec. IV, p. 20.
Geol. Surv., Canada, Mem. 81, 1915, pp. 93 and 233.
Rept. Mining Operations in the Province of Quebec, 1914, pp. 58, 60, 61. This report contains a history of operations to date by M. Theo. Denis. (*See* Appendix, pp. 104-121).

IV. Verchères District, Counties of Richelieu and Verchères

This district extends along the south side of the St. Lawrence from St.-Roch in Richelieu county to Verchères in Verchères county. The underlying rocks are Lorraine shales and limestone.

(1) St.-Ours, Richelieu county.

Several shallow wells gave enough gas to light houses but not to heat.

Amédée Plante has obtained enough to light and heat house for the past four years.

Gas known to occur here 25 years ago.

(2) St.-Roch, Richelieu county.

One well (No. 2) was drilled in 1909 by the Quebec Fuel Company, on the property of Albert Perron, lot 323, parish of St.-Roch, about 1½ miles west of the village. The well was located on a slight rise a little north of the

middle of the lot. It reached a depth of 2,950 feet and finished in limestone, presumably Trenton. A small amount of gas was obtained, but it was never piped or used. At present the standpipe is in place, but there is no flow of either water or gas.

In 1928 a well was drilled for water at the north end of lot 387, parish of St.-Roch, on the property of Paul St. Laurent. This well gave enough gas to ignite, but it has not been utilized.

(3) Contrecœur, Verchères county.

One well was drilled about a mile west of the village and south of the highway on the property of Zotique Giguère. This well was drilled for water, but escaping gas became ignited and set fire to a barn. No use has been made of the gas.

(4) Verchères, Verchères county.

Well No. 3 of the Quebec Fuel Company was drilled in 1909-10 on lot 27, Grande Côte, parish of Verchères. It reached a depth of 2,450 feet and finished in Trenton limestone. A little gas was voided, but no use was made of it at the time. The owner of the property (Ludovic Boisseau), however, has utilized the gas for lighting and cooking in his home.

Well No. 4 of the Quebec Fuel Company was drilled to a depth of 2,300 feet on lot 202, Grande Côte, parish of Verchères. The owner (Alexandre Hébert) is still using the gas for lighting and cooking.

On lot 114, Grande Côte, parish of Verchères (M. Laporte), a well was sunk 90 feet to bedrock about 30 years ago. This well gave enough gas for cooking and lighting until three years ago when the supply failed. A still older well on this property, said to have been drilled 50 years ago, gave gas for a time but failed during the winter.

On lot 198, Grande Côte, parish of Verchères (Wilfred Chicoine), a well was drilled 70 feet to rock about 1894. It is situated near the north-east corner of the part of the lot south of the road, and has furnished enough gas for cooking and lighting, in summer only, to the present time.

V. Yamaska District, Yamaska Seigniory, Yamaska County

1. Lot 566, parish of Yamaska.

A single well was drilled at this point by the Quebec Fuel Company in 1908-9. It reached a depth of 3,060 feet in shales, but was not continued to the Trenton limestone. No oil and but little gas is reported. The well is No. 1 of this company.

VI. St. Hyacinthe District, St. Hyacinthe County

The region embraced in this field lies chiefly to the east and north of St. Hyacinthe; it is very flat, and so deeply covered with drift that surface undulations give no information as to folds in the underlying rocks. Exposures are seen only in the deeper valleys of streams traversing the area. It would appear, however, that the general sequence of strata is as follows:

Red shales	Comparable with Queenston formation of Ontario
Grey shales	Richmond and Lorraine formations
Black shales	Utica (?) formation
Limestone	Trenton formation

The Yamaska river below St. Hyacinthe was studied in detail by Mr. R. Harvie of the Geological Survey, Canada; he finds the rock to be much more fractured and to dip at higher angles than the surface of the country suggests. A complete section on the Nicolet river is given by A. F. Foerste. The thickness measured below the red Queenston shale is 2,513 feet of shales and thin limestones; the upper part corresponds to the Waynesville division of the Richmond of Ohio, and the greater part to the Eden.[1]

It is thought that a series of folds, parallel to the great fault that extends from near Quebec to lake Champlain, traverses this area. The axes of these folds run approximately northeast. Erosion has removed the red shale from the up-folds (anticlines), but has left this rock in the down-folds (synclines). 'Drillers, in carrying on boring operations with a view to testing the possibilities of the lower geological horizons, should avoid these synclinal basins and thus obviate the necessity of penetrating the beds of red shale.'[2]

The escape of gas from pools and the occurrence of gas in wells bored for water led to the formation of a company, La Compagnie de Gaz et de Pétrole de St.-Barnabé, to systematically drill for oil and gas in the St. Hyacinthe district.

1. Lot 164, range St.-Amable North, parish of St.-Barnabé.

The first well of the new company was drilled on this property (Jos. Fontaine) in 1910. The log is given as follows:

0 to 100 feet	Drift clay, sand, and gravel
100 to 115 feet	"Soapy" shales
115 to 135 feet	White sandstone, carrying a little salt
135 to 935 feet	Red shales
935 to 1,108 feet	Grey shales
1,108 to 1,114 feet	Grey granite ? (sandstone)
1,114 to 1,265 feet	Black shale
1,265 to 1,280 feet	Magnesian rock, carrying salt
1,280 to 1,860 feet	Black shale
1,860 to 1,866 feet	Secondary calcite and quartz in shale, which carries or covers the gas
1,866 to 1,880 feet	Black shale

'In this well, a strong flow of gas was struck at 1,860 feet, the well was continued 20 feet farther and capped. The rock pressure was measured by an officer of the Mines Branch on November 10, and found to be 275 pounds per square inch.'[3]

The standpipe is in place, but there is no flow of water or gas from the well.

In 1915 the Canadian Natural Gas Company sank a well on the same lot, 1,000 feet to the southeast of the first well; it reached a depth of 2,700 feet without striking gas. The log indicates that the drill passed out of the red shales at 1,070 feet. 'This contact probably corresponds to the one struck at 935 feet in the first well . . . The two wells are apparently on the east limb of an anticline, the crest of which would lie to the northwest of the first well.'[4] There is no flow from this well at present.

[1]Geol. Surv., Canada, Mem. 83 (1916).
[2]Geol. Surv., Canada, Mem. 81, p. 95.
[3]Report Mining Operations in the Province of Quebec, 1914, pp. 64-65.
[4]Op. cit., p. 65.

2. Lot 1319, range St.-André, parish of St.-Thomas-d'Aquin.

The National Gas Company acquired rights in St.-André, Pointe-du-Jour, St.-Roch, and Michaudville. A well was sunk in 1914-15, near the road about midway of this lot, the property of Alberic Leblanc (now Thomas Leblanc). The log of this well follows:

Feet	
0 to 110	Surface deposits
110 to 140	Bluish shale
140 to 190	Grey shale
190 to 290	Red shale
290 to 320	Brown shale
320 to 440	Red shale
440 to 500	Grey rock
500 to 960	Red shale
960 to 1,020	Black shale
1,020 to 1,500	Grey shales
1,500 to 2,050	No report

There seems to be some difference of opinion regarding this well, I was told, on the ground that it had been drilled by the owner in search of water, that gas was encountered, and that an explosion of some violence occurred. The standpipe is still in place but there is no flow at present.

On the same lot a second well was drilled by the National Gas Company at a point 1,800 feet north of the old well, but without results. The standpipe is in place, but there is no flow. It may be that the log given above refers to this well.

3. Lot 982, concession Ste.-Rose, parish of St.-Jude.

A fourth well was drilled by the Canadian Natural Gas Company near the west side of the southern half of this lot, the property of Joseph Chartier. This well reached a depth of 2,450 feet. Some pockets of gas were struck, but no commercial yield is recorded and there is no flow at present.

4. Lot 18, range Ste.-Françoise, county of St. Hyacinthe.

A well was drilled on this lot, the property of Emile Lorquet, by a Sherbrooke syndicate with Mr. Cyrus F. French as president.

This well reached a depth of 250 feet, but the drilling was discontinued owing to the breaking down of the rig.

Some gas was encountered, but there is no flow at present.

All the companies engaged in this field met with failure and the properties and rights were acquired in 1919 by M. Bouchard of St. Hyacinthe.

Despite the failure it can scarcely be considered that the region has been fully tested. The wells were sunk almost at random and the anticlines were not systematically located. Further, the upper red and grey shales proved much thicker than had been expected, and it is questionable if the Trenton, regarded as the gas horizon, was ever penetrated.

'The covering of the Trenton is here much thicker than it was anticipated when prospecting was begun. The drift is very heavy, exceeding 100 feet in many cases, and the outcrops are few. So that in the absence of borings, the thickness of the underlying formations could only be surmised

from observations in neighbouring regions. In Ontario, for instance, a maximum thickness of 1,300 feet has been assigned to the shale beds of the Lorraine and Utica lying between the top of the Trenton and the base of the Queenston.

The deepest boring of the Canadian Natural Gas Company has penetrated 3,455 feet into these overlying shale beds, without any change of character indicating the possible approach of the Trenton limestone; the conclusions concerning their maximum thickness will, therefore, have to be revised.

The presence of a permanent source of natural gas has not yet been demonstrated in this field, and for a conclusive test, a well would have to be put down to the Trenton formation, which is here overlain by more than 3,455 feet of shales, in which exist pockets of gas.'[1]

Literature, St. Hyacinthe district:

Geol. Surv., Canada, Sum. Rept. 1910, p. 219.
Geol. Surv., Canada, Mem. 81, p. 94 (1915).
Report Mining Operations in the Province of Quebec, 1914, 1915, 1916.

VII. Montreal District

Many wells have been sunk on Montreal island and in the immediate vicinity on the north side of the St. Lawrence. Most of these had been drilled for water with indifferent success, as the flow was not great and the water unpalatable due to contamination by sulphur, salt, petroleum, and gas. It is not the purpose of this report to describe wells drilled for water. A full account with logs is given in "The Artesian and Other Deep Wells of the Island of Montreal", Adams and LeRoy, Geological Survey, Canada, Ann. Rept., vol. XIV, pt. O, 1905. This report is more optimistic than present conditions indicate for I am informed that little artesian water is now being used in Montreal although about 200 wells have been drilled. Several of the sites of these old wells were visited, particularly the Longue Pointe asylum, but the wells are either plugged or the use of water discontinued.[2]

With regard to the occurrence of gas on Montreal island, the following extract is of interest:

'Whilst sinking a well between the road and the river at Longue Pointe, at a depth of 34 feet, a strong flow of gas occurred which was diminished by filling the hole with water and earth up to a height of 10 feet. The size of the well was 3½ by 4½ feet, and the escape of the gas covered the whole of this area, shooting up a flame of 40 feet high. A grey loam was struck and the gas was probably liberated by cutting through the gravel which is found in that region at a depth of 35 feet.'[3]

1. Maisonneuve.

With the immediate purpose of testing for oil and gas, a well was drilled at Maisonneuve by the Natural Combustible Gas Company, about 1886. Gas was struck at several levels, as well as salt and sulphur water. The total depth was over 2,000 feet. The log as given by Abbé Laflamme is as follows:

[1]Report Mining Operations in the Province of Quebec, 1916, p. 60.
[2]Geol. Surv., Canada, Mem. 72 (1915).
[3]Rept. Com. Crown Lands, 1885, p. 119.

Log of Maisonneuve Well[1]

—	Thickness	Depth
	Feet	Feet
Drift	76	76
Utica shale	80	156
Trenton limestone	249	405
Limestone interstratified with black shales	125	530
Limestone, brown	130	660
Shales with odour of petroleum	30	690
Limestone	15	705
Shales, less bituminous than the preceding	20	725
Limestone	20	745
Limestone and bituminous shale	55	800
Limestone	200	1,000
Limestone with crystals of pyrite	240	1,240
Limestone, pale, crystalline, becoming slightly arenaceous at the bottom	260	1,500

Gas veins were struck at 270, 400, and 1,120 feet, with salt water at 630 feet and sulphur water at 1,120 feet. Total depth over 2,000 feet.

2. Lot 3, St.-Henri-de-Mascouche, l'Assomption county.

'Throughout the whole of the region comprised between St.-Paul-l'Ermite, l'Epiphanie, and St.-Henri-de-Mascouche, emanations of combustible gas have long been known to occur, often rising from the ground in the company of salt springs. These emanations are similar to those which I have mentioned on several previous occasions, and arise from the same source; that is to say, I believe they are all due to the presence of bodies of petroleum in the subterranean limestone. The conformation of the land and other indications are the same as those at the places previously examined.

At the place called Cabane Ronde, on the lot No. 3 of the cadastre of St.-Henri-de-Mascouche, Messrs. Renaud Brothers and Dubois began a boring of 3 inches in diameter. They traversed a bed 54 feet thick of blue, yellow, and red clay, then 16 feet of black sand and coarse gravel, and finally struck the schist rock at a depth of 70 feet. During the whole of the time the work was going on the escape of gas was regular and abundant. Operations were begun in the autumn of 1883, and resumed in the spring of this year. A remarkable circumstance, worthy of being recorded, then occurred. At the beginning of June, on inserting the drill, the workmen met with a resistance which the efforts of four men were unable to overcome, and withdrew the instrument, upon which a violent gush of matter from the opening took place. For forty-eight hours as I was told by the witnesses of the scene, a column of liquid, gas, and stones could be seen issuing to a height of over 50 feet. The gas was of the same character as that previously reported on; the water was very salt; and the stones, some of which were half the size of a man's fist, were composed of quartzites, limestones, black bituminous schists, various kinds of granite, etc., and generally in the shape of rounded pebbles.

[1]Trans. Roy. Soc. Canada, vol. VI, sec. IV, p. 19 (1888).

I was further informed that at the beginning of the discharge a score or so of oily drops of petroleum were observed to fall, but were not gathered, as it was hoped that a large quantity would be forthcoming. The boring has since been continued, but more slowly on account of the hardness of the rock.

These facts are all very important and merit serious consideration, in connexion, however, with my previous reports.

I encouraged the enterprising prospectors to persevere, and it is to be hoped that they will be able to continue their labour in boring to a greater depth, and ultimately see it crowned by a discovery which will be of the greatest importance to the country if a vein of petroleum be struck, as there is reason to expect will be the case.'[1]

This well, on the property of Médore Renaud, is situated on a slight knoll in generally level country. There is a steady flow of slightly saline water and a constant escape of gas. Water in small pools about the well is covered with a thin film of oil. The well is said to be 187 feet deep. No use is being made of the gas, although there is sufficient flow to supply a house.

It is remarkable that combustible gas has been constantly discharged by this shallow well for a period of 46 years.

3. Notre-Dame-de-Grace, Montreal island.

'During the fall of 1914, a number of claims for oil and gas were staked out on the island of Montreal, at Notre-Dame-de-Grace, in the vicinity of the Blue Bonnets race course. In the course of digging a well in the superficial deposits, a strong odour of oil is said to have been noticed, and iridescent films were observed floating on the surface of pools of water. This occurrence gave rise to the staking of several claims by local people.

It may be observed that the underlying rock in this district is the lower part of the Trenton limestone, and that the underlying Chazy outcrops a short distance to the north of the Canadian Pacific Railway branch line which connects Mile End and Montreal West. Therefore, even supposing that the Trenton limestone of this district had once been oil-bearing, the eroding down of these limestone beds to near the base of the formation, preceded by the removal of all the overlying rocks likely to form an impermeable cap for the oil, and also the disturbed and broken state of the rocks in the vicinity of the igneous intrusion of mount Royal, constitute very unfavourable factors for the presence of oil in this district.

No work has yet been done on these claims, but deep wells for water have been put down at St.-Laurent, at Côte-des-Neiges, Outremont, some to the depth of 600 feet, and in none of these has the presence of oil been reported. On the contrary, most of them yield potable water.'[2]

VIII. Lake St. John District, Charlevoix County

Two wells have been drilled in the bituminous shales and underlying Trenton limestones west of lake St. John. Oil and gas were yielded by both wells, but not in commercial quantity.

[1]Report Com. Crown Lands, 1884, p. 84.
[2]Report Mining Operations in the Province of Quebec, 1914, pp. 66-67.

(1) Lot 32, range I, Roberval.

On the property of Henri Boivin a well was drilled in 1909 by Georges Cayouette to a depth of 659 feet. The log is given as follows:

	Feet
Soil	70
Black shale	60
Limestone	100
Granite (?)	12
Sandstone	417

Water was struck at 400 feet. The well is now yielding a little water and hydrogen sulphide gas. It is stated that at the time of drilling, a bottle of water, on standing, would show an eighth of an inch of oil on the surface.

(2) Lot 34, range I, Roberval.

M. Cayouette drilled a second well, near that described above, on the property of Edmond Gérard. The log is stated to be as follows:

	Feet
Soil	83
Black shale	60
Limestone, Sandstone, Soapstone	257

Gas was struck at 273 feet. No water. The well is yielding nothing at present.

A local syndicate, the "Lake St. John Petroleum Syndicate," proposes to sink more wells in order to test the possibilities of oil and gas in this district.

CONCLUSIONS

Sufficient evidence is available to justify the conclusion that natural gas occurs in considerable quantity in the Palæozoic plain of Quebec. The most important yield has been obtained from shallow wells in the drift overlying the Utica bituminous shales. It would appear that slow distillation of shales has given rise to the gas. Deep wells, on the whole, have been less satisfactory, but some gas has been obtained—a fact of little or no significance.

The Trenton limestone, in other regions, certainly yields both oil and gas in commercial quantity. It is questionable if any of the wells south of the St. Lawrence have penetrated the Trenton, as the overlying Upper Ordovician formations are very thick. It can scarcely be said that the possibilities are exhausted.

Owing to the heavy covering of drift, the folding of the strata is very difficult, if not impossible, to determine. A detailed survey of the whole region might reveal anticlines that would justify further expenditure, but the drilling of deep and expensive wells before the necessary geological data are obtained is simply a waste of money."

EASTERN ONTARIO AREA

In the eastern Ontario area, bounded by Ottawa and St. Lawrence rivers, some drilling for gas has been done. The records of all wells are not available, but the following data supplied by the Borings Division of the Geological Survey, indicate that a certain amount of gas has been produced. The records are as follows:

Caledonia Township

Five wells were drilled during 1917 and 1918 on lot 12, concession V, to a depth of about 130 feet. Water and gas were obtained in these wells, but the records do not show that bedrock was penetrated.

South Plantagenet Township

A well drilled on concession X, in 1916-17, to a depth of 55 feet, gave both water and gas. The water was saline and flowed from the well.

North Plantagenet Township

A well drilled on lot 24, concession VIII, to a depth of 60 feet, gave both gas and water, the latter flowing from the well.

Clarence Township

Near the small village of Bourget on lot 23, concession III, a pipe was driven to a depth of 200 feet where shale was encountered. Gas in small quantities escaped from this hole for many years and later another well 30 feet deep yielded sufficient gas to be used in a farmhouse for lighting and cooking purposes. The gas evidently is derived from the unconsolidated materials overlying the bedrock.

CHAPTER VIII

GASPE PENINSULA

PHYSICAL FEATURES

Gaspe peninsula is that part of the province of Quebec that lies south of St. Lawrence river and east of Matapedia river. It is bounded on the south by Chaleur bay and Restigouche river. The width, north and south, is roughly 75 miles and the length, east and west, 150 miles. The peninsula is a part of the Appalachian system of mountains which in United States trend in a northeast and southwest direction, but in Gaspe turn to the east and then to the southeast where the mountain folds coming out to the coast form a very rugged shoreline. The trend of folding accounts for the striking contrast between the north and southeast coasts of the peninsula.

As stated by Coleman[1]

"the north side is a smoothly sweeping curve of shore without a single bay in which a ship can take shelter. The little harbours are at the mouths of the rivers and except at high tide can scarcely be entered even by coasting schooners; but the east and south sides are greatly indented and included the perfectly sheltered Gaspe basin in which large ships can anchor . . . . On the north side there are many bold shores with cliffs of rock rising hundreds of feet and sometimes running continuously for miles and there are similar relations on the east, especially near Roche-Percé, but on the south cliffs are less frequent and are low, and often the land sinks gently toward the sea as marshes, or sand stretches, or gravel bars. The north side of Gaspe is without an island and Bonaventure island, near Percé is the only important one on the southern coast."

The interior of Gaspe, according to Alcock[2]

"is a plateau, varying in height up to 4,200 feet. Standing anywhere on a summit where a distant view can be obtained a remarkably even skyline meets the eye in every direction. Ridge succeeds ridge with only an occasional elevation, slightly above the general level. The highest part is a belt extending for about 50 miles along the middle of the peninsula. The elevation of this part of the plateau, to which the name Shickshock mountain is given, varies from about 3,000 feet to 4,200 feet. Tabletop mountain is considered the eastern end of the Shickshocks proper. To the east of it the country is over 1,000 feet lower. At Tabletop the higher plateau country has a broader north and south extension . . . . In the region extending from Tourelle to Madeleine the plateau more nearly approaches the St. Lawrence shore, in places an elevation of over 3,000 feet being found within 6 miles of the coast. East of Tabletop the higher summits of the plateau country rise about 2,800 feet. To the south of the Shickshocks proper many of the broad, flat-topped areas between the river valleys rise to 1,800 and 2,000 feet. Throughout the peninsula the most striking feature of the topography is the flat-topped character of the interfluvial areas and the abrupt descent to the valley bottoms. On the flat divides there are occasional ponds and swamps.

The valleys throughout the peninsula show similar features. The streams are swift and their headwaters are frequently torrential. Rapids are present and in places there is an underground flow. The stream gradient varies considerably. On the main streams it is about 20 feet per mile. On the tributary streams there is commonly a gentle gradient near the headwaters and then a swift descent through deep-cut valleys to the main stream.

[1]Coleman, A. P.: Geol. Surv., Canada, Mus. Bull. 34, p. 6.
[2]Alcock, F. J.: "Mount Albert Map-area, Quebec"; Geol. Surv., Canada, Mem. 144, p. 12.

The valleys are entrenched below the plateau surface to depths of from 500 to 2,000 feet. The valley bottoms are narrow with flood-plains well developed only in their lower reaches. The valley slopes are steep, the actual angle depending to a great extent on the character and attitude of the bedrocks. Hard volcanics in places give almost vertical cliffs; in other places talus slopes lie at the angle of repose of the loose material. Limestone country as a rule gives more gentle slopes, but in places where the dips are low, it, too, forms vertical cliffs."

The oil-bearing region of Gaspe peninsula, according to Parks,[1]

"is essentially the lower part of the area drained by the York and St. John rivers; it is about 30 miles east and west and 10 miles north and south. Settlement has invaded the district to no appreciable extent; there is a mere fringe of cleared land along the shore and for a short distance up the river valleys. Practically the whole area, therefore, is densely wooded and without ready means of access. Canoes on the rivers and the roads and trails of the lumber companies are the only means of penetrating the country.

