XII.—*The Petroleum Field of Ontario.*

By ROBERT BELL, B. A. Sc., M. D., LL. D.

(Read May 27, 1887.)

The recent discoveries of natural gas and petroleum, by boring artesian wells in north-western Ohio and in western Pennsylvania, have given a new importance to the study of certain geological questions in connection with these products. In addition to the comfort and convenience arising from a cheap and abundant supply of natural gas for domestic purposes, the economy in power which it affords for manufactures gives such an advantage to the towns fortunate enough to possess it, that others cannot compete with them; and thus population and wealth are drawn to the sources of natural gas. A comparison of the Ohio gas and oil region with the petroleum field of Ontario, will, therefore, be interesting at the present time, in order that we may the better understand and generalise on what has been accomplished up to the present time, and be in a position to reap the benefits of the experience both of our neighbours and ourselves. The writer has endeavoured, in the following pages, to bring together and compare some facts and observations which may throw additional light on the subject. The present paper will also contain the latest statistics and other information in regard to the present condition of the petroleum industry of Ontario, including the methods employed in the production and refining of the oil. For the information of those not familiar with the history of the subject, it will be necessary first to notice, very briefly, the discovery of petroleum in Ontario, and the progress of its economic development.

More than forty years ago, the occurrence of petroleum in Western Canada and in the Gaspé Peninsula, was described in the early reports of the Geological Survey of the provinces, and specimens of the oil, still in its Museum, were collected in both these regions by the late Sir William Logan. Although at that time no use for the substance was known in Canada, except as a supposed remedy for rheumatism and for spavin in horses, Sir William, with characteristic sagacity, foresaw that it might some day become of value in this country, as it had long ago proved to be in the East. About the beginning of 1860, following the introduction into the province of illuminating oils distilled from coal and shale, and when attention was recalled to the existence of natural oil and "gum-beds" in the county of Lambton, in the west, and in Gaspé in the east, some gentlemen visited our provincial geologist at Montreal for the purpose of obtaining information on the subject. Before entering on a discussion of the matter, Sir William took them to the show-case containing bottles of the dark fluid from both of the above regions and said, "Gentlemen, I have been waiting for you for the last twenty years," and then proceeded to give them the benefit of his knowledge of a matter with which he was, even then, quite familiar, but which was new to almost everyone else in this country.

The petroleum field of Ontario may be described, in a general way, as situated near the south-western extremity of the province, and on rocks of Devonian age, overlaid by a considerable thickness of drift. The "gum-beds," above referred to, are situated on the level and wet clayey land in the southern part of the township of Enniskillen and in the northern range of Dawn adjoining; and in 1860 some oil was obtained by digging wells in the clay at this locality—one of them sunk by Mr. James M. Williams, of Hamilton, reaching the rock. On February 19th, 1861, W. James Shaw astonished the country by striking "rock-oil" in an artesian well which he sank in the shales and limestones beneath the drift clay at this place, to which the name of "Oil Springs" was now given, and which soon became a large village. It was here that the great flowing wells were struck in the winter of 1860-61. The oil then escaped so rapidly that many thousands of barrels were lost before it could be controlled or the means provided for saving it. When the writer visited the locality in the spring of 1862, 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 neighborhood. The drift clay is here from seventy to eighty-five feet in thickness, and is followed by 170 to 185 feet of soft bluish drab shale or marl, the "soapstone" of the drillers. This is succeeded by the Corniferous limestone, into which the wells were sunk only about ten feet, or to a total depth of 260 feet from the surface, where the best flow of oil was obtained. In 1886-87, many pumping wells were producing oil at a depth of about 100 feet below this level.

Soon after the discovery of petroleum in the underlying solid rock at Oil Springs, wells were sunk a little to the north of the centre of Enniskillen, where surface indications of oil had been observed. A considerable number of them proved to be flowing wells, and they afforded large quantities of petroleum for several months, but one by one, they were all at length reduced to pumping wells; and as the number of borings increased, the average yield of each diminished, or the wells gave out altogether. Since that time, however, the total quantity of oil produced each year has been kept up or increased by constantly sinking larger numbers of new wells, the process of well-boring and pumping having been greatly simplified and cheapened.