The whole area may be roughly regarded as a broad, synclinal valley with the north and south limbs included . . . . The rivers are about 5 miles apart and define a central strip that is comparatively level, seldom exceeding 600 or 800 feet in elevation, except towards the western end of the area. Both the northern and the southern flanks within a short distance from the rivers rise to greater altitudes, increasing in height westward to a maximum of about 2,000 feet. The numerous tributaries of the two rivers have deeply incised the flanks of the valley, cutting them into isolated hills with steep sides. The country is decidedly rough and difficult to traverse except in the region between the two rivers and for a short distance north of the York and south of the St. John. All the oil wells are located in this more level, central zone, the most northerly well having an altitude of 1,000 feet."

Coleman[2] has shown that

"the Labrador ice-sheet divided into two lobes at the western end of Gaspe peninsula, one lobe filling the St. Lawrence channel and the other following Matapedia valley and the basin of Chaleur bay. These lobes passed on each side of the peninsula but met beyond it and continued as a single sheet of ice. The space left between the two lobes was, however, not left bare, but was largely covered by local glaciers . . . . There is no evidence that glaciers worked on the highest parts of the Shickshock mountains, for their surfaces consist of loose blocks of the underlying rock, seldom showing any displacement, and no striated surfaces or boulder clay have been found above 2,500 feet . . . . . In general it may be said that the effects of local glaciation in Gaspe are not strongly marked and may easily be overlooked. Bell and Chalmers emphasize the frequent occurrence of residual soils where the rock has weathered in place, and most of the surface of Gaspe above the level of the marine deposits is of that character. Boulder clay is rarely found and then only in valleys, and it is mainly the scattered stones derived from the mountains that prove that ice once covered the lower ground. The residual soils and the V-shaped, zigzag river valleys are proofs that the region was in general only lightly touched by ice."

STRATIGRAPHY

Parks[3] describes the stratigraphy as follows:

"The rocks forming the peninsula are disposed roughly in bands parallel to its greater diameter, but instead of running due east and west, the various belts turn somewhat to the south at both ends of the area, more particularly the eastern. As a result, the belts of rock in the east run north of west, and those in the west a little north of east. The northern and southern belts of rock are of early Palæozoic age, but the central region is composed of strata of later age (Devonian). On the southern side are some patches of still later rocks (Carboniferous). To understand the general structure one must conceive: (1) that rocks of early Palæozoic time

[1]Parks, W. A.: Quebec Bureau of Mines, 1929, pt. B.
[2]Coleman, A. P.: Geol. Surv., Canada, Mus. Bull. 34, pp. 13-14 (1922).
[3]Parks, W. A.: Ann. Rept., Quebec Bureau of Mines, 1929, pt. B, p. 330.

were laid down in successive seas that at one time or another covered the whole area; (2) that earth movements raised the northern and southern margins of the area and depressed the central part; (3) that both fresh and marine waters occupied this central area in Devonian time and that a great thickness of sediments was formed therein; (4) that subsequent movements raised the whole peninsula and folded it into anticlines and synclines more or less parallel to its greater diameter. It is significant, also, that igneous activity played a part, both during the deposition of the Devonian rocks, and afterwards during the period of folding.

The Devonian rocks forming the central part of the Gaspe peninsula are alone of importance for the purposes of this report, as they alone have given evidence of petroliferous character. On the east coast the Devonian belt has a width of about 24 miles. Ells gives its width on the Bonaventure river as 33 miles, on the Little Cascapedia as 12 miles, and on the Cascapedia as 21 miles. The belt continues, with wide fluctuations in diameter, to the Matapedia river where its width, according to Ells' map, is inconsiderable.

Logan referred to these strata as the "Gaspe series" and divided them into a lower limestone formation "Gaspe limestone," and an upper sandstone formation "Gaspe sandstone." The former he regarded as Silurian in age and the latter as Devonian. Ells considered that the upper limestones, also, were Devonian, and Clarke at a later date placed the whole series, both limestones and sandstones, in the Lower and Middle Devonian.

GASPE LIMESTONE

The limestones of the northern rim were divided into several divisions, numerically indicated, by Logan; Clarke has grouped these under three formations as follows:

	Feet	
Grande Grève limestone	800	(Logan)
Cap Bon Ami limestone	1,050	"
St. Alban limestone	160	"

The upper limestone (Grande Grève) underlies the sandstone across the whole area from cape Gaspe to Percé, but the lower formations are much thinner, if not absent, on the southern rim of the basin.

Besides cropping out on the northern and southern sides of the basin, the limestones come to the surface inland, on the summits of folds, where the overlying sandstones have been removed by erosion. The limit of their extension inland is not very well known. Murray and Ells report them on the Bonaventure river, but it is questionable if the limestones south of the sandstone belt on the Great and Little Cascapedia are of this series, as their fossils mark them as true Silurian, not Lower Devonian. Alcock refers to Lower Devonian limestones near the Cascapedia river in Lemieux township. Here the limestones are associated with argillite and much tuff. Again, in the Mount Albert area, Alcock recognizes the Gaspe limestones, but admits that the lower beds may be of Silurian age. It would appear that these Lower Devonian limestones are associated with much more volcanic matter west of the Bonaventure river than to the eastward of that stream . . . . .

The limestones of cape Gaspe are hard but true limestones with many fossils. Logan noted the fact that rocks on the Dartmouth river, attributed to the same series, are hard, flinty, and without fossils. All limestones seen during the past summer, on the Dartmouth, York, and St. John rivers, and on their numerous tributaries, are of this character—thin-bedded, very hard, highly siliceous limestones, much contorted, folded, and faulted. The most careful search revealed not a single recognizable fossil.

Sections were made of this hard limestone from Mississippi brook; the more typical stone shows very fine crystals of calcite embedded in a small amount of amorphous silica. The flinty varieties are similar, but with a great quantity of amorphous silica. A specimen of the limestone from near the sandstone contact on Anse à Brillant brook is quite different: it consists of much larger crystals of calcite with numerous angular quartz fragments and some feldspars; there is no amorphous silica, but small pieces of broken fossils are present.

The total quantity of silica in the flinty limestones is enormous: the formation is probably a thousand feet thick and possibly consists of 25 per cent silica. The origin of this silica is questionable. I would venture the opinion, however, that it was derived from the leaching of ashes discharged from volcanoes known to exist in Lower Devonian time to the westward of the district under discussion.

GASPE SANDSTONES

Lying above the Grande Grève limestone and filling the central part of the geosyncline is the great series of sandstones, conglomerates, and shales to which Logan gave the name "Gaspe sandstones" and to which he attributed a thickness of 7,036 feet. These rocks form the whole coast from Little Gaspe cove on the north side of Gaspe bay to point St. Peter, and probably extend under the sea nearly to Percé. Inland, these strata occur on all the streams, from the Dartmouth to the Malbaie; they have a great width on the Bonaventure river, cross the Cascapedia, and probably reach the Matapedia river.

The presence of conglomerates, the prevalent crossbedding of the sandstones, and the rapid alternations of sandstones and shale indicate shallow water during the time of deposition, and the presence of numerous plant remains, of which some are terrestrial, attests freshwater conditions. On the other hand, the occurrence of occasional beds filled with marine fossils shows that the sea sometimes gained access to the basin. Dr. I. W. Jones reports marine fossils as far west as Cascapedia river.

The geography of Middle Devonian time must have been very different from that which now obtains in order to shut the sea out from the Gaspe geosyncline. We must postulate a land mass to the east. Clarke strongly advocates this view. 'Therefore . . . . we predicate with confidence a continental area outside and eastward of the great Appalachian depression, during all the period of deposit of sediments now filling it.'[1]

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[1]Clarke: Early Devonic History of New York and Eastern North America"; "N.Y. State Mus., Mem. 9, p. 97 (1908).

It is significant that conglomerates, typical off-shore deposits, occur in the coast section and on the Malbaie river, but are sparingly seen inland. There is reason to believe, also, that the strata inland represent only the lower part of the formation, as the reddish and greenish shales, so abundant in the coast section, are sparingly seen inland in the district examined, but they are reported by Dr. I. W. Jones on the Grand Cascapedia river. The chief rocks in the basins of the York and St. John rivers are grey sandstones and shales, the former frequently bituminous.

The whole series of Gaspe sandstones was carefully measured and described by Logan.[1] Subsequent writers have added little to his account. The series consists of bewildering repetitions of sandstones, shales, and conglomerates reaching a thickness of 7,036 feet. It is significant, however, that the lower 4,000 feet contains little conglomerate, while the middle and upper parts are far richer in this coarser type of stone. The upper part, also, is characterized by a far greater quantity of reddish shales and sands that distinctly colour the overlying soils, as at Cap Rouge, and on the south side of the Northwest arm of Gaspe bay, east of the bridge over the Dartmouth river. As the deepest wells in the interior penetrate less than 3,000 feet of sandstone and shale, with an average very much lower, it is apparent that all the upper and middle members of the series have been eroded from the basins of the York and St. John rivers. This erosion is further attested by the general absence of conglomerates in the interior. The various beds are frequently discontinuous and layers essentially alike are often repeated; in consequence, it is practically impossible to recognize definite horizons in isolated outcrops. The lower part of the series as exposed in the interior, shows a fairly constant sequence as follows:

Sandstone interstratified with thick bands of grey shale
Hard, yellowish weathering sandstones
Calcareous sandstone
Grande Grève limestone"

In regard to the relations of the Gaspe limestones and sandstones Parks states that "Logan believed that they are conformable and Clarke has practically endorsed this view. If this interpretation is correct, all subsequent folding affected similarly the limestones and the sandstones. On the other hand, if folding occurred after the formation of the limestones and before the sandstones were deposited, there will be irregularities on the surface of the limestone that will not be revealed by the overlying sandstones.

Where the two series are observed in contact—cape Gaspe, Dartmouth, York, St. John, Malbaie, Bonaventure rivers, and their various affluents—the sandstones seem to lie almost conformably on the limestones. There is, however, always a slight difference in dip. Wherever observed in the interior, the limestones are folded and faulted far in excess of the adjacent sandstones, strongly suggesting deformation before the deposition of the latter. Alcock records distinct unconformity between the two series in the township of Lemieux and suggests a like condition in the Mount Albert area. The fact that the Gaspe sandstones overlie indiscriminately Silurian and Devonian limestones and volcanics points to a greater depression of the basin implying earth movements in the interval."

[1]Geol. Surv., Canada, Rept. for 1834, pp. 80-110; ibid., Rept. 1863, pp. 394-396.

STRUCTURAL GEOLOGY

The sedimentary rocks now found in Gaspe peninsula were deposited in the St. Lawrence geosyncline. At least at two periods sedimentation was interrupted by mountain building accompanied by igneous activity. The first of these periods of mountain building took place in Ordovician time and these "primary or early folds," according to Clarke,[1]

"are those which find their centre or protaxis about the Shickshock or Notre Dame mountains . . . . . About this ridge of Precambrian crystallines are the great areas of crumpled shales which are designated by the Canadian geologists Cambric and Cambro-Siluric and which build the rock walls fronting the great river (St. Lawrence) as far as cape Rosier. These early Palæozoic rocks in the St. Lawrence valley, believed to represent strata continuing to the close of the Lower Siluric, are so irregularly disposed that their unconformity with beds above is evident . . . . . The valley of the lower St. Lawrence river was outlined by the primary folding, but was not completed until the date of the great folds of Devonic time."

According to Alcock[2] this Ordovician disturbance "was accompanied by the intrusion of serpentine rocks, but as far as it is known there are no granites in the peninsula related to this period of deformation."

The next period of mountain building took place, according to Schuchert and Dart, toward the close of the Middle Devonian when "the whole of the St. Lawrence trough was involved in mountain making, the Acadian disturbance, and the prophesy of this orogeny was already heralded in Middle Silurian time when volcanoes began to pour out much basalt."

According to Alcock[3]

"the main structural features of the peninsula today date from the period of Devonian folding. The whole region was thrown into broad folds along east and west lines, which was apparently the direction which the Ordovician folding had taken. In each case the thrust was against the old land of Precambrian rocks to the north, along whose border the geosyncline of Palæozoic rocks has been deposited. The folding was accompanied by faulting on a large scale . . . . . The Devonian period of folding was accompanied by the intrusion of a granite batholith . . . . . The period of Appalachian folding which affected the eastern United States in the Permian apparently did not extend, on any large scale at least, into Gaspe. The chief evidence for this lies in the structure of the series of conglomerates and sandstones, known as the Bonaventure series, which border Chaleur bay. This thick series is probably either late Devonian or early Carboniferous, but its age is not definitely known . . . . . The series uniformly lies horizontally or with very low angles of dip, but is broken by faults that may date from the Appalachian movement."

Since it is believed the oil prospects of Gaspe are confined to Devonian strata the extent and deformation of these rocks are important from the standpoint of petroleum geology. According to Parks[4]

"the Devonian basin of sedimentation, in the coastal region, extends transversely from Cape Rosier cove on the north side of cape Gaspe to near the mouth of the Little Pabos river, a distance of about 36 miles in a straight line south 25 degrees west. The axis of the basin is normal to this direction and stretches inland for a long distance . . . . . The underlying rock is limestone and the upper rock sandstone. The latter is more limited in width extending about 22 miles south 25 degrees west from the Little Gaspe cove.

This whole region may be regarded as a broad syncline with the upturned and denuded strata forming its northern and southern limbs. More or less parallel to the long diagonal of the basin, i.e. west 25 degrees north, the rocks are folded into anticlines and synclines and distorted by both strike and dip faults."

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[1]Clarke, J. M.: New York State Mus., Mem. 9, p. 15 (1908).
[2]Alcock, F. J.: Geol. Surv., Canada, Mem. 144, p. 50 (1926).
[3]Alcock, F. J.: Geol. Surv., Canada, Mem. 144, p. 50 (1926).
[4]Parks, W. A.: Ann. Rept., Quebec Bureau of Mines, 1929, pt. B, p. 41.

Sir Wm. Logan, who first studied Gaspe area, recognized certain definite structural features in the Devonian rocks. At a later date Ells published a map[1] of the Gaspe oil fields showing the position of the anticlines and faults that had been recognized. Parks has added a further contribution to the structural details and now recognizes, from north to south, the following main structural features[2] (*See* Figure 16): Northwest Arm syncline; Halidmand anticline; Haldimand fault; York River syncline; Mississippi anticline; York River fault; Tar Point anticline; and Point St. Peter anticline.

"The Point St. Peter anticline[3] is a very distinct fold, approximately parallel to the rim of the basin along cape Gaspe. The summit of the fold is denuded inland and the underlying limestones come to the surface to within a short distance of point St. Peter—much nearer than the old maps indicate. The St. John river follows the fractured crest of this fold for some distance; it then breaks across the northern limb and reaches the sea through the synclinal valley in the sandstones . . . . . The country between cape Gaspe and point St. Peter anticline constitutes a broad, synclinal valley, with the limestone floor depressed to a depth of at least 3,000 feet below sea-level and with its flanks rising to a height of nearly 2,000 feet above sea-level . . . . . In general it may be said that this syncline is upfolded into minor anticlines, cut by major faults both parallel and transverse to its axis and much faulted and jointed on a small scale."

The details of the structure according to Parks are as follows.[4]

"NORTHWEST ARM SYNCLINE

The strata on the northern side of Gaspe bay dip generally south 25 degrees west towards the water. At the extremity of the cape the dip is only 20 degrees, but the angle increases suddenly to 50 degrees or 60 degrees opposite cape Haldimand. At the Dartmouth bridge it is only 12 to 20 degrees, and it scarcely exceeds 30 degrees to the falls. All dips on the Dartmouth are southwestward, indicating that the river is north of the axis of the syncline. It is apparent that the strata are more sharply folded from the point opposite cape Haldimand to the mouth of the Dartmouth than either east or west of this stretch. This fact may be explained by the Haldimand anticline and it may indicate, also, that the latter structure may not extend far inland.

HALDIMAND ANTICLINE

A pronounced anticline extends from Cape Haldimand to above the mouth of the Dartmouth. I believe, however, that it dies out, or is cut off, by a transverse fault, at or near Watering brook. The strata dip on the average north 25 degrees east along the shore from near cape Haldimand to within a mile of the Dartmouth bridge. The angle of dip varies but is never low. On the road near Gaspe harbour, at the mouth of Bean brook, and on the hills above Gaspe village, the strata are vertical or even dip southwest. I believe this reversal to be due to overturning rather than to having passed the summit. About a mile below the Dartmouth bridge the dip is again vertical or even southwestward at very high angles. It is impossible to state whether this point marks the summit or whether the

[1]Map No. 802 to accompany Part A, Ann. Rept., Geol. Surv., Canada, vol. XV.
[2]Parks, W. A.: Ann. Rept., Quebec Bureau of Mines, 1929, pt. B, p. 42.
[3]Parks, W. A.: Op. cit., p. 42.
[4]Parks, W. A.: Op. cit., pp. 43-48.

strata are overturned. I am inclined to favour the latter conclusion as the locality is within a half mile of the synclinal axis. It is evident that the northern limb of the Haldimand anticline or the southern limb of the Northwest Arm syncline is much steeper than the northern. The shaly nature and red colour of the strata below the Dartmouth bridge indicate that they belong to the upper third of the series. Erosion seaward has removed these upper beds revealing the middle beds along the shore at Sandy beach.

The summit of the Haldimand anticline cannot be accurately located by the evidence at hand. It certainly lies between the shore and the chain of great hills that border the south side of the Northwest arm, for the few exposures that could be found between the shore and the hills indicate southerly dips at comparatively low angles. I think the crest strikes the shore west of Gaspe village. In the Haldimand peninsula the summit does not seem to follow the same line, but to be displaced to the west, and to be about at the point where the Douglastown road leaves the Southwest arm. From here it runs out to cape Haldimand. From Gaspe harbour to the road mentioned above, the dip is northward, but gradually decreases in angle; west of the road the dips are southwestward, also at low angles. The dislocation of the summit on the two sides of the arm may be due to a transverse fault; evidence of this kind of faulting is not wanting elsewhere.

The southern limb of the Haldimand anticline is not well defined. The dips are usually at a low angle southwestward, and are often irregular and confused. The most consistent series of observations was obtained on the south shore of the Southwest arm, averaging 20 degrees, south 32 degrees west.

The districts of highly inclined or overturned strata of the Haldimand anticline have facilitated the escape of petroleum; hence the spring at Sandy beach, the strong odour of the strata at Gaspe village, and the seepages along the upper part of the south shore of the Northwest arm.

HALDIMAND FAULT

A profound fault, a short distance south of the axis of the Haldimand anticline, has seriously affected the interpretation of the anticline itself; in fact, it seems to overshadow the anticline in the structure of the district. The upthrow is on the south side and the underlying limestones are exposed on a range of hills, 1,000 feet above sea-level. In view of the high dip towards the north of the sandstones along the coast it would not be necessary to assume a great displacement to account for the outcrops of limestone, were it not for the fact that the few dips observed along the north flank of the range are all at a low angle towards the southwest. It is assumed, therefore, that the anticline is steep only on its northern side and that the fault lies south of the summit. The northwestward extension of the fault is not known; it possibly reaches to the vicinity of the serpentine mountain, 8 or 10 miles above the Dartmouth bridge.

Eastward, the line of fault seems to strike the shore of the Southwest arm, about 1½ miles west of the wharf at Gaspe. The only indication is the disturbed condition of the strata. Across the arm, a similarly contorted area may represent the continuation of the fault. . . . . .

There is no doubt that a fault about in line with the Haldimand fault extends up the valley of Seal Cove brook. On the shore of the Douglastown barachois, where the extension of this line would strike the water, is an area of confused and irregular dips. It is possible that these two faults are continuous and represent the same line of fracture. The displacement seems to be more pronounced inland.

YORK RIVER SYNCLINE

A second synclinal depression between cape Gaspe and point St. Peter, perhaps to be regarded as the major down-fold, extends northwestward from the Douglastown barachois. In the western part of the area under review, the syncline is interrupted by a great anticlinal fold (Mississippi anticline) which divides it into two. The southern or main branch forms the valley of the York river; the northern branch lies between the Mississippi and Haldimand anticlines, and parts from the main branch near the mouth of the York river. It is probable, also, that the Northwest Arm syncline becomes confluent with this major down-fold under the water of Gaspe bay.

The dips of the sandstones towards the axis of the York River syncline are not high. The floor of the fold is broad and undulating; in consequence the exact line of axis is difficult to determine. A peculiar and unexpected feature is that the prevailing dips are not directly towards the axis but that they trend westward. Even along the assumed axis the dips are at a low angle to the west. There is no doubt that the main syncline plunges westward, whereas one would have expected an eastward plunge. As the limestones outcrop at much higher levels inland than on the coast, it might be concluded that both upward and downward foldings were more pronounced inland.

YORK RIVER FAULT

Dr. Ells records a fault south of the International Oil Company's well in York, with an upthrow on the south side; this same fault is recognized by him west of the mouth of the Little fork. There is no doubt of the occurrence of limestone in the bed of the York river along this line, which is approximately parallel to the great Haldimand fault. It seems a fairly safe assumption that the York River syncline is divided into two structural basins by this fault. West of the fault the plunging character of the syncline is most apparent. Here we have a distinct structural basin with scarcely a contradictory observation. . . . . .

East of the fault the broad valley again shows the prevailing westerly dips, but they are less pronounced near the coast. A minor, sharply folded anticline crosses the Big fork of the York about half-way between the axis of the syncline and the limestone outcrop to the north. . . . . .

The northern branch of the great syncline lies between the Haldimand and Mississippi anticlines. This area is elevated, deeply covered with drift, and difficult of access. Such observations as were possible show fairly flat-lying strata with low and varying dips.

MISSISSIPPI ANTICLINE

As already stated the main synclinal valley is interrupted in its western part by a broad anticline from the summit of which the sandstones have been eroded away except towards its eastern end. The anticline plunges eastwards, the limestone outcrop diminishes in width eastward and comes to an end a short distance west of the line between York and Gaspe Bay South. From this point the anticline continues east for about 5 miles in the sandstones. . . . . North of the axis, a few observations seem to indicate supplementary folds, but insufficient work was done to justify any details.

TAR POINT ANTICLINE

A pronounced fold at Tar point brings to sea-level the lowest layers of the Gaspe sandstones, if not the Grande Grève limestone itself. . . . .

It is true that from Tar point to Douglastown, and on the south shore of the barachois, the dip of the strata is consistently northward. It is also true, however, that the dip is likewise northward wherever observed between the limestone outcrop of the Point St. Peter anticline and the supposed extension of the Tar Point anticline inland. In other words, there is no evidence of a southern limb for the anticline if it runs as suggested. I am forced to the conclusion that the Point St. Peter fold dominates the Tar Point fold and that the latter is confined to a narrow belt along the coast.

The crest of the Tar Point anticline is clearly defined on the coast. The northern limb, near the summit, dips 65 degrees north 30 degrees west. On the immediate south side the dips are southward but variable in direction and degree as far as Anse à Brillant brook where the strata are disturbed by a fault. South of the brook the strata gradually assume a consistent dip at about 30 degrees, south 32 degrees east . . . . . A distinct fault, observed where the railway crosses a small brook north of Tar point, also strikes in practically the same direction. A fault occurs, also, at the mouth of Anse à Brillant brook; it is revealed only by greatly disturbed strata that do not permit its direction to be ascertained.

The coastal region between Tar Point anticline and the Douglastown barachois is more disturbed than the section along the coast would indicate. Observations on the railway and on the highway show strata in attitudes that would not be suspected. The dip, however, is generally northward. The most significant feature is the occurrence of a strong fault along Seal Cove brook. The strata dip northward on both sides of the stream, but the inclination is much less on the north side. It is a reasonable assumption that the tar and oil seepages along this brook are due to the fault. I have already suggested that there may be a connexion between this dislocation and the Haldimand fault. In any event, there is a zone of fracturing running in the same general direction that it would be well to avoid in a search for oil.

POINT ST. PETER ANTICLINE

This fold is the dominant structural feature of the district and bounds the southern side of the basin. Its summit is denuded of sandstone for the most part and only near the coast is it so covered."

EVIDENCES OF PETROLEUM

Seepages of oil have long been known to exist in Gaspe peninsula. Regarding these, T. Sterry Hunt[1] in 1866 reported "petroleum springs and gum beds or superficial accumulations of thickened petroleum are met with in a great number of places throughout this region, sometimes issuing from the outcrops of the limestone, but more generally from the overlying sandstone."

These petroleum indications were described by Sir Wm. Logan[2] in 1863 as follows.

"The limestones of this region . . . . are observed in various points on Dartmouth, York, and Malbaie rivers to be more or less impregnated with petroleum. The limestones are generally dark bluish grey with layers and nodules of chert and are traversed by numerous veins of white calc-spar sometimes including drusy cavities. These often hold petroleum which impregnates the calc-spar and is seen to rise to the surface when freshly broken fragments of the rock are thrown into water . . . . In many places throughout this region the limestone is overlaid by a sandstone . . . . This rock near the mouth of York river is like the limestone, impregnated with petroleum, and on the same river, about 12 miles from the entrance of Gaspe basin, small portions of solid bitumen were found in the cavities of a trap dyke cutting the sandstone . . . . . At the oil spring at Silver brook, a tributary of York river, the petroleum oozes from a mass of sandstone and arenaceous shale which dips southeasterly at an angle of 13 degrees and is nearly a mile to the south of the crown of the anticlinal. The oil, which here collects in pools along the brook, has a greenish colour and an aromatic odour . . . . From a boring which has been sunk in the sandstone to a depth of about 200 feet there is an abundant flow of water accompanied with a little gas and very small quantities of oil. Farther westward, at about 12 miles from the mouth of the river, oil was observed on the surface of the water at the outcrop of the limestone. Petroleum is met with at Adams' oil spring in the rear of lot B of York nearly 2 miles east of south from the entrance of Gaspe basin. It is here found in small quantities floating upon the surface of the water; and nearby is a layer of thickened petroleum mixed with mould, at a depth of a foot beneath the surface of the soil. A mile to the eastward, at Sandy beach, oil is said to occur, and again at Haldimand town where it rises through the mud on the shore. These three localities are upon the sandstone . . . . . Farther to the southeast . . . . . about 2 miles west of Tar point, which takes its name from the petroleum found there, another oil spring is said to be found, three-quarters of a mile south of Seal cove. On the south side of the Douglastown lagoon and about a mile west of the village, oil rises in small quantities from the mud on the beach . . . . . Farther to the westward oil is said to occur on the second fork of the Douglastown river. Traces of it have also been observed in a brook near St. George cove on the northeast side of Gaspe bay. In none of these localities do the springs yield any large quantities of oil; nor have the borings which have been made in two places, been as yet successful."

The same author also describes the presence of oil in a greenstone dyke at Tar point. Cavities in the dyke "are filled with petroleum; this in some instances has hardened to the consistency of pitch."

Regarding the presence of oil seepages in Gaspe Parks states[3] that "more than eighty localities of oil seepages were known long ago and it would not be difficult to cite one hundred or more at the present date."

Development of the Field

The following account by Parks[4] gives an outline of the search for oil and gas in Gaspe.

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[1]Hunt, T. Sterry: Geol. Surv., Canada, Rept. of Prog. 1866, p. 260.
[2]Logan, Sir Wm.: "Geology of Canada, 1863," pp. 788-9.
[3]Parks, W. A.: Ann. Rept., Bureau of Mines, Quebec, 1929, pt. B, p. 10.
[4]Parks, W. A.: Op. cit., pp. 1-10, 12-27.

"The first published reference to the occurrence of petroleum in Gaspe appeared in the "Proceedings of the Literary and Historical Society of Quebec" in 1836. The article was written by Mr. McConnell and the material was referred to as "Barbadoes tar." In the Report for 1844 of the Geological Survey, Canada, Sir William Logan described in detail the coast section of Gaspe, and referred to the bituminous matter at Tar point, and to petroleum springs or seepages on the beach above Douglastown and on Silver brook. These occurrences, and many others known to the inhabitants of the district, stimulated a desire to find some use for the material. In 1846 Count de Rottermund made some suggestions in this respect, but it was not until after the discovery of petroleum in Pennsylvania in 1859 that serious attention was directed to the Gaspe occurrence.

The first attempt to drill for oil was made in 1860 by the Gaspe Mining Company which drilled two shallow wells, one on the Douglastown beach near the oil springs, and the other near the spring on Silver brook (Campbell well). Neither of these wells yielded more than a trace of oil.

Attention was again drawn to the Gaspe oil field by the more complete description contained in the report for 1863 of the Geological Survey, Canada. By this time the commercial value of petroleum had been fully established and the search for new fields was being actively carried on. The revival of interest was shown in the drilling of a well near the site of the oil spring at Sandy beach by the Gaspe Petroleum Company (Gaspe Oil Company) in 1865-66. This well, known as the Conant or Adams well, produced a small quantity of dark oil and continues to yield a similar product to the present day.[1] This company acquired nearly 30,000 acres of land in blocks 20, 38, 40, 42, 44, 34. The failure of these early attempts discouraged further operations and it was not until about 1889 that a more serious exploitation of the region was begun by the International Oil Company of St. Paul, Minnesota. This company acquired from the government 400 acres in block 41, township of Galt, built a road of 17 miles from Gaspe basin, and sank a well in the vicinity of several oil springs long known to occur at this point. Like its predecessors this well proved unproductive.

About this time the Petroleum Oil Trust was organized in England and began operations on a larger scale in 1889. This company acquired 50,413 acres of land which were selected by Charles Robb in the area he considered most likely to prove productive, i.e., along the lines of anticlines that were supposed to traverse the basin drained by the York and St. John rivers. The company, under the presidency of Alfred W. Carpenter of London, carried on the work both independently and through subsidiary companies of which the following were the more important: Canada Petroleum Company, Belgium Oil Company (La Société Belge des Pétroles du Canada), and Irish Proprietary Oil Fields of Gaspe (afterwards, Oil Fields of Gaspe, Limited). The Petroleum Oil Trust drilled some fifty wells, either for itself or for the subsidiary companies, those of the Canada Petroleum Company alone being given separate numbers. While many of the wells were dry or yielded only salt water and a limited quantity of gas, some produced enough oil to encourage the laying of pipe-lines and the erection of a refinery. The refinery was built by the Canada

[1]Canadian Scenery, Gaspe, John Lovell, Montreal, 1889.

Petroleum Company in 1900-1901 on the north side of the York river on the south halves of lots 31 and 32, range I, Gaspe Bay South. 'The plant consists of two stills of 150 barrels capacity each, with a series of tanks and the necessary pumps and engines with a central tank of 2,500 barrels capacity. The tanks are made of iron and connected by pipes. There are ten of 500 barrels, two of 300 barrels, besides one of 500 barrels in the Mississippi district, and those of the western wells. The total capacity is from 8,000 to 9,000 barrels and the refinery is connected with Mississippi and other regions by about 15 miles of 2-inch pipe.'[1] This optimism seems scarcely to have been justified in view of the fact that Ells estimates the total yield during the years 1901 and 1902 at 235 barrels exclusive of certain quantities lost by fire and other causes. Operations ceased entirely at the close of 1902 and shortly afterwards the company went into liquidation. At a sheriff's sale in London, December 30, 1905, the following properties of the P. O. T. were disposed of:

(1) Beach lot, township of York, McConnell point, on the south side of Gaspe basin.
(2) Beach lot, township of York, south side of Gaspe basin.
(3) Lots 3 and 9, range II, York.
(4) Lots 30, 31, 32, 33, 34, 35, 36, 37, 39, range I, Gaspe Bay South; lot 22, range III, York; lots 5, 6, 7, range II, Gaspe Bay South.
(5) Block 20, township of Blanchet.
(6) Blocks 32 and 42, township of Galt.
(7) Blocks 38 and 40, township of Laroque.
(8) Blocks 44 and 56, township of Baillargeon.

The bulk of this acreage, together with mining rights, is now the property of the Canadian International Pulp and Paper Company as follows:

			Acres
Block	20	Township of Blanchet	5,000
"	32, 42	" Galt	10,890
"	38, 40	" Larocque	11,232
"	44, 56	" Baillargeon	9,543

This company also holds certain lands and mining rights in range II, Gaspe Bay South. The tracts in range I, Gaspe Bay South, belong to LeBoutillier and Whalen of Gaspe harbour and about 10,000 acres of mining rights in Gaspe village, York, Gaspe Bay South, and Douglas belong to an English gentleman who acquired them from the liquidators of the Petroleum Oil Trust.

The wells of all these companies were located in the vicinity of Gaspe bay, particularly in the area drained by the York and St. John rivers. The selection of sites was controlled by two factors—the presence of oil seepages, and the supposed position of three anticlinal folds, Haldimand, Tar Point, and St. Peter, as determined in the coast section by Sir William Logan.

The failure of any of the wells to produce oil in commercial quantity led to complete cessation of operations in 1903. About ten years later another attempt was made and a single well was drilled near the north side of the Malbaie river about 9 miles above Barachois. This well was located on a fourth anticline, south of those named above, and called by Sir William Logan the Malbaie anticline. No greater success attended this venture than had rewarded the earlier attempts, and no further operations have been undertaken to the present date. . . . . .

[1]Mining Operations in the Province of Quebec, 1901, p. 35.

Grouped according to location, the oil wells of Gaspe may be arranged in three main areas with scattered single wells at other localities. Omitting a well on the Malbaie river and proceeding from east to west may be considered as below. The logs and pumping records are taken chiefly from Ells' report.

The numbers are those given by the companies: P.O.T., Petroleum Oil Trust; C.P.C., Canada Petroleum Company.

(1) Seal Cove Area. Near shore. One well.[1]

P.O.T., 4. Lot 1, range I, Bois Brûlé, township of Douglas. One-half mile from shore. Elevation 100 feet.

Log incomplete; sandstone and shale. Drilling good to 2,540 feet where hard rock was encountered; continued to total depth of 2,970 feet; tools stuck and lost. A small show of oil at 2,215 feet. Abandoned.

Near Tar Point anticline in strata dipping steeply to northeast.

Present condition: negative.

(2) Haldimand Area. North shore Douglastown barachois, near shore. One well.[2]

P.O.T., 3. Lot 1, Haldimand range, township of Douglas. Elevation, 20 feet.

Log incomplete. Commenced October 14, 1890; reached a depth of 2,235 feet, salt water at 1,304 feet, no oil.

South of Haldimand anticline. Strata dip southward at low angle.

Present condition: negative.

(3) Douglastown Area. South shore Douglastown barachois, near shore. One well.[3] 1860.

Gaspe Bay Mining Company. Lot 17, range I, township of Douglas.

Log unknown, well shallow, about 600 feet deep. Drilled in 1860. Trace of oil.

Probably in strata dipping south at low angle, near oil seepages on shore, and probably near a fault.

Present condition: negative.

(4) Sandy Beach Area. South shore Gaspe harbour. Four wells.[4]

This site was chosen owing to the proximity of a well-known oil seepage (Adams oil spring). All the wells are drilled in steep strata on the north side of the Haldimand anticline near its summit.

Gaspe Oil Company, Conant Well (Adams Well). Lot A6, range I, Sandy beach, township of Douglas. Elevation 200 feet. Drilled in 1865.

The log is given as follows:

Feet	
83	gas and oil
120	pale red shale
138	fine, grey sandstone
160	dark red shale
200	very fine sandstone with shale

[1]Well No. 1 on Figure 16.
[2]Well No. 2 on Figure 16.
[3]Well No. 3 on Figure 16.
[4]Locality No. 4 on Figure 16.

Feet	
238	bluish sandstone, very salt water, strong black gas, show of thin, light oil
260	coarse, grey sandstone, one-third white and hard
420	same rock
460	alternate shale and sandstone
425 and 430	shows of oil
444	good show of oil
510	this show ceases
600	show of oil and gas, sandstone
601	purple shale
648	sandstone, fine beds, oil, and considerable gas
684	bottom

Pumping gave intermittent gushes of oil of " a beautiful dark green colour." In nine hours 25 to 30 barrels were produced. The well was abandoned owing to loss of tools. It is said that two other shallow wells were bored here, but no detail concerning them is available.[1]

Present condition: standpipe, flow of salt water, and a little black oil. It is said that a gallon can be bailed at any time.

P.O.T., 1. Lot A6, Sandy beach, township of Douglas. Elevation 200 feet, 1889-1891.

Log imperfect, salt water at 1,325 feet and at 1,700 feet. Oil at 2,048 feet and 2,400 feet. Pumping yielded no oil.

Well drilled in steeply inclined strata near top of Haldimand anticline.

Present condition: standpipe, no flow.

P.O.T., 2. Lot B1, Sandy beach, township of Douglas. Elevation 210 feet, 1890.

Water at several points. Shows of oil at 500 feet, 965 feet, and at bottom, 2,582 feet. The well was shot at 900 feet, 1,200 feet, 2,036 feet, and bottom, but no oil was obtained.

Present condition: standpipe, no flow.

P.O.T., 8. Lot B1, Sandy beach, township of Douglas. Elevation 215 feet, 1892.

Salt water at 745 feet 936 feet, 1,775 feet, and 1,450 feet. No oil.

Present condition: standpipe, no flow.

(5) North West Arm Area. Near south shore. One well.[2]

P.O.T., 9. Lot 14, I North range, Gaspe Bay South. Elevation 263 feet, 1894.

Hole in sandstone and shale throughout. Water at 495 feet and 560 feet. Total depth, 2,719 feet. No oil.

This well is in the upper members of the Gaspe sandstone series, in steeply dipping strata, a short distance north of the Haldimand fault that brings the underlying limestones to the surface at a level probably 700 feet above well.

Present condition: negative.

[1]Rept. Com. Crown Lands, 1898, p. 43.
[2]Well No. 5 on Figure 16.

(6) EASTERN ST. JOHN RIVER AREA. South of river in range III, township of York. Two wells.

P.O.T., 23.[1] Lot 25, range III, township of York. Elevation 160 feet, 1896.

Sandstone to 1,480 feet, limestone to 1,790 feet, salt water at 1,670 feet. No oil. In this well a 10-inch casing to 110 feet, a 6-inch casing to 600 feet, and a 4-inch casing to 1,800 feet.

On north side of St. Peter anticline, not far from limestone, in strata dipping north at moderate angle.

Present condition: standpipe, plugged; smell of oil.

P.O.T., 24.[2] Lot 3, range III, township of York. Elevation 300 feet, 1896.

Sandstone thin, boring mostly in limestone to 1,230 feet. Hard to drill in steeply dipping limestones. No oil. On north side of St. Peter anticline, near the limestone contact in strata dipping northward at high angle.

Present condition: standpipe, no flow of water, oil, or gas.

(7) WESTERN ST. JOHN RIVER AREA. North of river, in range II, township of York. One well.[3]

P.O.T., 26. Lot 50, range II, York, close to river. Elevation 96 feet, 1896.

Sandstones and shales to 2,200 feet, limestone and sandy layers to bottom, 2,900 feet. A little gas at 1,700 feet. No oil.

Well on north side of Point St. Peter anticline, not far from limestone, in strata dipping north at moderate angle.

Present condition: standpipe with small flow of salt water and gas.

(8) EASTERN YORK RIVER (SILVER BROOK) AREA.[4] North of river in ranges I and II of Gaspe Bay South. Fifteen wells. An anticline (Mississippi) crosses the northern part of the area; most of the wells are on south side of fold.

P.O.T., 12. Lot 33, range I, Gaspe Bay South, near river. Elevation 12 feet, 1894.

Sandstones and shales to 2,550 feet, limestone to 3,002 feet; small shows of oil at 2,075 feet and 2,837 feet. Well was plugged for shooting at 2,830 feet; no oil worth recording, not pumped.

This well is the farthest south of the group and farthest from axis of anticline. Strata dip south at low angle.

Present condition: standpipe with water and a little oil.

P.O.T., 7. Lot 34, range I, Gaspe Bay South, 250 yards south of road. Elevation 29 feet, 1892-93.

Sandstone to 2,385 feet, hard siliceous limestone to 2,867 feet. Salt water and show of oil at contact, oil at 2,589 feet and 2,650 feet. Shot with 200 quarts of nitro-glycerine at 2,589 feet on November 29; pumping commenced December 15; water only at first, but on December 16, 20

[1]Well No. 6 on Figure 16.
[2]Well No. 7 on Figure 16.
[3]Well No. 8 on Figure 16.
[4]Locality No. 9 on Figure 16.

barrels of oil; on December 19, 3 barrels; on December 23, a half barrel; on January 5 and 6, 1893, a half barrel; 200 barrels lost by accident on February 14.

Situated on south side of anticline in strata dipping south at low angle.

Present condition: standpipe, flow of salt water and a very little oil.

C.P.C., 10. Lot 33, range I, Gaspe Bay South, 200 yards south of road. Elevation 37 feet.

Sandstone for 2,360 feet, limestone to 2,383 feet. No oil found in drilling, but Ells reports three barrels in July, 1901, and a little in standpipe in 1902.

Situated in sandstone dipping south at low angle.

Present condition: standpipe, slight flow of salt water, film of oil.

P.O.T., 5. Lot 3, range I, Gaspe Bay South, just south of road. Elevation 55 feet, 1891-92.

Sandstone to 2,360 feet, limestone to 2,640 feet. Small shows of oil at 1,850 feet and 2,360 feet and none lower. Four barrels bailed in January, 1892. Well was shot on October 25 and 2 barrels pumped on November 9; shot again on December 11, 1893, without result. Yielded about 2 quarts a day on isolated pumpings to January 6, 1894.

Situated on south side of anticline in strata dipping at low angle to south.

Present condition: water, but no steady flow, a few bubbles of gas; oil on surface of water, a quart can be obtained at any time in depression around standpipe.

C.P.C., 7. Lot 29, range I, Gaspe Bay South, north of road, near Big brook. Elevation 100 feet.

Sandstone to 2,046 feet, limestone to 2,063 feet; oil at 1,945 feet; 2 or 3 barrels obtained.

Strata dip south at 12 degrees, near crown of anticline, according to Ells.

Present condition: water and smell of oil.

P.O.T., 10. Lot 30, range I, Gaspe Bay South, north of road. Elevation 80 feet, 1895.

All sandstone to 1,400 feet. Water and gas at 775 feet; small shows of oil at 1,108 feet and at 1,170 feet. Shot with 160 quarts of nitroglycerine at 1,400 feet. No oil taken out; abandoned on account of water and caving of sides. In another place Ells states that well No. 10 gave 125 gallons on June 5, 8 gallons on June 24, and 1 gallon on June 27. Situated near supposed crown of anticline, probably south of it.

Present condition: standpipe with wooden pump-log casing, salt water to near top, slight flow; foamy oil with bubbles of gas on surface.

C.P.C., 9. Lot 31, range I, Gaspe Bay South, north of road. Elevation 60 feet.

Sandstone to 2,360 feet, limestone to 2,226 feet. Much water but no oil.

Situated on south side of anticline in strata dipping at low angle to south.

Present condition: negative.

P.O.T., 13. Lot 32, range I, Gaspe Bay South, north of road. Elevation 60 feet, 1894.

Sandstone and shale to 2,050 feet. Much salt and sulphur water, no oil.

Situated south of the anticline; strata dip south at low angle.

Present condition: flowing saline and sulphurous water freely, bubbles of gas, and a little oil.

C.P.C., 3. Lot 34, range I, Gaspe Bay South, near north end of lot. Elevation 64 feet, 1899.

Sandstone to 2,230 feet, limestone to 2,230 feet. No oil.

Situated south of anticline in strata dipping to south.

Present condition: not seen.

P.O.T., 11. Lot 35, range I, Gaspe Bay South, near north end of lot. Elevation 74 feet, 1893-95.

Sandstone to 2,080 feet, limestone to 2,957 feet. Oil and gas at 2,220 feet. Explosion occurred and rig was burned; several hundred barrels of oil reported to be lost. Oil again encountered at 2,485 feet. Well shot twice in September, 1895. Pumped for four days only. On May 25, 1901, it gave 4 gallons; on June 4, 50 gallons; on June 28, 17 gallons; and on July 6 only 4 gallons—in all 72 gallons.

Situated on south side of anticline.

Present condition: no standpipe, water and a little clear oil in hole, bubbles of gas.

P.O.T., 14. Lot 36, range I, Gaspe Bay South, near road on north side. Elevation 76 feet, 1895-1897.

Sandstone to 2,265 feet, limestone to 2,775 feet. No oil, salt water, or gas. Pumped, it gave 16 gallons on June 25, 1 gallon on June 26, and 1 gallon on July 6.

Situated on south side of anticline.

Present condition: no standpipe, ground around hole for a radius of 10 feet soaked with oil; water and a little oil flowing from hole.

Campbell Well, Gaspe Bay Mining Company. Lot 16, range II, Gaspe Bay South, near Silver brook. Elevation 230 feet, 1,860.

One of the first wells drilled, shallow, probably not more than 600 feet in sandstone. No oil.

Situated on south flank of anticline near a well-known oil spring on Silver brook.

Present condition: negative.

P.O.T., 15. Lot 6, range II, Gaspe Bay South, near south end of lot. Elevation 243 feet. 1895.

Sandstone to 1,880 feet, limestone to 2,012 feet. Fifty barrels of oil bailed at contact. Well shot at bottom and pumped, yielded continuously 7 or 8 gallons a day for several months; in spring of 1901 gave about 2 gallons a day.

Situated on south side of anticline, nearer the axis than wells previously described. Strata dip 20 degrees south.

Present condition: standpipe and wooden casing; both show oil on water 3 feet down. No permanent flow, but looks as if it overflowed at times.

P.O.T., 39. Lot 5, range II, Gaspe Bay South, near west side of lot and half-way from south end. Elevation 360 feet (398 feet Ells).

Located near summit of anticline; rig erected but well not drilled. The site looks promising and it is to be regretted that the work was not continued. Just north of well the dip is north 15 degrees east at 20 degrees.

P.O.T., 36. Lot 7, range II, Gaspe Bay South, near north end of lot. Elevation 804 feet, 1901.

Sandstone to 1,780 feet, limestone to 1,950 feet. Salt water at 1,065 feet. No oil.

Situated on north side of anticline close to its axis. Strata dip 11 degrees north. This well would be considered as favourably located; its failure led to the abandonment of No. 39.

(9) Southeast Galt Area. One well[1].

P.O.T., 16. Block 42, township of Galt, near southeast corner, about 1½ miles from road (2,631 paces). Elevation 510 feet. 1895.

Sandstone to 2,880 feet, limestone to 2,995 feet. Only small show of oil 2,664 feet; little salt water. Pumped, it gave 150 gallons on June 10, 1901.

Situated on south side of anticline. Strata dip about 9 degrees south.

Present condition: flowing water with a little oil; ground around for 100 square feet soaked with oil.

(10) Upper Silver Brook Area. The angle of Blocks 31 and 42 of Galt and range III, Gaspe Bay South. Three wells.[2]

P.O.T., 22. Lot 22, range III, Gaspe Bay South, in northwestern angle of lot. Elevation 1,000 feet, 1896-1897.

Sandstone to 2,750 feet, limestone to 3,130 feet. No oil at contact, but a show, with water and gas, at 2,945 feet. In a white sand within the limestone, oil and gas at 3,105 feet and strong brine at 3,107 feet. The pumping record is as follows: April 5, good show in water; April 22, one-half barrel; April 23, 4 barrels; April 26, 3 barrels; April 29, 3 barrels; April 30, 2 barrels; May 3, 1 barrel; May 4, half barrel; May 8, 1½ barrels; May 15, less than a half barrel; May 28, 1 barrel: May 29, 3 barrels; June 5, 2 barrels; June 12, 1½ barrels; June 16, only a pint.

This well is situated north of the crown of the main anticline in strata that are practically horizontal. The location is favourable; it is significant that the oil was obtained in the limestone.

Present condition: oil stains and odour, no flow.

P.O.T., 37. Block 31, township of Galt, near south line of block and about a mile west of the southeast corner. Elevation 917 feet, 1901.

The log of this well is somewhat different from the others in that the record shows an alternation of sandstone and limestone. Bands of hard limestone were struck at 455 feet and continued down to 645 feet. Below this, to a depth of 2,600 feet the rocks were all sandstones which were calcareous for the last 200 feet. Small show of green oil at 2,218 feet; salt water at 927 feet and 1,875 feet, and gas at 1,925 feet. Two barrels of oil taken out.

[1]Well No. 10 on Figure 16.
[2]Locality No. 11 on Figure 16.

Situated near the axis of anticline, probably to the north. The dips are low in various directions in the vicinity.

Present condition: negative.

P.O.T., 38. Block 42, Galt, near northeast corner of block. Elevation 877 feet, 1901-1902.

Sandstone to 2,089 feet, calcareous for last 50 feet. Small show of oil at 2,030 feet, salt water at 955 feet and 200 feet. Copious flow of water prevented drilling to greater depth. No oil. Limestone not reached. Situated near anticline, probably to north of main fold.

Present condition: not seen.

(11) Little Fork of York River Area. Near mouth of Little Fork in Block 42, Galt. One well[1].

P.O.T., 6. Block 42, Galt, near crossing of main road and Little Fork. Elevation 246 feet, 1892.

Sandstone and shales to 3,640 feet. Small show of oil at 2,950 feet. Salt water at 395 feet, 440 feet, 590 feet, and 690 feet. Strata in the vicinity dip at low angles in different directions, probably southward at well. Ells states that limestones cross the road a short distance west of the location: I was unable to find this limestone.

Present condition: negative.

(12) Block 41 Area. Township of Galt. One well.[2]

International Oil Company. East side of block near middle. Elevation 385 feet.

Sandstone to 1,700 feet. No oil.

Ells states that a fault crosses to the southwest of the well, whereby the limestones are brought to the surface. These limestones are bituminous and three large oil springs occur along the line of fault in a distance of half a mile. I am informed that a very large oil spring is located at the head of the little stream that passes near the well. The strata dip southwest at 16 degrees to 25 degrees.

Present condition: wooden casing, dry. There is a pipe in one of the springs showing oil 8 feet from top, slightly bubbling by escape of gas.

(13) Fourth Lake Area. Block 44, Galt. One well.[3]

P.O.T., 25. Block 44, Galt, just north of Fourth lake. Elevation 660 feet, 1895-1896.

Sandstone to 2,200 feet, sandy limestone to 2,978 feet. Gas at 1,700 and 2,550 feet. No oil.

Situated on north side of Point St. Peter anticline, in strata dipping northwestward at 20 degrees.

Present condition: negative.

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[1]Well No. 12 on Figure 16.
[2]Well No. 13 on Figure 16.
[3]Well No. 14 on Figure 16.

(14) Mississippi Brook Area. Block 40, Larocque. Twenty wells.[1] The wells all lie near the bottom of a syncline; most are on its northern slope and only the most southern on the south limb. The general dip is south and west at low angles; on the south limb it is north and west. The wells will be described from the south to the north.

P.O.T., 33. Block 40, Larocque, near west side of block close to York river. Elevation 200 feet, 1899-1901.

Sandstone and shale to 2,607 feet. Gas at several points. No oil.

Situated on south limb of syncline, near axis; strata dip northwest at 5 degrees.

Present condition: saline and sulphurous water flowed freely, now plugged.

P.O.T., 31. Block 40, Larocque, just west of mouth of Mississippi brook. Elevation 164 feet, 1898-1899.

Sandstone to 2,450 feet, limestone to 2,815 feet. Small show of oil at 1,700 feet. Pumping yielded 1 barrel per diem for a short time—23 barrels in all.

Situated near bottom of syncline. Strata dip at low angle a little south of west.

Present condition: rig burned, 8-inch standpipe, oil in pipe 2 feet 6 inches down, does not overflow but it is always possible to bail out several gallons of oil; bubbling by escape of gas. For description of oil *See* page 29.

C.P.C., 5. Block 40, Larocque, 200 yards east of Mississippi brook and 300 yards north of York river. Elevation 200 feet.

Sandstone to 2,200 feet. Shows of oil at 1,349 and 2,140 feet. About 3 barrels obtained by bailing.

Situated near bottom of syncline.

Present condition: rig burned, negative.

P.O.T., 29. Block 40, Larocque, close to York river, about one-half mile east of Mississippi brook. Elevation 130 feet, 1897-1898.

Drift, 61½ feet, sandstone to 2,600 feet. A little gas and oil at 2,180 feet; and salt water at 840 feet, 1,209 feet, 1,380 feet, and 1,450 feet. The central collecting tank for the area was located at this point and from here the pipe-line extended 11 miles to the refinery. Ells records 200 to 300 barrels of amber oil in the tank at the time of his visit.

Situated near bottom of syncline.

Present condition: standpipe full of salt water, slight bubbling of gas, and a little foamy oil. Does not overflow except at intervals.

C.P.C., 2. Block 40, Larocque, north and a little west of P.O.T., 29. Elevation 230 feet, 1901.

Sandstone and shale to 1,591 feet. Small quantity of oil and gas at 1,570 feet. Output only 3 gallons.

Situated near bottom of syncline on north limb.

Present condition: rig burned, standpipe removed.

P.O.T., 27. Block 40, Larocque, one-fourth mile north of P.O.T., 29. Elevation 320 feet, 1897.

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[1]Locality No. 15 on Figure 16.

Sandstone and conglomerate to 2,200 feet to limestone contact; occasional bands of conglomerate with pebbles of white quartz. This record is interesting as very little conglomerate is seen in the district. Strong flow of oil and gas at 1,467 feet in a stratum of conglomerate. A considerable quantity of oil was obtained, but much was lost at the time of tapping the conglomerate, and later several hundred barrels were destroyed by fire. The oil thus burned probably did not all come from this well.

The well was pumped, in 1901, from April 5 to August 15. The yield was 385 gallons, an average of about 2½ gallons a day. In 1902, it was pumped from June 18 to August 9 with an output of 192 gallons. Ells records that in July, 1902, the well was pumping about 2 gallons a day.

The well is situated on the north flank of the syncline in strata dipping southwest at a low angle.

Present condition: rig burned, negative.

P.O.T., 32. Block 40, Larocque, 200 yards north of York river, near eastern line of block. Elevation 200 feet, 1899.

Sandstone to 1,825 feet, limestone to 1,925 feet. Oil and gas at the contact. Pumping began on March 22, 1901, and continued to September 21. In 1902 it was pumped from April 26 to August 9. The total yield was 1,745 gallons, an average of about 9½ gallons a day. In the latter year the yield varied greatly, ranging from 1 gallon a day upwards, and for the last month averaged about 4 gallons a day.

Located on north flank of syncline.

Present condition: unable to locate in brûlé.

C.P.C., 11. Block 40, Larocque, close to York river and on eastern line of block. Elevation 150 feet.

Sandstone to 1,900 feet, limestone to 1,924 feet. Salt water and a little oil at 1,490 feet. No oil of importance.

The most easterly well of the area. Strata dip 11 degrees to southwest.

Present condition: no standpipe, no flow.

P.O.T., 30. Block 40, Larocque, near junction of Twenty brook and Mississippi river. Elevation 215 feet. 1898-1899.

Sandstone to 1,580 feet, no limestone. Heavy flows of salt water at 860, 930, 1,022, 1,075, 1,150, 1,210, 1,450, and 1,480 feet. No oil or gas. Abandoned on account of water.

Strata dip nearly west at low angle. Hole is near axis of syncline which may account for excessive water.

Present condition: Rig burned, no standpipe.

C.P.C., 8. Block 40, Larocque, 200 yards northeast of P.O.T., 30. Elevation 210 feet.

Sandstone to 2,340 feet, limestone to 2,394 feet. Small trace of oil at contact. Salt water in upper part. Well was shot without results and abandoned.

Situated near axis of syncline.

Present condition: unable to locate well on account of brûlé.

C.P.C., 6. Block 40, Larocque, close to and east of C.P.C., 8. Elevation 246 feet.

Sandstone to 2,360 feet to limestone contact. Trace of oil at 2,340 feet, no yield.

Sandstones near well dip at low angle to southwest.

Present condition: rig burned, no standpipe, no flow.

C.P.C., 1. Block 40, Larocque, close to and east of C.P.C., 6. Elevation 270 feet, 1899.

Sandstone to 1,582 feet, limestone not reached. Oil and gas at 1,550 feet. Pumped from June 25 to September 21, 1901, with a yield of 949 gallons, also from May 22 to July 24, 1902, with a yield of 75 gallons. In August, 1902, the well was flowing salt water. Total oil 1,024 gallons.

Situated on north flank of the syncline.

Present condition: wooden casing around pump-log, strong smell of oil, no sign of present activity.

C.P.C., 4. Block 40, Larocque, east of C.P.C., 1. Elevation 276 feet, 1901.

Sandstone and shale to 2,100 or 2,200 feet to limestone contact. Salt water, no oil.

Situated in strata dipping southwest at low angle.

Present condition: rig burned, no standpipe.

P.O.T., 35. Block 40, Larocque, east of east branch of Mississippi brook, about three-eighths of a mile from main road on the old Howard Smith road up to Mississippi. Elevation 360 feet, 1901.

Sandstone to 1,800 feet, limestone to 1,810 feet. No oil. Highly siliceous limestone broke tools and stopped drilling.

Situated north of axis of syncline in strata dipping southward.

Present condition: no standpipe, no flow of water, no trace of oil.

P.O.T., 34. Block 40, Larocque, near main road, about a mile east of Mississippi crossing. Elevation 310 feet, 1900.

Sandstone to 1,677 feet limestone not reached, small quantity of oil and salt water at 1,600 feet. Pumped half a barrel a day for some time. Total yield to May 24, 1902, 1,744 gallons.

Strata dip southwest at low angle.

Present condition: unable to locate in brûlé.

P.O.T., 19. Block 40, Larocque, south of road and north of C.P.C., 6. Elevation 355 feet, 1895-1896.

Shale and sandstone to 2,340 feet to limestone contact. Salt water at 700 feet and 1,500 feet. Shows of oil at 1,185 feet, 1,792 feet, and 2,050 feet. Well was shot with 100 quarts of nitro-glycerine at 2,040 feet. It yielded at first about a half barrel of amber oil a day; afterwards 10 gallons, and by August 2, 1902, only 2 or 3 gallons. Total output 850 gallons.

Located in strata dipping southwest at low angle.

Present condition: unable to locate in brûlé.

P.O.T., 17. Block 40, Larocque, just south of main road, about half-way between Big fork and Mississippi crossings. Elevation 370 feet, 1895-1897.

Sandstone to 2,000 feet, limestone to 2,550 feet. Oil at 1,013, 1,045, 1,200, and 1,286 feet. One and a half barrels bailed at 2,348 feet.

Strata dip southwest at 18 degrees.

Present condition: no standpipe, no flow. This point has become a sort of centre for the traffic on the road. Oil buildings are used by fire rangers and travellers.

P.O.T., 18. Block 40, Larocque, about one-third mile north of road and east of the brook that passes near P.O.T., 17. (Seventeen brook). Elevation 280 feet, 1895-1896.

Sandstone and shale to 1,865 feet, limestone to 1,960 feet. Small shows of oil at 990 and 1,095 feet. Shot with 25 quarts of nitro-glycerine, but no oil found in the boring. In 1902, a small show of oil in pipe.

Situated well up on north limb of syncline.

Present condition: trail obliterated in the brûlé.

P.O.T., 20. Block 40, Larocque, about centre of block and a short distance north of the most northerly point on the road. Elevation 442 feet, 1896.

Sandstone to 2,050 feet, limestone to 2,173 feet. Oil and gas at contact, salt water at 595 feet. Shot with 100 quarts of nitro-glycerine at 2,059 feet without results, only a half barrel being bailed out in 24 hours. On August 5 it was tubed and pumped, giving about 5 gallons a day for a time. In July, 1902, it yielded from ½ to 1 gallon a day. Total output, 1,750 gallons.

Strata near well dip southwest at 15 degrees.

Present conditions: constantly flowing a small quantity of clear amber oil that runs down the outside of standpipe, keeping it clear of rust; gas bubbles accompany the oil. It is said that 5 gallons may be bailed out at any time and the pipe will be full next day. It is stated, also, that a barrel has been bailed out at one time. This well is undoubtedly the most active in the whole district at the present time.

P.O.T., 21. Block 40, Larocque, about three-fourths of a mile northwest of P.O.T., 20. Elevation 780 feet, 1896-1897.

Sandstone and shale to 1,555 feet, limestone to 1,830 feet. Trace of gas and oil at contact. No yield of oil.

Strata not exposed near well, but probably dip southward. High hills to north, west, and south.

Present condition: standpipe with strong flow of cold, slightly saline, more distinctly sulphurous water that makes its way up the pipe although it is filled with sand. The water is palatable and may possess medicinal value. This is the most northerly well of the area.

(15) Block 39 Area. Township of Larocque. One well.[1]

C.P.C., 12. Block 39, Larocque, near mouth of Narrows brook. Elevation 270 feet.

Sandstones and shale to 1,500 feet, a band of black shale at 280 feet. No oil.

Situated on south limb of syncline. Strata dip northward and northwestward at varying angles.

Present condition: standpipe removed, wooden casing remains, hole open but no flow of water.

[1]Well No. 16 on Figure 16.

(16) Block 38 Area. Township of Larocque. Two wells.

P.O.T., 28.[1] Block 38, Larocque, close to main road at crossing of Narrows brook. Elevation 920 feet, 1897-1898.

Sandstone and shale to 3,525 feet, no limestone. Salt water at 1,100 feet. No oil.

Situated near axis of syncline.

Present condition: no standpipe but wooden casing is flowing freely, slightly saline and sulphurous water.

P.O.T., 40.[2] Block 38, Larocque, at crossing of main road over Falls brook. Elevation 827 feet.

Sandstone to 2,305 feet, no limestone.

Situated near axis of syncline in strata dipping southwest at a low angle.

Present condition: standpipe plugged, but a flow of sulphurous water is escaping through holes and around the pipe. This is the most westerly well in the whole district.

In addition to the wells described above, one more was drilled at a much later date (1913) near the north side of the Malbaie river about 9 miles from its mouth. The work was done by the Eastern Canada Company under the management of Mr. C. B. K. Carpenter. The hole reached a depth of 2,950 feet in sandstone; at the surface it had a diameter of 14 inches; this was reduced to 8 inches and finished at 6¼ inches. Salt water was encountered but no oil. The elevation is 205 feet. The rocks in the vicinity are coarse sandstones and conglomerates, the latter rocks being much more in evidence than on the St. John and York rivers. The strata on the river, near the well, strike, on the average, north 62 degrees west, and dip invariably at high angles (70-85 degrees) northeast. The well is evidently located in steeply dipping strata on the north flank of the Malbaie anticline. The location is not favourable.

The standpipe and wooden casing are still in place. The pipe is full of fresh water but there is no flow."

As will be seen from the above description a certain amount of oil was discovered in a number of wells. The following description of the oils is by Parks.[3]

"The operators, at the time of activity in the Gaspe field, recognized that different qualities of oil were yielded by different wells. The classification seems to have been on the basis of colour alone. An old record of the wells pumping at a certain date contains the following information:

Green oil—
- P.O.T. 5, two tanks.
- P.O.T. 7, two tanks.
- P.O.T. 11, one tank.
- P.O.T. 15, one tank.

Amber oil—
- P.O.T. 19, one tank.
- P.O.T. 20, one tank.
- P.O.T. 27, pumping.

Brown oil—
- P.O.T. 1 and 2.

[1]Well No. 17 on Figure 16.
[2]Well No. 18 on Figure 16.
[3]Parks, W. A.: Op. cit., pp. 27-29.

Ells classifies the oils as 'a light amber oil which has been obtained from the upper or sandy portion of the formation, and a dark green, heavier oil which was obtained usually from the lower or calcareous underlying rocks.'[1] Unfortunately Ells' report does not indicate the kind of oil yielded by the various wells, but it enables us to add P.O.T. wells 10 and 37 to the list of producers of green oil.

I would venture the opinion that the normal oil of the district is green. The black or brown are found in seepages of springs along fault planes and, also, in the wells drilled in proximity to such vents. The dark colour and heavy nature of these oils are due to the escape of the more volatile constituents. The amber oils occur in the sandstones and represent volatile parts of the original green oil that have risen and accumulated therein.

Analyses of Gaspe oils according to older methods are given in the following tables:

Older Analyses of Gaspe Oils

——	Light green oil, district 27	Amber oil, district 5
Density at 60° F.	0·828	0·795
Lighting point, Abel test	0° F.	20° F.
Light essences (gasoline, benzine)	16%	21%
Kerosene	41% (density, 0·804)	35% (density, 0·780)
Intermediate products and heavy oils with solid hydrocarburets	40%	.....
Lubricating oils and paraffins	.....	42%
Coke	1·36%	0·75%
Losses	1·00%	1·00%

'These results were obtained by cooling to 20 degrees F., but by employing the usual process of distillation, 79 per cent is obtained of a product with a density of 0·799, and a lighting point at 73 degrees F., from which the paraffin can be afterwards separated by cooling.'[2]

Samples were collected during the summer from all wells that could be located and that are at present voiding oil. These samples have been examined in detail by Professor Rolland with the following results:

[1]Geol. Surv., Canada, Sum. Rept. 1902, pt. A, p. 345.
[2]Report Mining Operations in the Province of Quebec, 1899, pp. 38-41.

Analyses of Gaspe Oils by Professor Rolland

—	Conant well	P. O. T. 20	I. O. Co. spring	P. O. T. 15	P. O. T. 5	P. O. T. 31
Quantity submitted	300 c.c.	900 c.c.	400 c.c.	60 c.c.	275 c.c.	900 c.c.
Water	50%	.....	.....	.....	20%	.....
Baumé at 60° F	30·1	45·6	28·3	38·1	33·9	47·1
Specific gravity at 60° F	0·8765	0·7990	0·8855	0·8343	0·8555	0·7923
Viscosity, Saybolt Universal, 100° F	159 sec.	43 sec.	115 sec.	55 sec.	53 sec.	36 sec.
Flash point, Cleveland Open Cup	180° F.	.....	205° F.	Not enough oil	190° F.	
Fire point, Cleveland Open Cup	200° F.	.....	225° F.	"	205° F.	
Flash point, Tagliabus Closed Tester	.....	140° F.	.....	.....	.....	140° F.
Colour, Union Colorimeter	Darker than 8[1]	No. 4½	Darker than 8[1]	Darker than 8[1]	No. 8[1]	No. 4½
Calorific power, B.T.U. per pound	17,820	19,380	18,530	19,210	18,700	19,990
Sulphur	0·25%	0·18%	0·21%	0·15%	0·22%	0·12%
Distillation						
First drop	100° C.	110° C.	145° C.	75° C.	110° C.	90° C.
Between 100–200° C	4%	.....	.....	.....	.....	
" 110–150° C	.....	16%	.....	.....	.....	
" 145–200° C	.....	.....	4%	.....	.....	
" 75–150° C	.....	.....	.....	11%	.....	
" 110–200° C	.....	.....	.....	.....	20%	
" 90–150° C	.....	.....	.....	.....	.....	23%
" 150–200° C	.....	17%	.....	14%	.....	13%
" 200–250° C	13%	15%	20%	23%	16%	15%
" 250–300° C	15%	13%	16%	16%	14%	15%
" 300–350° C	63%	34%	52%	24%	48%	31%
Residue	6%	5%	8%	13%	2%	3%

[1]Sample diluted.

RELATION OF DRILLING DONE TO PRODUCTION PROSPECTS

An analysis of the merits of the wells already drilled as a test of the petroleum prospects, presupposes a knowledge of conditions under which petroleum accumulates. These conditions are, briefly: (1) a source rock for oil; (2) porous horizons in which the oil may accumulate; (3) favourable structure to cause accumulation of oil; and (4) impervious cover to prevent the escape of the oil subsequent to its accumulation.

The Gaspe group of rocks are known to be highly petroliferous and the structure, as already outlined, seems adequate to cause accumulation of the oil. According to Parks "the numerous bands of shale, some of them more than a hundred feet thick, are adequate caps provided they have not been shattered." He states, however, "that in almost every exposure of shales they seem to be less competent than the sandstones and to have yielded more to the forces of deformation, with the result that they are much shattered and their ability to act as caps seriously impaired." In general, however, it is admitted that petroliferous strata exist, that adequate cover is present, and that the structure is not unfavourable. If, therefore, the wells were properly located in regard to the structure their results would be a fair test of the petroleum prospects.

Wells on the Haldimand Anticline

Wells drilled on or in proximity to the Haldimand anticline include a group of wells on Dean brook,[1] south of the mouth of York river, a well drilled near Haldimand town,[2] and a well drilled on the southwest shore of Northwest bay on the north flank of the Haldimand anticline.[3] Shows of oil at different levels were reported in two of the wells drilled on Dean brook, but no commercial quantity was obtained. These wells were drilled close to a seepage in highly tilted or almost vertical strata. The well on the north flank of the Haldimand anticline was also drilled in very steeply tilted strata. It is concluded, therefore, that these wells were not in what would be considered favourable locations. The well near Haldimand town was drilled on gently southward dipping strata and reached a depth of 2,235 feet without obtaining oil, although the well as shown on Ells'[4] map was drilled close to a seepage that is thought to originate on a fault. There is no information as to the position of the bore-hole relative to the fault. Dr. Parks, however, states that on both the Haldimand and York River faults the upthrow is to the south. If these faults are thrust faults as might be supposed from the general knowledge of this area, then the well at Haldimand town may have drilled through a fault and at depth the hole would be on the north or downthrow side, a rather unfavourable position in which to hope for oil accumulation.

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[1]Locality No. 4 on Figure 16.
[2]Well No. 2 on Figure 16.
[3]Well No. 5 on Figure 16.
[4]Ells, R. W.: Map No. 802, Geol. Surv., Canada.

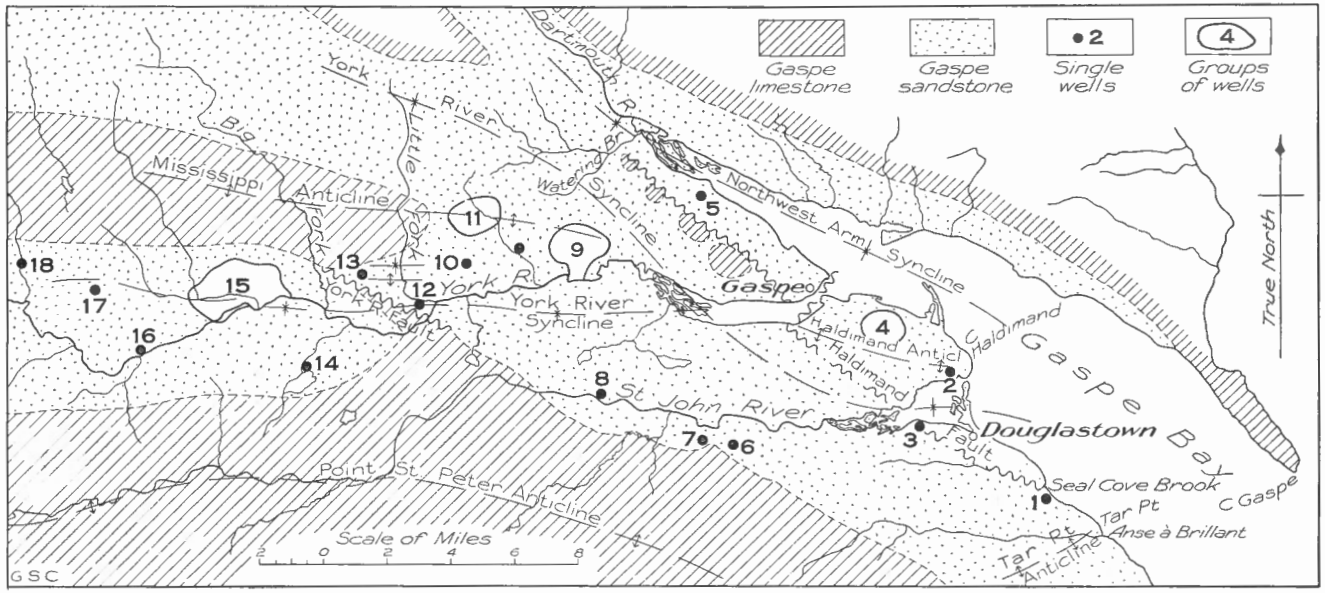

Figure 16. Gaspe oil field, Quebec (From map by W. A. Parks).

Wells on the York River Syncline and Mississippi Anticline

On the old maps, the Tar Point anticline is shown as extending inland to the vicinity of the wells drilled on Silver brook.[1] Dr. Parks[2] is of the opinion that this is not the case and that the Tar Point anticline is confined to a narrow belt along the coast. He thinks that most of the Silver Brook wells are on the northern flank of the York River syncline, but places Petroleum Oil Trust wells Nos. 36 and 39[3], and 38[4] near the summit of the Mississippi anticline which in the west divides the York River syncline into two structural basins. If this is so the Silver Brook group of wells must be well up the southern flank of the Mississippi anticline and hence on the whole might be considered to be favourably located for a fair test of the oil prospects at this place. Petroleum Oil Trust wells[5] Nos. 23, 24, and 26 are well down the southern flank of the York River syncline.

According to Dr. Parks the most favourably located wells, i.e., Petroleum Oil Trust wells Nos. 36, 38, and 39, at or near the summit of the Mississippi anticline, gave only salt water and no oil, although other wells in the Silver Brook group gave some oil. Many of these wells drilled through the Gaspe sandstones into the underlying Grande Grève limestones and the records may be summarized as follows:

Well	Total depth	Depth to sandstone-limestone contact	Oil at contact	Oil in sandstone, depth of oil horizon	Oil in limestone, depth of oil horizon
	Feet	Feet		Feet	Feet
P.O.T. 5	2,640	2,360	Oil	1,850	
P.O.T. 7	2,867	2,385	Oil	.....	2,589 and 2,650
P.O.T. 10	1,400	.....	.....	1,108 and 1,170	
P.O.T. 11	2,957	2,080	.....	.....	2,220 and 2,485
P.O.T. 12	3,002	2,550	.....	2,075	2,837
P.O.T. 14	2,775	2,265	.....	.....	
P.O.T. 15	2,012	1,880	Oil	.....	
P.O.T. 16	2,995	2,880	.....	2,664	
P.O.T. 22	3,130	2,750	.....	.....	2,945 and 3,105
P.O.T. 36	1,950	1,780	.....	.....	
P.O.T. 37	Record	not clear			
C.P.C. 3	2,240	2,230	.....	.....	
C.P.C. 7	2,063	2,046	.....	1,945	
C.P.C. 10	2,383	2,360	.....	.....	

P.O.T. Petroleum Oil Trust.
C.P.C. Canada Petroleum Company.

A number of other wells did not reach the limestone.

[1]Locality No. 9 on Figure 16.
[2]Parks, W. A.: Op. cit., p. 47.
[3]Locality No. 9 on Figure 16.
[4]Locality No. 11 on Figure 16.
[5]Respectively, Wells Nos. 6, 7, and 8 on Figure 16.

From the above records it can be seen that oil occurred: (1) in sandstones of the Gaspe series; (2) at the contact of the sandstones and limestones; (3) in the limestones. The amount of oil yielded by all wells was comparatively small. The greatest yields, however, came from the limestones and according to Ells[1] the amounts were as follows.

Well No. 22 P.O.T. "No oil was observed at the contact and the first small show was met at 2,945 feet with water and gas. On March 20, 1895, a large vein of gas and oil was reported at the contact with a white sand at a depth of 3,105 feet and strong brine was struck at 3,107 feet . . . . . This well apparently tested the anticlinal axis better than any of the previous ones."

Well No. 11 P.O.T. "At 2,220 feet in the limestone gas and oil were reported . . . . Oil flowed and a supposed large quantity was lost during the night, estimated at some hundreds of barrels. The boring was resumed and a small show of oil was again reported on September 7 at a depth of 2,485 feet."

Well No. 12 P.O.T. "was also pumped for three days only. In 1901, June 26, 30 gallons, July 3 it gave 1 gallon, on July 26, 55 gallons; in all 86 gallons."

Well No. 7 P.O.T. "The well was shot with 200 quarts of nitro-glycerine at 2,589 feet on November 29 (1893) and pumping was commenced on December 15. Water only was pumped at first, but on December 16 an amount of oil estimated at 20 barrels was obtained. On December 19 it pumped about 3 barrels, on December 23 an average of about a half a barrel per day. In 1894, January 5 and 6, the well is said to have yielded at the rate of a half a barrel per day."

Two wells—Nos. 5 and 15, Petroleum Oil Trust—produced a small amount of oil from the contact between the sandstone and the underlying limestones. The record of these two wells, according to Ells, is as follows.

Well No. 5 P.O.T. "In January, 1892, it is reported that 4 barrels were bailed out. The well was shot on October 25 of that year without any satisfactory result, only about 2 barrels being pumped on November 9. . . . . On December 23, 1893, this well is said to have pumped oil, after being shot, at the rate of 2 quarts per day and the same amount on January 5 and 6, 1894."

Well No. 15 P.O.T. "It commenced on April 1, 1895, and reached a depth of 2,012 feet on August 17, the limestone being struck at 1,880 feet. At this depth it is said that about 50 barrels oil were bailed out . . . . . Yielded continuously about 7 to 8 gallons oil for several months. In spring of 1901 gave about two gallons per day."

Three wells—Nos. 10 and 16, Petroleum Oil Trust, and No. 7, Canadian Petroleum Company—produced small amounts of oil from the sandstones. The record of these wells, according to Ells, is as follows.

Well No. 10 P.O.T. "Water and gas were struck at 775 feet and small shows of oil at 1,108 and 1,170 feet . . . . no oil was taken out."

Well No. 16 P.O.T. "Only one small show of oil was found at a depth of 2,664 feet . . . . . no oil was taken out."

Well No. 7 C.P.C. "Oil reported at 1,945 feet. Took out from 2 to 3 barrels only."

From these records it is seen that the greatest production of oil was obtained from the limestones.

The group of wells drilled in the vicinity of the mouth of Mississippi brook[2] were originally considered to be on the Point St. Peter anticline. Parks, however, is of the opinion that this is not the case and that the wells were located close to the axis of the York River syncline. If this is so the location of these wells may not be very favourable for oil.

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[1]Ells, R. W.: Geol. Surv., Canada, vol. XV, pt. A, p. 361 (1907).
[2]Locality No. 15 on Figure 16.

A number of wells in the Mississippi group drilled through the Gaspe sandstones into the underlying Grand Grève limestones. The records of these wells may be summarized as follows:

Well	Depth to sandstone-limestone contact	Total depth	Oil at contact	Oil in sandstone	Oil in limestone
	Feet	Feet		Feet	Feet
P.O.T. 17	2,000	2,550	.....	Shows	2,348
P.O.T. 18	1,865	1,960	.....	Shows	
P.O.T. 19	2,340	2,340	.....	2,040	
P.O.T. 20	2,050	2,173	Oil and gas		
P.O.T. 21	1,555	1,830	Trace of oil		
P.O.T. 27	2,200	.....	.....	1,467 (congl.)	
P.O.T. 29	Not reached	.....	.....	2,180	
P.O.T. 30					
P.O.T. 31	2,450	2,815	.....	1,700	
P.O.T. 32	1,825	1,925	Oil		
P.O.T. 35	1,800	1,810	.....	.....	
C.P.C. 1	Not reached	.....	.....	1,550	
C.P.C. 4	2,200?	2,200?	.....	.....	
C.P.C. 5	.....	2,200	.....	2,140?	
C.P.C. 6	2,360	.....	.....	2,340 (show)	
C.P.C. 8	2,340	2,394	Show		
C.P.C. 11	1,900	1,924	.....	1,490 (show)	

The only wells of those that produced oil in any appreciable quantity were Petroleum Oils Trust Nos. 27 and 32. The record of these wells, according to Ells, is as follows.

Well No. 27 P.O.T. "It was commenced on February 28, 1897, and bored to a depth of 1,467 feet in sandstone with occasional bands of pebble conglomerate, the pebbles being mostly white quartz. At this depth a vein of oil and gas was struck in the conglomerate which is said to have flowed three times before being plugged. The oil was all lost. The well was subsequently carried down to a depth of 2,200 feet and a considerable quantity of oil taken out."

Well No. 32 P.O.T. "Boring began in January, 1899, and the whole was carried down in sandstone and shale to a depth of 1,825 feet to the limestone, in which the boring continued to a total depth of 1,925 feet on June 13. A little gas and oil were found at the contact and are reported to have yielded about 10 gallons of oil per day for a time. In July, 1902, it pumped from 5 to 6 gallons a day, but irregularly. The pumping log of this well gives a total yield to August 9, 1902, of 1,745 gallons."

It will be seen that No. 27 P.O.T. well flowed from a conglomerate zone in the sandstone and that No. 32 P.O.T. gave some oil from the sandstone-limestone contact.

The conclusion that seems most obvious from a study of the oil production of these wells is that regardless of structure a number of wells yielded small quantities of oil and that wells located on the anticlines yielded no more favourable results than those located in the synclines. In the writer's opinion the oil production was controlled by the degree of porosity present in favourable horizons. Well No. 27 P.O.T., although

located in a synclinal area, is reported to have flowed in the beginning. This is the only well recorded as yielding oil from a conglomerate bed. Regarding the production of the wells Ells[1] states

"After the wells have been standing for some days or months there is manifestly an accumulation of oil in some of them which has gathered by slow percolation from the surrounding rocks, probably along fissures. Thus, when pumping operations were commenced in 1901 on some of these the output for several days was fairly large, but in a short time it fell off to a few gallons or even quarts, and in some cases entirely ceased."

This is taken to mean that the failure of the production was due to the absence of a suitably porous reservoir rock and hence the prospects for future drilling do not seem to be very hopeful. This failure to produce oil is interesting in relation to the results of scientific investigations that have recently been done concerning the porosity and productivity of limestones, because in the Gaspe field the best results from a number of wells were obtained from the limestones.

It has been shown[2] that in the oil fields of the world where production is secured from limestones, such limestones are unconformably overlain by later deposits, and that production of oil comes from the upper part of the limestones within a few hundred feet below the unconformity. Experiments carried on by Murray and Love[3] have indicated that

"in nature two groups of organic acids may act as solvents of limestone. The first group is composed of acids which are produced by the plant during its growth and which are leached out after the plant dies. In the second group are acids produced by the bacterial decomposition of such plant materials as cellulose, hemicelluloses, pectin, and gums."

The experiments carried out by Murray and Love demonstrated at least four conclusions as follows:

(1) Soil bacteria possess the ability to generate acids which are capable of dissolving calcium carbonate.

(2) Carbon dioxide is generated in large quantities as a result of bacterial decomposition of plant material and also as a result of the reaction between the acids generated and calcium carbonate.

(3) The bacteria become dormant when the solutions are made alkaline.

(4) The time involved in the bacterial decomposition of plants is sufficient to allow the percolation of solutions containing bacteria to considerable depths before toxic conditions are set up.

"It may thus be seen that solutions containing acids and carbon dioxide may percolate downward through limestone and that the solvent action of these solutions is carried on from the surface of the earth to the water table. At the latter depth the solutions in contact with carbonates become alkaline and reactions between them and the limestone probably cease. Not only do the solutions carry carbon dioxide into the rock, but carbon dioxide is generated within the rock itself and this carbon dioxide, being in intimate contact with the rock, may well exert more effective action than atmospheric carbon dioxide which has been carried down by rain."

The action under conditions outlined above assumes that the limestones were exposed to surface conditions and that during this time the porosity resulted. Later the limestones were buried unconformably beneath other sediments, and under certain favourable conditions where a source rock for the generation of oil was in contact with the limestone and favourable structure resulted from deformation, oil would accumulate in the limestone reservoir.

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[1]Ells, R. W.: Geol. Surv., Canada, vol. XV, pt. A, p. 360.
[2]Howard, W. V.: Am. Pet. Inst., Research Project No. 23.
[3]Murray, A. N., and Love, W. W.: Am. Ass. Pet. Geol., vol, 13, No. 11, p. 1467 (1929).

In Gaspe area the Grand Grève limestones unconformably underlie a series of sandstones, shales, and conglomerates and this limestone produced favourable "shows" of oil. The limestones must either have generated oil within themselves or have been in contact with suitable source beds, since the petroliferous character of the rock is well recognized. The structure, too, so far as can be judged from descriptions of it, seems to have been favourable for the accumulation of oil in suitable reservoirs, provided these were present. It would appear, therefore, that even though conditions may have been favourable for the formation of porosity in the limestones during the period of time represented by the unconformity with the overlying Gaspe sandstones, the porosity that developed was insufficient for the formation of commercial oil fields. It is believed by the writer that the explanation of this is to be found in the character of the limestones themselves. The description of the limestones by Dr. Parks[1] is highly instructive. He states

"sections were made of this (Grand Grève) hard limestone from Mississippi brook. The more typical stone shows very fine crystals of calcite embedded in a small amount of amorphous silica. The flinty varieties are similar, but with a great quantity of amorphous silica . . . . . The total quantity of silica in this flinty limestone is enormous, the formation is probably a thousand feet thick, and possibly consists of 25 per cent silica. The origin of the silica is questionable. I would venture the opinion, however, that it was derived from the leaching of ashes discharged from volcanoes known to exist in Lower Devonian time to the westward of the district under discussion."

The records of wells gives further proof that the limestones encountered in drilling were highly siliceous. It is probable that a great amount of this silica was deposited with the limestones and such limestones would not be expected to be very susceptible to solvent action by weak, acidic solutions during the interval of weathering. Sir Wm. Logan[2] mentions the presence of chert in the top beds of the limestones in certain places. This suggests a secondary deposition and since solutions from the overlying Gaspe sandstones might be expected to be siliceous it might be possible, if any porosity had been present in the upper part of the limestones prior to the deposition of the Gaspe sandstones, that this porosity would be eliminated or greatly reduced by the deposition of silica. The action of the wells suggests that the zones that contained oil in the limestones had a low porosity and if this is the case, whatever the cause may be, the prospects for commercial oil fields from these rocks would not seem very favourable. There still remains the prospects of oil from the sandstones and conglomerates of the Gaspe series. Some oil was found in various horizons in these rocks and also salt water was present in many wells. The most discouraging feature about the prospects of producing oil from these horizons seems to be the conclusion by both Ells and Parks that some of the wells that were considered to be the most favourably located on anticlinal structure did not yield a commercial supply of petroleum. Conclusions, however, have been based for the most part on a limited amount of information regarding the details of the structure, owing to the general inaccessibility of much of the country and the lack of exposures of rock. It is possible, therefore, that in certain areas in Gaspe, as more geological data become available, further test wells will be justified, although on the whole drilling has given, so far, very discouraging results.

[1]Parks, W. A.: Op. cit., p. 32.
[2]Logan, Sir Wm.: "Geology of Canada, 1863," p. 393.

CHAPTER IX

OIL AND GAS PROSPECTS OF THE MARITIME PROVINCES

THE STRATIGRAPHY OF BITUMINOUS-BEARING FORMATIONS OF SOUTHERN NEW BRUNSWICK, NOVA SCOTIA, AND PRINCE EDWARD ISLAND

By W. A. Bell

INTRODUCTION

For the purpose of the geologist interested in oil-bearing formations, the best initial comprehensive view of the geology of Acadia is afforded by the physiographic features. This is so because the major upland tracts of the region are underlain by igneous rocks and by associated sediments that, in the main, are too closely folded, brecciated, and metamorphosed to be of any value as potential sources of oil. The pattern of upland and lowland, consequently, serves as a rough index to the distribution of possible favourable rock formations. But in this particular region it goes farther and the distribution of land forms serves to guide the judgment as to what formations in the lowlands are favourable, as it is in a way a composite picture sketched by past geological events; events that must be taken into consideration in evaluating possible economic sources of oil. For the physiographic pattern is the resultant not of a single age of folding, but of various warping and folding movements during the period of sedimentation. Warping movements included: (1) long-continued, progressive subsidence of narrow, fold-like troughs or miniature geosynclines in which sediments were protected from erosion by sinking below the base level. These troughs were separated by complementary uprising watersheds that furnished them with abundant local supplies of sediment; and (2) broad, vertical movements of a more regional character involving tilting or basin-and-dome warping. It is the first or geosynclinal type of warping that is mainly reflected in the present uplands and lowlands—the uplands corresponding roughly to former upwarps or positive areas, the intervening lowlands to complementary downsinking or negative areas.

Folding movements cannot be sharply differentiated from linear warping ones, but practically they are considered to be of a minor order of more localized intensity, and of more rapid formation. Severe folding in general is destructive of oil accumulations. Faults delimit the present margins of the uplands in places and in that respect obscure somewhat the historical structural significance of the latter. As in other regions they are of interest to the oil geologist as they may have afforded conduits of escape and of subsequent loss of oil, paths of ready migration, or impervious covers or dams for oil reservoirs.

The above considerations justify a brief glance at the physiographic plan of lowland and upland prior to a discussion of details of stratigraphy. Thereby there is brought to view not only the pattern of rock formations, but as well the major tectonic units.

PHYSIOGRAPHIC ELEMENTS OF ACADIA

About 45 per cent or, roughly, the southern half of the province of Nova Scotia, is a physiographic unit, a rolling glaciated plain that has been termed the Southern Upland (*See* Figure 17). The term upland is justified by the fact that the plain reaches an altitude of 600 to 700 feet along its northern border, high enough to dominate lower country to the north of it. It slopes seaward to dip beneath the Atlantic with a low, much-indented shoreline that testifies to post-glacial drowning. This sloping, upland surface is underlain by granites invading quartzites and slates of great thickness and closely folded. The sediments are unfossiliferous and are generally held to be of late Precambrian age. They were strongly folded prior to their intrusion, in Middle Devonian time, by a granite batholith.

Paralleling the northern border of the southern upland for 120 miles and fronting Fundy bay, a volcanic upland ridge, known as North mountain, has an elevation of about 550 feet for 80 miles of its length. For the remainder of its course, from Digby westward, the crest rapidly declines. North mountain is separated from the southern upland by the Annapolis-Cornwallis valley, a linear lowland, only 2 to 6 miles broad, floored by Upper Triassic freshwater sediments. This lowland is part of a broader lowland of Triassic sediments that is largely submerged in Fundy bay and that is flanked on the north by Cobequid Upland. North mountain has not the same significance in tectonics or sedimentation as have many of the other uplands, as it is merely a palisade of Triassic basic volcanic flows. Its even crest is obviously a remnant of the physiographic surface of the southern upland.

The surface of the remaining parts of Nova Scotia and southern New Brunswick consists of isolated remnants of upland surfaces surrounded by, or jutting into, lowlands. For the most part the uplands are linear areas whose long axes parallel, or roughly coincide with, Carboniferous tectonic axes. In Inverness-Victoria counties, Cape Breton island, there is present, however, a broader, elongated tableland, about 1,200 feet high, and on the mainland, in eastern Pictou and Antigonish counties, an upland tract partakes both of the linear and tableland type. Examples of the linear type may be briefly noted. In southern New Brunswick the Caledonian upland extends in a northeasterly direction from St. John to near Petitcodiac river in Albert county, a distance of 80 miles. It has a maximum width of 16 miles and an average elevation of about 1,200 feet. The underlying rocks of the upland are extrusives, intrusives, and metamorphosed sediments, some of which are of Precambrian age. Cobequid upland, 100 miles long, in few places more than 10 miles wide, with an average elevation of about 800 feet, crosses Cumberland and Colchester counties, Nova Scotia, in a direction 10 degrees south of west and forms the backbone of a peninsula that splits the head of Fundy bay into two parts, Chignecto and Minas bays, respectively. The Cobequid upland is an

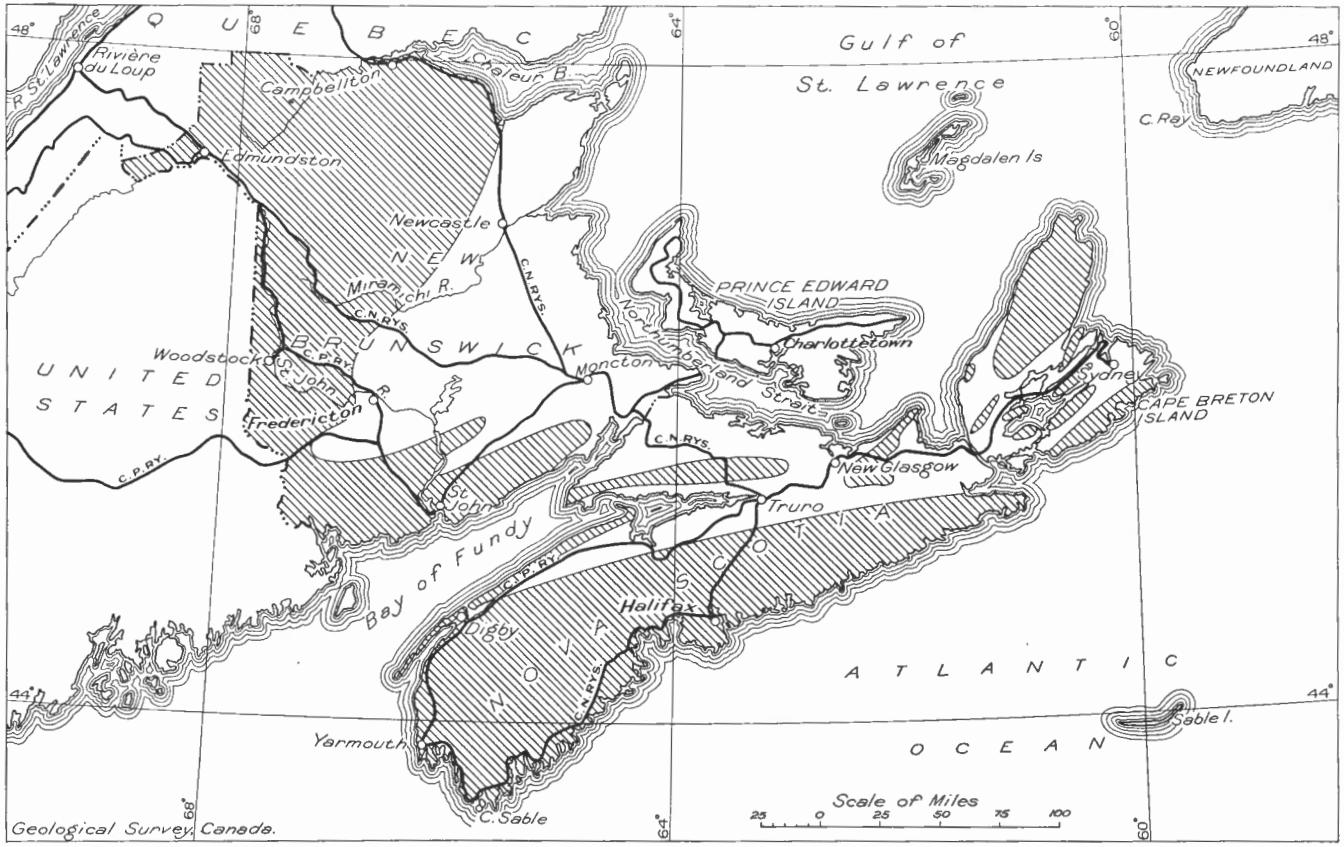

Figure 17. Showing main upland areas (pattern of ruling) of the Maritime Provinces.

excellent example of a present day physiographic watershed that represents a remnant of a Carboniferous tectonic unit that had an important control over sedimentation to the north and south of it. It is a complex of igneous rocks and metamorphic sediments of Lower Carboniferous and older ages of no direct interest to the oil geologist, but which in Carboniferous time underwent intermittent elevation and furnished material for alluvial fans along its borders. Its final warping movement is discerned in alluvial sediments at its eastern end that are folded in an anticline that plunges eastward.

In Cape Breton there are a number of smaller linear uplands with general northeasterly trends, of which the geological history was in part analogous to that of the Cobequid upland. In the western part of the island there is the Craignish upland, 25 miles long, 5 miles maximum width, 700 to 900 feet elevation; North or Marble mountain, 16 miles long, 3½ miles wide, elevation of 700 feet; Sporting mountain, 12 miles long, 3½ miles wide, elevation of 500 feet; Kelly mountain, 18 miles long, maximum width 9 miles, elevation 800 to 1,000 feet; Boisdale hills, 27 miles long, 6 miles wide, average elevation about 700 feet; Coxheath hills, an outlying spur of the Boisdale, 14 miles long, maximum width 2½ miles, elevation about 550 feet; East Bay hills, 32 miles long, 5 miles wide, elevation 500 feet; and finally, along the southeast coast of the island is a low upland, sloping seaward, 60 miles long, 14 miles wide. These Cape Breton uplands, together with a number of smaller ones and the larger tableland in the north, make up considerably more than half of the total land area of Cape Breton island and are underlain by igneous rocks and metamorphic sediments of no value to the oil prospector. Of the sedimentary rocks the oldest are of Precambrian age, probably early Precambrian as they include crystalline limestone and gneisses. Cambrian sediments, mainly quartzites, shales, and argillites, have been recognized, and strongly folded Ordovician sediments are possibly present as well. The intervening lowlands are floored entirely by Carboniferous sediments.

Northern New Brunswick consists mainly of an upland underlain by highly folded metamorphosed pre-Carboniferous sediments and by volcanics and igneous rocks, a terrain not favourable for oil and gas.

PRE-CARBONIFEROUS STRATIGRAPHY

Extensive magmatic intrusions of granite in Middle Devonian time, an event tectonically known as the Acadian or Schickshockian disturbance, marks a convenient dividing line in the region under review between sediments that have undergone great compression or alteration, and sediments in which metamorphism has commonly not proceeded beyond limits theoretically permitting of oil accumulation. Middle Devonian orogeny was the most significant widespread event in the tectonic history of the Maritime Provinces. It gave rise in the north, in Gaspe, to Schickshock mountains, the present plateau core of Gaspe, and in the south to a former mountainous tract that at present makes up the low-lying southern upland of Nova Scotia. The only Devonian rocks of later age than the Acadian disturbance are present in Gaspe and in northern New Brunswick. The pre-Middle Devonian sediments of Nova Scotia and southern New Brunswick are generally closely folded and intruded by igneous rocks. Those of

Cambrian age consist chiefly of slates and quartzites; Ordovician strata comprise slates, argillites, associated with volcanic rocks; the Silurian in addition to slates, shales, sandstones, and quartzites, includes impure limestone, and calcareous shales. In general the Silurian strata are not as closely folded or altered as are the Ordovician rocks of the same districts. They form part of the stratified rocks of the Cobequid upland and the Pictou-Antigonish highlands, and they outcrop in a narrow area in Cornwallis-Annapolis valley along the flanks of a Devonian granite batholith. Lower Devonian strata are practically restricted to the latter district and like the Silurian have been strongly disturbed.

It may be concluded from the geological history of the pre-Carboniferous rocks in the region under discussion that they have no possible value as a potential source of oil. Wherever exposed they show the effects of the Acadian orogenic disturbance. Almost everywhere they have been compressed into close folds and dip at high angles, shales have been altered to argillites or slates, sandstones cemented to quartzites; they have been subjected to igneous intrusions, and finally have been seriously dislocated by faults. It is inevitable that any oil that was originally free to migrate, has long since escaped beyond recovery.

CARBONIFEROUS STRATIGRAPHY

Sediments of Carboniferous age are the only ones that require serious consideration in evaluating oil possibilities in Nova Scotia, Prince Edward Island, and southern New Brunswick. This is so because the sediments of pre-Carboniferous age are greatly deformed and because the remaining sediments belong to the Carboniferous with the exception of the freshwater Triassic strata of Minas basin.

The general succession of Carboniferous strata is as follows:

Permian or Upper Pennsylvanian	Stephanian (?)	Upper strata of Prince Edward Island	Chocolate and salmon-coloured conglomerates, sandstones, shales; freshwater origin
Pennsylvanian	Upper Westphalian (Radstockian: Lower Alleghany)	Pictou series	Conglomerates, sandstones, shales, thin limestones, coals; freshwater origin; maximum thickness 7,000+ feet
	(Staffordian: uppermost Pottsville and transitional epoch)	Stellarton series	Conglomerates, sandstones, shales, oil-shales, coals; freshwater origin; maximum thickness 5,000 feet
	Middle Westphalian (Yorkian: Upper Pottsville)	Cumberland series (Joggins formation)	Conglomerates, sandstones, shales, thin limestones, coals; freshwater origin; maximum thickness 7,000+ feet

	Lower Westphalian (Lanarkian: Middle and Lower Pottsville)	Riversdale series (Boss Point[1] Lismore[1], Parrsboro, Harrington River, Hawkesbury formations)	Conglomerates, sandstones, shales, thin limestones, coals; freshwater origin; maximum thickness 9,000+ feet
Mississippian	Visean (Chesterian).....	Windsor series	Conglomerates, breccias, sandstones, shales, limestones, anhydrite, gypsum, rock salt; both marine and continental origin; maximum thickness 3,000+ feet
	Tournaisian (Pocono)	Horton series (Horton Bluff, Cheverie, Kennebecasis, Albert, Weldon formations)	Conglomerates, breccias, sandstones, shales, oil-shale, limestone, thin coals; freshwater origin; maximum thickness 8,000+ feet

The most noticeable features of the Carboniferous strata are the dominance of freshwater sediments and the remarkable thicknesses of individual formations and series. The great thicknesses are partly related to the presence within the Horton, Windsor, Cumberland, and Pictou series, of alluvial fans of conglomerates or breccias, of great maximum thickness and developed in the vicinity of certain of the present uplands. The boulders of these conglomerates were derived from ancient linear uplands of which the present are remnants. Uplands revealing such relations are obviously not parts of the pre-Carboniferous floor upfolded in some single epoch of post-Carboniferous folding. That the uplands were not so produced is further indicated by evidence of transgressive overlaps having taken place along one side or both sides of the present uplands during stages ranging from Upper Horton to Upper Pennsylvanian time. Moreover, strata on one side of an upland when compared with synchronous strata on the other side reveal quite distinct facies. Such relations unmistakably indicate that Carboniferous sedimentation was controlled by a definite tectonic system, and it is thought to have been of the nature of intermittent but long-continued warpings. Sedimentation is conceived as having proceeded in progressively sinking, structural river valleys separated by progressively rising watersheds, but the movements were intermittent or at least of varying intensity, so that the sediments of a basin tended to transgress the intervening uplands and, at times, to override them. For example: at a late stage of the Cumberland epoch, deposits forming in a trough north of the present Cobequid upland, transgressed onto the ancient representative of the upland and, in places at least, overrode it. Similarly, the Pictou series was a transgressive freshwater series and the area receiving sediments in late Pictou time was more extensive than that of early Pictou time.

The lack of marine sediments in the Pennsylvanian is considered to be unfavourable to oil formation. On the other hand oil-shales that ultimately may prove of economic value are present in the Stellarton series. No free oil of any consequence has been found associated with the Stellarton deposits. Rare seepages of oil have been recorded in the coal mines of the Pictou coal field, but sufficient drilling has been done for coal to

[1]The Boss Point and Lismore formations, approximately synchronous, may possibly belong to a basal division of Cumberland series; they are placed here on the evidence of their freshwater faunules as their florules have not yet been studied in sufficient detail.

prove the absence of free oil in the sands of this field. A hole drilled for oil on Prince Edward Island by the H. L. Doherty Company cut a monotonous succession of sandstones, grits, and shales like the freshwater strata of the Pictou series on the mainland where more than 7,000 feet of such sediments are known. The data obtained substantiate the general view that the thick freshwater deposits of the Maritimes are not favourable terrains for oil formation or accumulation. A specific exception to this generalization is the occurrence of oil in the Horton series of Moncton district, which will be treated more fully below.

Oil-shales are present in the Stellarton series as already noted and also in the Horton series. The richest seam in the Stellarton series has yielded upwards of 50 gallons to the ton. This seam of torbanitic shale called stellarite, is several feet thick and is associated with a thin bed of bituminous coal. There are other thin bands of oil-shale allied to torbanite present in the Stellarton series, but the quantity of oil-shale that will yield 20 gallons or more oil to the ton is very limited and is confined to bands only several feet thick. At the present time they could scarcely be worked at a profit for their oil content alone, but they yield a by-product of ammonium sulphate and the spent shale after retorting might be exploited to some extent.

Oil-shale is present in the Horton series in certain parts of Nova Scotia, e.g. in Antigonish county, but so far as known is too lean or the deposits much too thin to warrant exploration. In Albert county, New Brunswick, however, there are thicker, richer, and more extensive bands of oil-shale within the Albert formation of the Horton series. The oil-shales of the Albert series are interbedded with low-grade and barren shale, and the upper part of the formation consists mainly of interbedded sandstones, dark grey shales, and impure silty and argillaceous limestones. The sandstones are seemingly discontinuous and lenticular. Many of them contain valuable supplies of natural gas under high pressure as well as of petroleum of a grade particularly suitable for high-class lubrication. An area, known as the Stony Creek gas and oil field, has been actively developed for its natural gas and incidentally to these operations about 100,000 barrels of oil has been marketed.

STRATIGRAPHY OF THE STONY CREEK OIL AND GAS FIELD, N.B.

By G. W. H. Norman

The district (*See* Figure 18) in Albert and Westmorland counties, New Brunswick, in the vicinity of Hillsborough and extending for several miles on either side of Petitcodiac river, is of particular interest since it includes the Stony Creek oil and gas field. The strata of this area are of two main types and ages. An older group, probably Precambrian in age, consists of metamorphic and igneous rocks and underlies an upland, plateau-like area known as Caledonia mountain and whose maximum elevation is about 1,200 feet above sea-level. The northeastern limit of this upland lies a few miles southwest of Hillsborough. A younger group, of sedimentary rocks of Carboniferous age, underlies the flanks of this upland and also the country to the east and north which slopes gradually away from this upland surface.

The stratigraphic succession of the Carboniferous rocks presented below is tentative and is a modification of that proposed by Wright.[1] The general sequence is believed to be correct, although the mutual relations of the various members of the Horton series have as yet not been satisfactorily determined.

Pennsylvanian (Lower Westphalian)		Petitcodiac formation (Zones 2 and 3 of Petitcodiac series of Wright)	Conglomerate, sandstone, shale; freshwater origin; thickness 300+ feet
Mississippian (Visean)	Windsor series	Demoiselle formation (Zone 1 of Petitcodiac series of Wright)	Conglomerate, shale, limestone, sandstone; mainly freshwater; marine or brackish horizons at base; thickness 1,000+ feet
		Hillsborough formation (Zones 2, 3, 4 of Hillsborough series of Wright)	Limestone, shale, anhydrite, gypsum; mainly marine; thickness 700± feet
Mississippian (Tournaisian)	Horton series	Hillsborough formation (Zone 1 of Hillsborough series of Wright)	Red and greenish conglomerate and arkosic sandstone; thickness 2,000± feet
		Weldon formation (Weldon series of Wright)	Conglomerate, breccia, sandstone, shale; freshwater origin; thickness 2,000± feet
		[2](Boyd formation) (Boyd series of Wright)	Conglomerate, shale, ash rock, Kunkur lime deposits; probably freshwater origin; thickness 700± feet
		[2]Gautreau formation	Shale rock, salt; possibly lacustrine origin; thickness 1,000± feet
		Albert formation (Albert series of Wright)	Conglomerate, sandstone, shale, oil-shale, limestone; freshwater origin; thickness 5,300± feet

ALBERT FORMATION

The Albert formation is well exposed on both sides of Petitcodiac river near Dover where it occupies the south limb of the Stony Creek anticline. It has an estimated thickness of between 5,000 and 6,000 feet. Grey shale predominates in it, although at intervals groups of grey sandstone beds are intercalated. The relative positions of these groups in the formation appear to remain constant, although the individual members may be lenticular and discontinuous. Thick beds of bituminous shale occur, especially in the lower part of the formation. Grey limestone beds[3] are present locally in the upper part.

On Memramcook river a group of beds 3,000± feet in thickness conformably underlies the Albert formation and consists of an upper member of red, arenaceous shale with red sandstone interbeds and a lower one of grey to purplish arkosic sandstone with pebble conglomerate beds and chocolate brown, shaly interbeds. The group does not occur on the flanks

[1]Wright, W. J.: "Geology of the Moncton Map-area"; Geol. Surv., Canada, Mem. 129, p. 2 (1922).

[2]The position within the section of the Boyd and Gautreau formations is not known beyond that they are both older than the Demoiselle formation and younger than the greater part of the Albert formation.

[3]These contain a considerable percentage of barite at Upper Dorchester bridge.

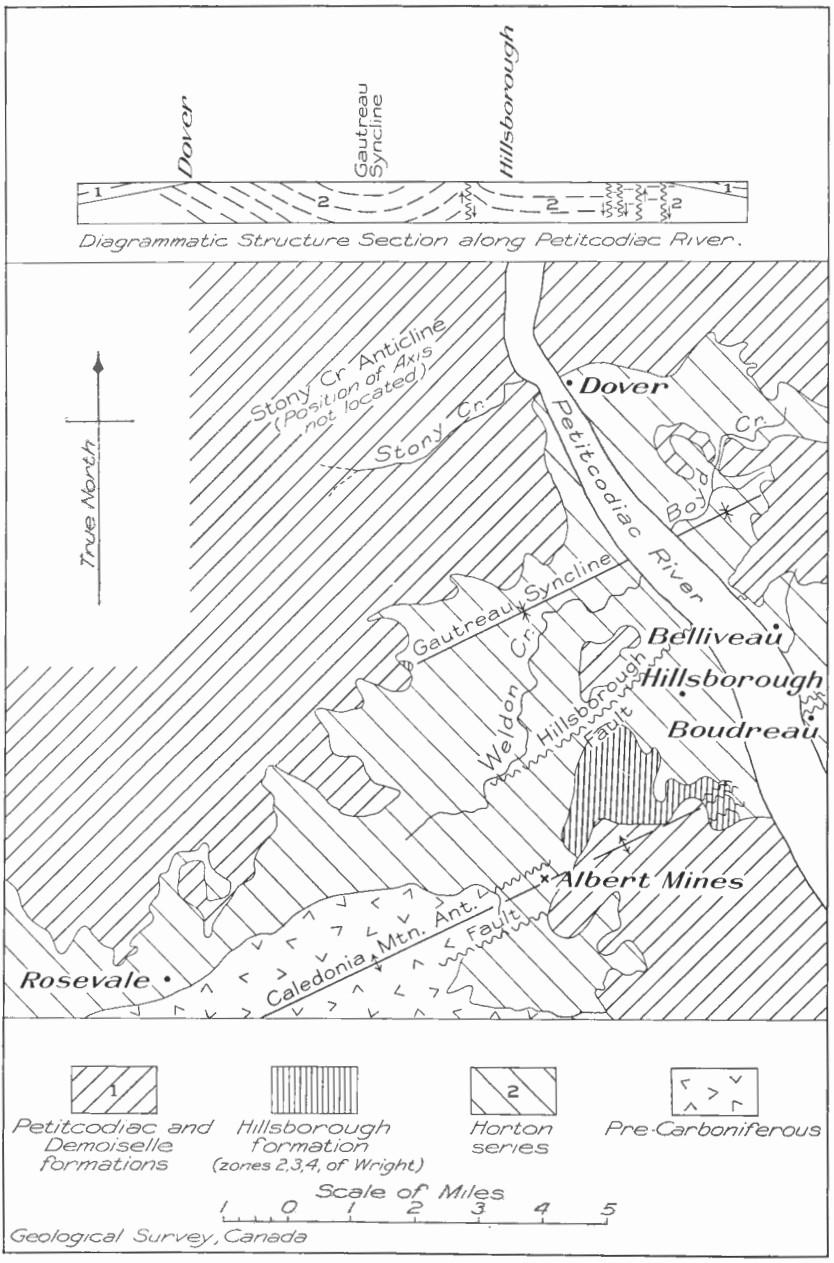

Figure 18. Hillsborough district, New Brunswick.

of Caledonia mountain where grey shale with interbeds of boulder conglomerate represent the Albert formation and rest directly on Precambrian rocks.

GAUTREAU FORMATION

Overlying the Albert shale in the centre of a synclinal structure at Gautreau are beds of rock salt to which the name Gautreau formation is here applied. The salt member was discovered by wells drilled on Boyd creek. Its occurrence was a great surprise, since no indication of salt is suggested either by springs or the general topography. The salt member has been penetrated by two wells, it is probably lenticular, but its lateral extension is unknown.

BOYD FORMATION

The Boyd formation, as mapped by Wright[1] on Boyd creek, occupies the north limb of the Gautreau syncline. The lower zones,[2] Nos. 1 to 4, consist of red and grey shale with purple volcanic ash interbeds, and conform in strike and dip with the uppermost beds of the Albert formation exposed farther upstream on Boyd creek, but from which they are separated by a concealed interval. The uppermost zone, No. 5, of the Boyd formation of Wright, is a conglomerate that contains fragments of purple volcanic ash of the lower zones. Although this indicates a break in sedimentation it may not mean a prolonged interval of non-deposition. On the other hand, this conglomerate is identical lithologically with zone 1 of the Hillsborough formation and may belong to this group. That, possibly, it should be so assigned is also indicated by the fact that it outcrops on the east side of Petitcodiac river on the strike of the Hillsborough formation, zone 1 occurring near the mouth of Weldon brook on the west side of the river. The most important feature of the Boyd formation is the purple volcanic ash beds. These form a valuable horizon marker and afford a key to the synclinal structure north of the Hillsborough fault.

WELDON FORMATION

The strata of the Weldon formation, which consists of red shales and sandstone containing concretionary calcareous nodules and a massive basal conglomerate, are faulted down against the Albert shales at Albert Mines. The basal conglomerate appears to be a local facies deposited against the flanks of an upland surface. It is absent from the section of the Weldon formation on the east side of Petitcodiac river at Belleveau. The valley of Belleveau creek conceals the contact of the Weldon with the Albert strata that outcrop along the ridge north of Boudreau village. Unless faulting has confused the relationships, the strikes and dips of the strata of the two formations on either side the concealed interval suggest structural conformity. The apparent absence of the Gautreau salt member in this part of the field is possibly due to non-deposition. The volcanic ash beds of the Boyd formation do not outcrop here, but these may be concealed. North of the Hillsborough fault, between Weldon brook and Pound creek, the Demoiselle conglomerate conceals the relations of the Boyd and Weldon formations, but judging by the strikes and dips there is no suggestion of a break in sedimentation between these two groups.

[1]Wright, W. J.: Geol. Surv., Canada, Mem. 129. *See* Geological map.
[2]Wright, W. J.: Op. cit., p. 14.

From the foregoing statements it may be concluded that no major breaks in sedimentation due to movements, occurred between the close of the period of deposition of the Albert strata and the beginning of the period of deposition of the Weldon strata. The Weldon formation does indeed overlap the Albert formation between Albert Mines and Rosevale where it lies directly on Precambrain rocks, but this does not necessarily indicate any significant time break.

HILLSBOROUGH FORMATION

Zone 1 (of Wright) of the Hillsborough formation consists of massive conglomerate, arkose, and sandstone. In the immediate vicinity of the Precambrian rocks on Wilson brook and on the streams that drain Caledonia mountain on its northern side, massive conglomerate predominates. The boulders of this conglomerate are of Precambrian rocks and range in size up to a diameter of 2 feet. The conglomerate is usually reddish brown. At a distance from Caledonia mountain the formation (Zone 1) consists, characteristically, of coarse, arkosic grits with pebble conglomerate bands and thin lenses of reddish brown sandstone. South of the Albert Mines area and west of Hayward brook, a tributary of Prosser creek, the Hillsborough formation overlaps the Weldon and Albert formations and rests directly on Precambrian rocks. In the vicinity of Hillsborough and along the north flank of Caledonia mountain, gentle dips are characteristic of this formation. Near the mouth of Weldon brook, however, dips up to 60 degrees occur on sharp, subsidiary folds in the major synclinal structure, i.e., the Gautreau syncline.

Zones 2, 3, and 4 (of Wright), of the Hillsborough formation, are part of the Windsor series. The base of the group is a persistent limestone, in part well laminated and unfossiliferous. The laminated beds grade laterally into massive fossiliferous limestones south of Wilson brook, where they rest directly on Precambrian rocks. A thick, gypsum-anhydrite bed is the only other exposed member of the formation. This bed is preserved in synclinal structures south of Hillsborough and again on Wilson brook. The basal limestone outcrops on the south bank of the headwaters of Cat creek, a tributary of Weldon brook. It is also exposed on the west branch of Turtle brook about one mile south of Berryton post office. The major part of the intervening territory is buried under the overlap of Pennsylvanian sandstone, with a gentle, southerly dip of approximately 8 degrees. The position and attitude of these limestone outcrops, however, suggest a synclinal structure.

DEMOISELLE FORMATION

The Demoiselle formation of conglomerate, sandstone, and shale varies considerably in lithology and thickness. It is well exposed south of Caledonia mountain, on Shepody mountain, and at Hopewell cape, where it is composed principally of massive conglomerate beds with minor lenses of red sandstone. The conglomerate facies appears to occupy a linear strip along the south side of Caledonia mountain. Farther south this facies is partly replaced by shales. Limestone boulders in this formation contain a few fossils of Lower Windsor age and appear to have been

derived from the Hillsborough formation. The Demoiselle strata rest unconformably on the Hillsborough beds and overlap all older formations. Very gentle dips are characteristic and the structure conforms with that of the overlying Pennsylvanian beds.

PETITCODIAC FORMATION

The Petitcodiac formation forms a thick blanket of grey to buff, quartz-pebble conglomerate, sandstone, and red shale. It dips gently to the north and conceals all older formations north of Stony brook as far as Lutz and Indian mountains. It rests with apparent structural conformity on the Demoiselle formation, but overlaps the latter along the northern flanks of Caledonia mountain and there rests for the most part directly on the Hillsborough formation, Zone 1 of Wright.

STRUCTURE

The folds and faults of the Mississippian rocks are largely concealed beneath the simpler structures of the Pennsylvanian beds. As a generalized picture, requiring modification in detail, the structure of the lower rocks may be visualized as three major folds with northeasterly trends. From south to north these are Caledonia Mountain anticline, Gautreau syncline, and Stony Creek anticline.

The Caledonia Mountain anticline plunges to the northeast, so that its core of Precambrian rocks disappears beneath the Carboniferous sedimentary formations at Albert Mines. Faults are present on the borders as well as on the axis of the anticline northeast of Albert Mines. Thrust faulting toward the axis occurs on both flanks. To the south a major fault extends from Alma to Hopewell cape. To the north of Shepody mountain this fault thrusts a long, narrow wedge of Precambrian rocks northward against Pennsylvanian rocks. Northeast from Albert Mines, along the axis of Caledonia mountain, the structure is complicated by a series of faults with a general northeast trend. These form a series of fault blocks on the anticlinal structure. Albert shales are exposed along the broken crest of the Caledonia Mountain anticline at Albert Mines, Boudreau, Taylor village, and Upper Dorchester. Elsewhere they are concealed by the south-dipping Pennsylvanian sandstone. Red shale and sandstone are exposed in a small creek one-half mile north of Upper Dorchester. These beds probably belong to the pre-Albert red shale group exposed farther north at Memramcook. Their presence indicates that east of Upper Dorchester the Albert shales were removed by erosion from the crest of this anticlinal structure prior to the deposition of the Pennsylvanian rocks which rest directly on the pre-Albert red beds. Steep dips, sharp flexures, and crumpling accompanied by small slips characterize the structures of the Albert shales where they are exposed between Albert Mines and Upper Dorchester, a distance of about 10 miles. Owing to these conditions the prospects for oil along this structure are thought to be unfavourable. A considerable percentage of the petroleum content of the beds no doubt has escaped, judging by the numerous veins of albertite and the bituminous material in the matrix of the conglomerate overlying the Albert shales. South of the Caledonia Mountain anticline the Horton strata are concealed by younger Carboniferous rocks of the Cumberland basin.

To the north and east of Caledonia mountain the Hillsborough fault occurs and extends in a southwesterly direction passing about a mile north of Hillsborough. It thrusts the Boyd and Weldon formations southward against the Hillsborough formation, Zone 1 of Wright. The westerly extension of this fault is difficult to trace where it cuts shales of the Weldon formation. Its extension farther westward would parallel the Precambrian-Carboniferous contact on the north side of Caledonia mountain.

Between the Hillsborough fault and the south limb of the Stony Creek anticline the general structure is a syncline—the Gautreau syncline. This plunges to the west and disappears beneath the cover of Pennsylvanian rocks. The eastern part of the syncline is well exposed east of Petitcodiac river near the mouth of Boyd creek. The north limb is marked by the outcrops of purple ash rock on the west side of Petitcodiac river and on Boyd creek. The south limb is broken by the Hillsborough fault. It is in the centre of this syncline on the east side of Petitcodiac river that the salt bed was located below the Boyd formation. In the centre of this syncline, near the mouth of Weldon brook, the strata have anomalous strikes and dips that do not fit into the general synclinal structure, but appear to represent minor undulations on it. Only part of the south limb of the Stony Creek anticline that borders the Gautreau syncline on the north is exposed. The remainder of this fold is concealed beneath a capping of Pennsylvanian sandstone.

RELATION OF STONY CREEK OIL AND GAS FIELD TO STRUCTURE

By G. S. Hume

The Stony Creek oil and gas field lies about 8 miles south of Moncton and extends west from Petitcodiac river. The eastern part of the field is on a pronounced hill, but the topography has no relation to the structure of the underlying Albert series from which the gas and oil are produced. The field is in reality divided into two parts by what is considered by Dr. J. A. L. Henderson to be a fault in the vicinity of Meadow brook, a small stream that flows north to join Stony creek. The main oil field, as so far developed, lies east of this fault, although some oil has been found in gas wells west of it. In the eastern part of the field, the gas-producing area lies to the north of the oil field (*See* Figure 19). Directly west of this oil field, across Meadow brook, gas is found and it is a logical conclusion from the study of the field to expect oil to occur in the undeveloped area south of the gas field west of Meadow brook. The western limits of the gas field are unknown and there seems to be no reason why the field should not extend considerably to the south and west on the west side of Meadow brook. As the field has been developed on south-dipping strata on the south flank of the Stony Creek structure, the relative positions of the gas and oil areas are explainable and, as already stated, give rise to the expectation of an oil area being situated south of the gas area west of Meadow brook.

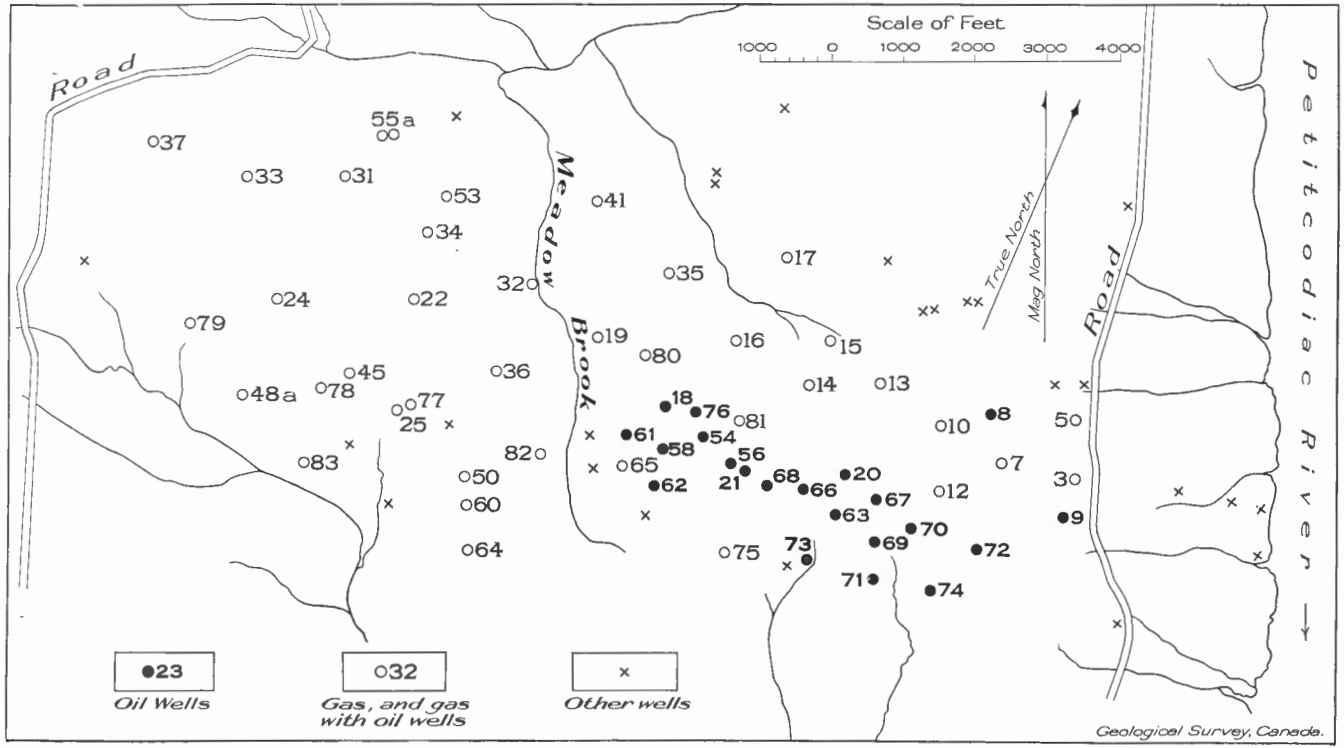

Figure 19. Stony Creek oil and gas field showing locations of wells.

Only the Albert series in Moncton area has been found to be gas and oil-bearing. This series, although consisting predominantly of shales, contains many sandstone beds that are thought to be lenticular. Groups of sandstone beds occur at definite horizons and six such groups have been recognized by the staff of the New Brunswick Gas and Oilfields, Limited. The upper two groups of sandstone beds are comparatively thin and are highly micaceous. They have produced only black oil quite different from the high-grade oil which is produced principally from the lowest of the six groups. Each of the four lower groups produces gas, but the productive horizons are not at the same stratigraphic height in every well. It is probable that the production of both gas and oil is related to the effective porosity within the productive sandstones as well as to the structure.

As the Albert series is considered, at present, to be the only favourable gas and oil-bearing formation in this area its extension and the structures affecting it are the two important considerations in the search for new producing areas. The extent of the Albert formation has been outlined by Young[1] as follows:

"The fact that the Albert series is known to outcrop at intervals over a length of more than 30 miles, and possibly over a much greater distance, and since, though locally closely folded, the strata on the whole have low angles of dip—indicating that through crumpling there has not necessarily been much narrowing of the original width of the basin of the Albert series—it seems not improbable that the strata or remnants of the strata may extend in a northerly direction beneath the covering of younger strata to a much greater width than the present outcrops show. Furthermore, on the hill known as Lutz mountain lying a few miles north of Moncton there are exposed tilted strata resembling the Albert series. Though from the lack of good exposures and the lack of fossil evidence it is not possible to settle beyond doubt that these beds of Lutz mountain do belong to the Albert series,[2] yet they may be held to furnish corroborative evidence indicating that the Albert series does extend at least that far north beneath the covering of Millstone Grit and other formations and that the basin of the Albert series has a width of at least 25 or 30 miles.

As regards the extension of the Albert series in an east and west direction, the late R. W. Ells has recorded his belief that the Albert series are the equivalents of certain strata exposed as far west as the neighbourhood of St. John city and possibly even farther west. If this correlation holds true it is also equivalent, in some measure, to setting a limit to the extension of the oil region in that direction, for these oil-shales no longer occur in the strata, but that the bituminous strata do extend beyond Elgin is indicated by the report long ago of the finding of small veins of albertite (solidified petroleum?) 30 miles southwest of Elgin. The possibilities of the extension of the Albert series to the east beyond the outcrops in the valley of the Memramcook, the last in this direction, can only be definitely determined by borings, since in that direction the Albert series disappears under a continuous mantle of Millstone Grit and overlying younger strata that extend to Northumberland strait. It would, however, be a remarkable coincidence if the eastern limits of the outcrops of the Albert series should also mark the eastern end of the basin of this series. It seems more probable that the Albert series does occur for some considerable distance to the eastward beneath the cover of younger measures.

There thus seems to be good grounds for supposing that the basin of the Albert series extends for at least 50 miles from beyond Elgin on the west to beyond the valley of Memramcook on the east and, less certainly, that it has a width of at least 20 or 30 miles from the foot of Caledonia mountain northwards. Of course, during the periods of erosion in early Carboniferous time, the Albert series may have been swept away from a considerable part of this area once possibly occupied by it.

Granting that the Albert series was and is still present, though largely concealed, over a region as large or larger than the one rudely outlined above, it does not follow that oil-shales and the associated bituminous beds occur everywhere in the Albert series of this area. Not only may the richer bituminous shales have been removed from erosion from considerable areas, but also since the oil-shales possess rather exceptional characters it is

[1]Young, G. A.: Geol. Surv., Canada. Sum. Rept. 1911, p. 319.

[2]Since the foregoing was written pits have been made on Indian mountain exposing oil-shales. These indicate definitely the presence of Albert strata here.

entirely probable that their distribution is more limited than that of the containing strata. There are indications that in a westerly direction, Elgin approximately marks their limit, for in the western part of the field the quality and amount of the oil-shales seem to decrease. On the other hand, the oil-shales of the Memramcook valley in the easternmost exposures of the Albert series, are as rich in hydrocarbons as any found elsewhere, and, therefore, it seems safe to assume that if the Albert series continue eastward beneath the there continuous covering of Millstone Grit and younger strata, the oil-shales will also extend eastward.

As to what are the conditions necessary for the accumulation of gas and oil in pools, other than the presence of the oil-shales and a suitable reservoir, it is difficult, if not impossible, to state. Doubtless an anticlinal or analogous structure and the absence of unsealed partings, fissures, and fractures, and other channels by which the oil and gas might be dissipated, are also necessary factors.

As to how far these conditions prevail in those areas where, though the Albert series may exist, it is hidden by younger formations, it seems impossible to say, and positive proof of the presence or absence of oil and gas can only be obtained by drilling."

Since the above was written the D'Arcy Exploration Company, in 1919 to 1929, drilled ten test wells, distributed over a wide area extending east of the Stony Creek field to Northumberland strait. They did not locate any profitable sands, although they obtained some showings of gas. Wells were located at Port Elgin (depth 3,230 feet), Cape Bald (two wells, 1,171 and 2,520 feet deep, respectively), Memramcook (two wells, 600 and 2,720 feet deep, respectively), Gautreau (1,873 feet), Coal Branch (2,480 feet), Buctouche (2,430 feet), and Rogersville (3,645 feet). More recently the Imperial Oil Company has done some preliminary prospecting work in the area of the Minudie anticlinorium, a narrow belt of folding that runs about eastward from cape Maringouin, New Brunswick, to Nappan, Nova Scotia, and beyond. This anticlinal area brings continental and marine strata of the Middle and Lower Windsor series to the surface and is receiving attention in the hope that the Albert formations may here lie within reach of the drill.

HISTORY OF DEVELOPMENT[1] OF STONY CREEK OIL AND GAS FIELD, NEW BRUNSWICK

The occurrence of oil and natural gas has been known in New Brunswick since the early settlement of the country. Seepages of oil and gas are reported to have occurred in widely separated districts, but the most prolific flows are said to have come from a series of bituminous and petroliferous shales and sandstones that are now grouped under the Albert series. The most abundant evidences of oil occurred in the areas east and west of Petitcodiac river in Albert and Westmorland counties. In Westmorland county, between Petitcodiac and Memramcook rivers, the early settlers found beds of maltha in some cases covering acres to a depth of 1 to 18 inches[2] and gas issued from springs of water, particularly in the area about Dover.

In 1849 a vein of albertite, 16 feet wide, was discovered in Albert shale on Frederick brook, about 4 miles southwest from the town of Hillsborough. This material was at first judged to be a coal and as such was mined in accordance with the regulations governing coal mining. It is now known, however, that the albertite occurred in a true fissure vein instead of as a bedded deposit, and it is considered to be a form of bitumen which in a

[1]The main source of information for this history is from a private communication from Dr. J. A. L. Henderson.
[2]Young, G. A.: Geol. Surv., Canada, Sum. Rept. 1911, p. 316.

liquid state flowed into and filled a fissure in the Albert shales. The albertite deposit was worked for fourteen years, during which time more than 200,000 tons were mined. The material was sold mostly in United States where it was used principally for enrichment of coal gas, the yield being 14,500 cubic feet per ton. During the course of operations in the mine, which was extended over a length of half a mile and attained a maximum depth of 1,100 feet, many evidences of oil and gas were apparent, principally from the sandstones associated with the shales and "buckets placed in certain positions were found, after periods more or less prolonged, to be filled with oil."[1]

These evidences of petroleum and gas in the Albert shales suggested to those who were familiar with conditions, that crude oil in quantity might occur in favourable localities and since the beds of maltha between Petitcodiac and Memramcook rivers furnished the best evidence of oil in quantity, attention was first directed to this region in the search for oil fields by drilling wells. In 1859 Dr. H. C. Tweedel, an oil refiner and chemist of Pittsburgh, Pa., secured leases and drilled four shallow wells, the deepest about 190 feet, near two oil seepages. Although small flows of gas and oil were found, operations were abandoned owing to the production of oil in large quantity in Pennsylvania, following the discovery well of Colonel Edwin L. Drake in 1859.

The next attempts were made in 1876-1879 when two companies—the St. Joseph Petroleum Company under the direction of R. S. Merrill and the Emery Oil Company under the direction of Lewis Emery of Bradford, Pa.—were organized to undertake development. Three wells were drilled in the vicinity of Dover, three near St. Joseph, and one south of Memramcook. It is reported[2] that

"six of these wells either started in the Albert rocks or else entered them after passing through a thin cover of younger strata. The seventh well, which proved to be a complete failure, was drilled entirely in strata younger than the Albert series. The wells were drilled to depths of from 1,000 to 1,900 feet and in all, except the one above mentioned, considerable volumes of gas were found, and in the case of two wells oil in considerable quantities was obtained, one well yielding at the rate of 20 barrels per day for some three or four days."

The operations were, however, abandoned, the wells being drowned out by water and the venture not proving a financial success due to the low prevalent price for oil—49 cents a barrel in United States.

Reports by Professor John F. Carll, State Geologist of Pennsylvania, Dr. F. H. Oliphant of Oil City, Pa., and Professor H. S. Shaler, of Harvard, induced local interests to undertake further tests and a local company, New Brunswick Petroleum Company, was formed in 1899, which secured the sole right from the Crown to test possible petroliferous territory in New Brunswick and to select therefrom a blanket lease covering 10,000 square miles.

Between 1901 and 1906, seventy-eight shallow wells, generally a few hundred feet deep, were drilled on or adjacent to outcrops. These were principally in Dover and St. Joseph area, Westmorland county, but one well was drilled at Beersville, Kent county, and four on the west side of Petitcodiac river between the river and the present oil and gas field in

[1]Bailey, L. W.: Geol. Surv., Canada, Ann. Rept., vol. X, pt. M, p. 71 (1899).
[2]Young, G. A.: Geol. Surv., Canada, Sum. Rept. 1911, p. 316.

Albert county. It is reported that "the wells in Kent and Albert counties were without result, but of those drilled in the St. Joseph and Dover fields, about half produced oil in commercial quantities. The majority yielded from ½ to 2½ barrels a day, although one well is stated to have produced at a rate of 50 barrels a day at the start." About 3,000 barrels of oil were produced, but the wells were improperly drilled and were drowned out by water.

In 1907 Dr. J. A. L. Henderson of London, England, visited the area and as a result he formed a private English company, Maritime Oil Fields, Limited, to test the area. The drilling rights of the New Brunswick Petroleum Company were secured. These included a Crown lease dated August 16, 1907, covering the exclusive right to search for and work oil and natural gas for a period of ninety-nine years, renewable for a like period, under a royalty of 5 per cent of the output of oil and natural gas delivered at the well's mouth, or 5 per cent of the commercial value thereof. In 1909 drilling operations were begun resulting in the discovery of natural gas in large quantity in addition to a promising quantity of oil at Stony Creek, Albert county. By 1911 the Stony Creek field was established. The discovery of oil and gas is attributed to the application of geology in the selection of well sites by Dr. Henderson.

A distributing company, Moncton Tramways, Electricity, and Gas Company, was formed by Maritime Oilfields, Limited, to pipe and market the gas to the city of Moncton and the town of Hillsborough, and in the spring of 1912 regular delivery of gas to consumers was begun. The supply of gas for the increasing number of users has been maintained by field pressures alone, even during the winter periods. The distributing company has subsequently been acquired by other interests and takes delivery of the gas 50 feet from the well mouth. The present rates charged to consumers are 40 cents a 1,000 cubic feet for industrial gas and 50 cents for domestic gas. The natural gas is free from sulphur and has a thermal value of about 1,130 B.T.U. per cubic foot.

The productive gas field at Stony Creek has been developed along the structure in an east-west direction for 2½ miles in length and up to 1 mile in breadth. The northern limit of the field has been reached and the oil area occurs to the south of the gas area. The limits in an east-west direction are unknown and it is thought it may be possible to extend the field to the east side of Petitcodiac river. It is certain, however, that the field can be extended for an unknown distance to the west. There are now twenty-five productive gas wells yielding an open flow of about 10,100,000 cubic feet a day. A number of wells yielded initial flows of approximately 10,000,000 cubic feet a day and the largest had an initial flow of more than 17,000,000 cubic feet. The closed or rock pressures are high, with a maximum of about 1,200 pounds a square inch.

The quantity of gas sold from the field to October, 1928, was about 10,313,000,000 cubic feet, the average production per well being 300,000,000 cubic feet.

Subsequent to the close of the war attention has been directed toward determining the oil prospects of the field. The first deep test well for oil was drilled in June, 1919, and this found a thick oil sand in what is known as group VI, by the officials of the New Brunswick Gas and Oil fields,

Limited. Sixteen oil wells have been drilled and these have proved an area of about 400 acres along a length of 1¼ miles and across a width of about ½ mile. It is probable that the oil field can be extended for the whole length of the gas field.

From pumping tests of individual wells continuing over an extended period of years and from a six-month continuous pumping test of all the wells, it is thought the decline of the wells will be slow and the life of each well will be long, the officials of the company estimating an ultimate production of 20,000 to 25,000 barrels a well over twenty years. It has not been the policy of the present company to produce oil, since the value of the oil is dependent on the quantity and quality of the lubricants contained, although the gasoline yield is more than 15 per cent by weight. Arrangements are now pending for the erection of a small refinery, and since June, 1927, the wells have been for the most part shut in, such production as has been made having been sold to the railway. The wells have yielded more than 101,000 barrels of oil, of which 92,100 barrels have been sold, realizing over $305,000.

During 1919 to 1921, in agreement with the New Brunswick Gas and Oilfields, Limited, the D'Arcy Exploration Company carried on a considerable amount of geological work and drilled ten test wells in various outlying parts of the large area under lease. Some shows of gas were encountered in these wells, but no commercial production of either gas or oil was secured.

PRODUCTION

The following figures of production of the Stony Creek oil and gas field were supplied by Dr. J. A. L. Henderson.

Year	Production in barrels	Sales barrels	Realized gross value including bounty
			$
1911	4,050	2,592	7,501 80
1912	2,679	3,062	7,352 34
1913	2,096	874	3,360 85
1914	1,822	986	3,486 52
1915	1,021·3	944·3	3,018 28
1916	1,344·8	834·1	2,837 56
1917	2,340·8	4,242	12,872 39
1918	3,009	2,789·5	9,797 73
1919	4,275	4,225·3	15,385 92
1920	5,703·29	5,148·68	22,957 61
1921	7,479·34	6,333·09	28,464 46
1922	7,798·69	7,247·93	30,502 33
1923	8,828·14	7,191·50	29,839 43
1924	5,732·84	5,511·18	21,312 97
	Bounty abolished in 1924		
1925	6,472	5,377	18,712 41
1926	11,381	10,544·23	30,548 51
1927	24,562·06	18,244·56	41,747 81
	Test for 6 months only		
1928 (end of September)	1,067·56	5,960·86	15,867 06
Totals	101,666·82	92,108·23	305,565 98

Natural Gas

Year	Production	Sales	Realized gross value
		Cubic feet	$
1911	42,000,000		
1912	186,973,000	172,716,000	36,544 00
1913	856,156,000	828,603,000	167,984 00
1914	435,236,400	425,826,000	135,623 49
1915	431,898,600	428,894,000	144,844 54
1916	610,295,750	599,454,000	195,590 74
1917	796,800,400	778,854,000	253,511 52
1918	792,396,250	775,077,000	269,604 80
1919	682,889,864	667,914,000	294,684 60
1920	682,502,191	666,066,000	326,266 00
1921	708,743,261	690,681,000	339,408 00
1922	753,897,933	740,215,000	363,257 70
1923	640,310,196	619,673,000	305,009 20
1924	599,971,818	574,437,000	283,941 90
1925	639,235,453	618,272,000	304,934 92
1926	648,316,055	624,380,000	308,933 00
1927	630,755,215	620,380,000	306,467 70
1928 (end of September)	489,778,096	481,307,000	237,589 80
Total	10,628,156,482	10,312,749,000	4,274,195 91

The initial flow with initial pressure of the gas wells and total yield of the oil wells is as follows.

Petroleum

Well No.	Initial flow per day	Total yield to October 31, 1928	Remarks
8	32·0	8,724·2	Gas and oil well
9	8·0	847·5	" "
18	14·0	10,049·2	
20	12·0	6,349·95	
21	30·0	4,718·0	Abandoned
		May, 1921	
		Replaced by well 56	
54	10·0	9,541·2	
56	24·0	4,788·5	
58	56·0	4,269·74	
61	6·0	362·0	No sustained test
62	12·0	414·0	" "
63	34·0	3,807·0	
66	20·5	2,485·25	
67	37·6	3,583·3	
68	26·0	2,536·2	
69	66·0	3,774·6	
70	110·0	6,944·8	
71	44·4	2,714·2	
72	40·0	743·8	Oil and gas well
73	24·0	4,476·27	
74	6·0	1,494·9	
76	20·0	2,101·3	
80	6·0	.....	Not yet tested for production
81	18·0		
Totals	656·5	84,725·91	

In addition to this, 17,286·74 barrels of oil have been produced from gas wells between 1909 and October, 1928, making the total of oil produced during this time 102,012·65 barrels.

Gas Wells

Well number	Total initial flow in cubic feet	Maximum rock pressure in pounds (observed)
3	300,000	95
5	2,589,000	225
7	3,704,000	660+
8	6,737,000	245
9	1,100,000	730
10	1,850,000	940
12	10,900,000	1,000
13	8,410,000	1,000+ estimated
14	11,630,000	252
15	15,061,000	1,060
16	5,207,000	375
17	150,000	200
19	5,700,000	373
20	6,829,000[1]	405+
22	17,185,000	750
24	1,490,000	712
25	125,760	580
31	400,000	240
32	14,286,000	225
33	100,000	480
34	65,000	530
35	9,361,000	190+
36	9,941,538	725
37	1,000,000 (estimated)	
41	9,565,000	274+
45	3,707,000	90+
48A	2,585,000	1,005
50	53,000	
53	16,143,000	620
54	110,000[1]	
55A	420,872	
60	2,411,000	1,190+
62	177,000[1]	710
63	2,666,822[1]	165
64	2,184,052	1,000 (estimated)
65	2,155,278[1]	
66	680,000[1]	110
67	3,817,000[1]	232
68	657,000[1]	266
69	1,877,379[1]	118
70	3,419,264[1]	620
71	209,448[1]	90
72	1,335,000[1]	870
73	1,665,760[1]	410
74	240,600[1]	80
75	177,000	
76	423,520[1]	235
77	7,614,545	815
78	6,961,644	1,000
79	324,000	720
80	3,155,000	120
81	1,246,735	123
82	3,674,432	740
83	1,700,000[1]	1,045

[1]Oil wells

These pressures in a number of wells do not indicate the maximum pressures, as it was not always possible on account of the condition of the wells to completely shut them in.

The following is a typical analysis[1] of the general storage crude oil of the Stony Creek field.

Sp. gravity at 60° F.	0·8388
Bé. at 60° F. A.P.I.	37·2
Closed flash point	Ordinary temperature
Cold test	50° to 60° F.
Viscosity at 70° F.	277 seconds
Viscosity at 100° F.	97 seconds
Sulphur	Traces to 0·08 per cent
Nitrogen	0·2 per cent
Colour	Green to dark green

OIL PROSPECTS OF LAKE AINSLIE AREA, CAPE BRETON

By G. W. H. Norman

INTRODUCTION

Lake Ainslie area (*See* Figure 20) is in Inverness county, Cape Breton. The topography presents the characteristic upland and lowland features that are observable elsewhere in Nova Scotia. The uplands range in elevation from 1,000 to 700 feet, and are represented by Mabou mountain and by isolated hills east and south of lake Ainslie. The surface of the uplands is deeply incised by youthful valleys, but that part of the original surface that remains is moderately undulating.

The uplands are demarcated from the lowlands by distinct, scarp-like borders. The lowland surface has been moulded by erosion into mature valleys and ridges, locally with superimposed youthful features.

The uplands are underlain by metamorphic and igneous rocks, whereas the intervening lowland has been developed on Carboniferous sedimentary rocks forming a geosynclinal structure with minor anticlinal and synclinal folds, trending principally in a general northeasterly direction. The minor folds have controlled the drainage. The softer rocks are preserved in synclinal valleys and basins; the harder rocks stand out in anticlinal ridges and domes.

HISTORY OF DRILLING OPERATIONS

Indications of petroleum on the western shores of lake Ainslie have been noted since the middle of the last century and although considerable drilling has been executed the results have been invariably disappointing.

Reliable details of the results obtained by borings put down through the Lower Carboniferous Horton sandstones and shales on the west side of lake Ainslie have not been preserved, Meagre information, much of it contradictory in nature, can be obtained from several of the Nova Scotia Department of Mines reports and also from some of the Annual Reports of the Geological Survey, Canada.

[1]Supplied by Mr. Findlater, New Brunswick Gas and Oilfields, Ltd.

Shortly after 1864[1] two holes were put down to depths of, respectively, 650 and 900 feet on McIsaac farm on the west side of lake Ainslie $1\frac{1}{2}$ miles south of Hay river. The second hole gave the best results, yielding, it is said, nearly 100 gallons of oil after boring activities had ceased for a few days.

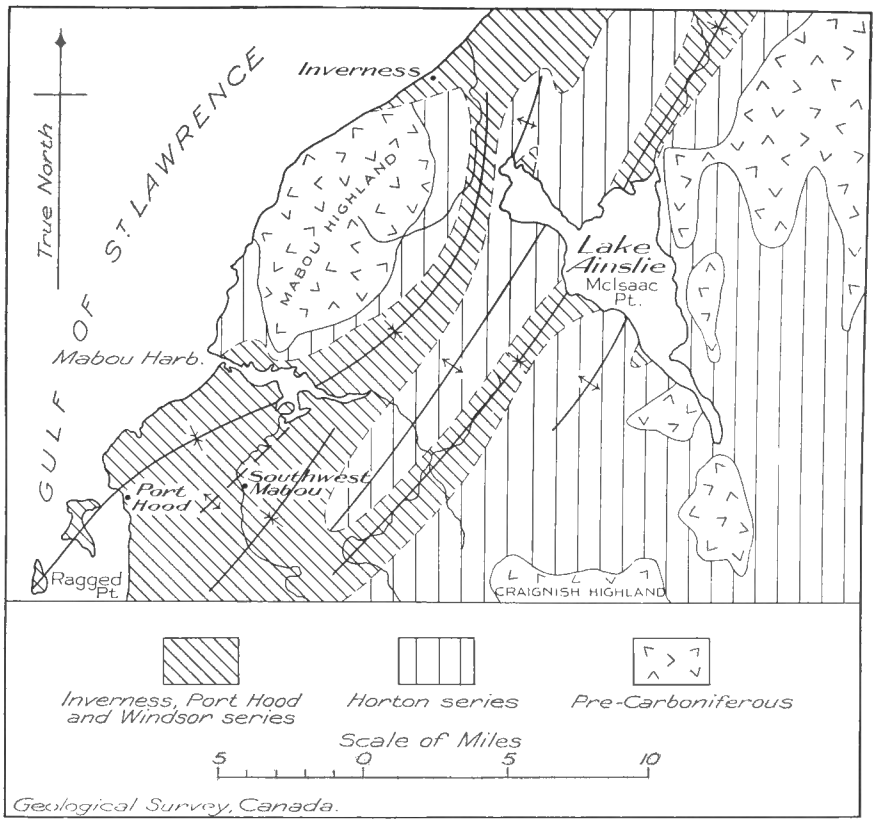

Figure 20. Diagrammatic geological index map of Lake Ainslie district, Cape Breton island.

During 1879-1880[2] interest in the field revived. Numerous companies were organized and an active program of drilling ensued. Seven holes were put down on the west shore of lake Ainslie, one of which, bored by the Cape Breton Oil and Mining Company, reached a depth of 1,100 feet. The account of the results of the borings may be given verbatim from the provincial report which states "Considerable quantities of oil have been secured and barrelled for testing in the states. At present the quantity of salt water in the strata has caused delay and necessitated fresh pumping appliances. The oil is stated to give the following results: gravity 22·5; flash test 390 degrees; fire test 440 degrees; it was found to be limpid at

[1]Nova Scotia Dept. of Mines Rept., 1874, p. 59; 1880, p. 17.
[2]Nova Scotia Dept. of Mines Rept., 1880, p. 17.

zero, and in a crude state to be equal to any manufactured lubricant." A sufficient quantity of oil to make these enterprises commercially successful was evidently not obtained and the drilling operations ceased.

Dr. I. C. White[1] paid a visit to Cape Breton in 1897. He noted the presence of petroleum-bearing strata, but believed that the surface showings did not promise the presence of commercial pools of oil.

In 1898[2] a bore-hole 2,240 feet deep was put down on the west side of lake Ainslie. In this salt water was encountered at 1,600 feet, but apparently no indications of oil were found.

Two holes, respectively, 3,260 feet and 1,100 feet deep, were put down in 1902,[3] the former at lake Ainslie and the other at Skye Glen to the southwest of the lake. No oil or gas indications were obtained.

Further unsuccessful boring was carried on during the years 1912, 1913, and 1914[4] immediately north of lake Ainslie in the vicinity of Dunbar brook.

The prospect of commercial pools of petroleum in the Maritime Provinces again attracted popular attention in 1924. Dr. DeLaat[5] for the Eastern Gulf Oil Corporation paid a hasty visit to Cape Breton during this year and suggested a detailed examination of Lake Ainslie area. This work was carried out in 1925 by Dr. Kirtley F. Mather and Dr. Parker D. Trask who advised the use of drills to obtain additional information regarding the structure.[6] Drills were, therefore, employed, during the years 1926 and 1927, to test the faulted anticlinal structure which extends northeastwards from Ragged point on the coast south of Port Hood across Southwest Mabou river towards Mabou harbour. A dozen or more holes were put down in the vicinity of Southwest Mabou post office, through steeply dipping, gypsiferous strata of Mississippian age.

The gypsiferous strata form an incompetent series between two competent series of sandstone and shale. They have yielded more readily than the competent members and locally exhibit most complex structures, due to closely compressed, overturned folds and considerable faulting. The complexity of some of these structures is such that they are exceedingly difficult to interpret even where completely exposed in continuous surface outcrops. The cores of the bore-holes mentioned above penetrated steeply dipping, gypsiferous strata devoid of recognizable horizons that would aid in interpreting the structure. They, therefore, yielded information regarding the nature of the underlying rock only, and furnished no key whatever either to the true thickness of the beds or to their structure. These test-holes do not furnish any information regarding the petroleum possibilities of the anticlinal structure across which they were situated, as no hole reached the Horton strata below, in which the oil at lake Ainslie occurs. They show that Windsor strata are present along the crest of the anticline and to a depth of 900 feet.

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[1]Geol. Surv., Canada, Ann. Rept., vol. X, pt. A, p. 103 (1899).
[2]Nova Scotia Dept. of Mines Report, 1898, p. 26.
[3]Geol. Surv., Canada, Ann. Rept., vol. XV, pt. A, p. 393 (1907).
[4]Nova Scotia Dept. of Mines Report, 1928, p. 267.
[5]Nova Scotia Dept. of Mines Report, 1928, p. 265.
[6]Nova Scotia Dept. of Mines Rept., 1928, pp. 263-300.

The following table presents the main subdivisions into which the rocks of Ainslie area may be grouped. The thicknesses are approximate only and are estimated from traverses made of stream and coast sections.

Middle Pennsylvanian	Inverness series		Massive, brown sandstone and arkose; grey shale; coal: 3,000± feet
Lower Pennsylvanian	Port Hood series	Upper group	Massive, brown sandstone; grey shale; coal: 4,000± feet
		Lower group	Grey to red sandstone and shale, with a few limestone beds: 3,000 ± feet
Upper Mississippian	Windsor series		Red shale and sandstone; gypsum and anhydrite; limestone: 2,000± feet
Lower Mississippian	Horton series		Grey to red sandstone, shale, conglomerate, and arkose: 5,700 ± feet
Pre-Carboniferous			Volcanic tuffs and flows; granite, diorite; schist; limestone, quartzite

The Carboniferous strata form a major geosynclinal structure whose central axis extends from Judique on the west coast of Cape Breton across the centre of Lake Ainslie area to Margaree harbour on the northwest coast. The structure is bounded on the southeast by a long ridge of pre-Carboniferous rocks in Craignish hills and Northern Tableland and on the northwest by the similar rocks of Mabou mountain.

Details regarding the stratigraphy of the Carboniferous formations have been given by Bell[1] and it need only be mentioned here that with the exception of the Windsor strata, which are probably marine, the Carboniferous sedimentation took place under continental conditions.

Indications of the presence of petroleum are found on the north and west sides of lake Ainslie at the contact of the strata of the Windsor and Horton series. The lowest member of the Windsor strata is a grey, finely laminated limestone and it is in contact with massive, brown sandstone at McIsaac point on the west side of lake Ainslie. The brown colour of this sandstone is due to petroleum residues and the rock when heated over a fire yields hydrocarbon vapours. In the neighbourhood of this point globules of petroleum have been observed rising to the surface of the lake. These indications of petroleum suggested the presence of possible reservoirs in the underlying Horton strata and initiated the drilling west of lake Ainslie.

The continental sedimentation that resulted in the deposition of the Horton series favoured the preservation of but little organic material, though locally, very impure coal horizons containing fragmental plant material are intercalated with the sandstone. The shale members are very sparingly fossiliferous and contain only a few plant seeds and fish scales. The source of the oil in the Horton strata is unknown. There seems little doubt, however, that petroleum source rocks are present,

[1]Bell, W. A.· Geol. Surv., Canada. Sum. Rept. 1926, pt. C, pp. 100-109

but whether they are of sufficient magnitude to furnish oil in commercial quantity can only be determined by drilling on a suitable structure. The structures west of lake Ainslie, which were tested during the last century, are not favourable for the preservation of such oil as may have existed. The absence of cap rocks here would have permitted the oil to ascend to the present surface and become dissipated.

The Windsor strata are predominantly composed of red, calcareous sandstones, with interbedded gypsum, anhydrite, and limestone. Traces of bituminous material are frequently encountered in the gypsum and limestone, but are not of a promising nature.

The basal, laminated limestone of the Windsor strata is capped by impervious clays and because of its fissile character forms an excellent water-bearing horizon, a fact that is indicated by the frequent presence of strong springs at its surface outcrops. Since the indications of oil about lake Ainslie are usually associated with this limestone, the water circulation probably aided the migration of oil to the surface. The impervious clays overlying this limestone no doubt were also a factor in this migration.

The association of oil with the Horton strata and with the basal member of the Windsor group suggests that should anticlinal structures exist where these rocks are buried at depth, a reservoir of oil might occur there. In Lake Ainslie area no such simple, anticlinal structures exist. One structure, which may so incline and seal the oil-bearing strata, extends from Ragged point south of Port Hood in a northeasterly direction for 7 miles towards Mabou Harbour. As interpreted from surface outcrops the structure begins as an anticline at Mabou Harbour and merges into a fault or a series of faults extending southwest from Southwest Mabou post office. Upper Windsor strata are exposed along the axis of this structure and are flanked by Pennsylvanian rocks. Test-holes varying in depth to as much as 900 feet were put down across the structure at Southwest Mabou post office by the Eastern Gulf Oil Company. None of these holes reached the base of the Windsor beds.

In order to test thoroughly the structure a hole should be put down on the east side of Southwest Mabou river about 1,500 feet northwest of the steel bridge at Southwest Mabou post office. Because of the complexity of the structure it is impossible to estimate the depth at which the Horton strata would be reached. The Windsor strata are approximately 2,000 feet thick. At Southwest Mabou the upper beds appear to be cut out by faulting, but those present may be duplicated by overturned folding and faulting.

There is no assurance that this structure would yield a commercial supply of oil, or at what depth the oil, if present, would be found. Several important factors should be considered. It is known that petroleum source rocks occur in the vicinity of lake Ainslie as evidenced by oil seepages, and the records of previous drilling. Although their character and position are unproved, they probably occur in the Horton rather than in the Windsor series. This belief is based on two facts, namely, that impervious clays are present at the base of the Windsor series and it is below these

impervious beds that the brown, petroliferous sandstone at lake Ainslie occurs, and that oil was actually obtained by drilling into the Horton strata. On the other hand, the varied character of the Horton continental sedimentation renders improbable any great lateral extension of any particular horizon, and, therefore, any petroleum source rocks present at lake Ainslie may be either thicker or thinner at Southwest Mabou which is 12 miles distant. Again, since a disconformity exists between the Horton and Windsor strata and since this disconformity appears to merge into an unconformity as the old pre-Carboniferous axes are approached, it is probable that the Horton strata are thicker at Southwest Mabou than at lake Ainslie and, therefore, the position of any particular horizon in the Horton strata relative to the base of the Windsor series cannot be predicted.