The Corniferous limestone, having been supposed to be the oil-bearing stratum in Enniskillen, and the same formation being found to contain petroleum in its cavities in various parts of south-western Ontario, boring for oil in these rocks was soon commenced at random in numerous localities underlaid by this formation before the distribution or mode of occurrence of the fluid was known to be governed by any law. These efforts resulted in finding petroleum in small quantities in widely separated places, as well as in the more productive amounts which were discovered at Bothwell, twenty-three miles south-east of Petrolia; in Oxford, east of London; and near Tilsonburg in Dereham, in the country between London and Long Point. The general want of ultimate success of these enterprises, except in Enniskillen, and the low price of oil, soon confined operations to that township. By degrees the area of the petroleum field came to be pretty accurately defined. Before this had been accomplished, all sorts of theories had been indulged in as to the course which the supposed "oil-bearing belt" should take, and later as to the form and extent of the productive territory. Meantime, the mode of occurrence of petroleum and its relations to geological structure were being investigated elsewhere.

The anticlinal theory in connection 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. He was then in the habit of comparing the filling of a soda-water bottle with gas and water to the process which he believed went on under the impervious strata of an anticlinal. But this idea seems to have originated with his colleague, Dr. T. Sterry Hunt, who mentioned it in a lecture delivered in Montreal and published in the *Gazette* of that city on March 1st, 1861. According to this hypothesis, gas and oil, following hydrostatic laws, accumulate at the highest points, or the domes, along anticlinal folds. All the transverse joints and fissures, and the spaces or channels between beds in deep-seated, unaltered, sedimentary rocks, are believed to be filled with water. The particles of gas and oil, as they are generated or become liberated in bitumeniferous rocks, naturally tend to rise through these waters aided, perhaps, by earth-tremors and earthquake jars and shocks, such as are common in Canada and the northern United States. Downward projections and irregularities in the forms of the water-spaces would arrest the gas and oil till these receptacles became filled to overflowing. Ultimately the lighter fluids from all points, following upward the slopes of the strata, would accumulate in largest quantity under the summit of the dome. The gas would take the highest place, the oil the next, while the water would be forced downward to an extent which would counterbalance the elastic force of the gas and the weight of the accumulated petroleum. The compressed gas would force back the oil and water alike from all the upper spaces. If the crown of such an anticlinal dome were tapped by a bore-hole from above, the gas would, of course, escape first, followed by the oil, and then by the water. This is what actually takes place in productive oil regions, and experience in Canada, the United States, Galicia, Baku, Burma, etc., has shewn that the accumulations of petroleum are connected with anticlinals in the manner just described. The more extensive the anticlinal, as to either breadth or depth, the greater are the quantities of gas and oil which become collected, as the result of what may be called the larger drainage area. Profitable supplies of petroleum and gas are, therefore, not to be looked for on anticlinals of small extent. We know, from analyses of average samples, the approximate amount of oil which hydrocarbons in a given weight or bulk of rock are capable of yielding by artificial means, but even the most moderate of these calculations shew a proportion of oil and gas, far in excess of that which has ever been taken from the richest areas in productive fields; and it must be remembered, too, that most of this has, no doubt, been originally derived from other areas at greater or less distances from those actually drawn upon. It is evident, therefore, that only a small proportion of the hydrocarbons actually present in petroleum-bearing strata ever become converted into the liquid or gaseous form by natural processes. As already stated, experience has proved the correctness of the anticlinal theory in regard to petroleum and gas; and this fact has become useful, not only to point out probable localities for their occurrence, but also to indicate large areas in which, from the attitude of the beds, it would be useless to look for them, although they may be constantly forming in the strata, the unfavorable indications for their accumulation being altogether due to geological structure.

An essential condition for the retention of the petroleum in the situations which have been described, is that the reservoir must be covered by an impervious stratum, such as a considerable thickness of shales, clays or marls to hold them down. When this is not the case, or where the anticlinal fold has been too sharp and has become fissured,

vast quantities of gas and oil have in many instances escaped to the surface, or have saturated the higher porous strata, as, for example, the remarkable and very extensive petroleum-bearing sand-beds of the Athabasca district, in the Northwest Territories of Canada.

Another necessary feature for a productive oil-field is a sufficient body of porous or fissured and channelled rock for storing the accumulated oil. This may be the oil-producing formation itself, or it may be a non-productive rock lying above the source of the oil or below the impervious cap. Sometimes, leading fissures or joints and spaces between beds communicate with a vast number of other fissures or channels, and when one of these, or a branch closely connected with it, happens to be struck by a bore-hole, a great reservoir of the pent-up oil may be freely let out. In the commoner case of small fissures, it is now customary in Enniskillen, when the proper depth has been bored, to explode a torpedo in the bottom of the hole, in order to open new channels for the oil, before attempting to pump at all. The conditions necessary for a productive oil-field are, therefore: (1) An anticlinal or a dome-like structure on a large scale, in unaltered sedimentary strata; (2) Deeply-seated petroleum-forming rocks of considerable volume; (3) A stratum of porous, fissured or channelled rock, which may be either coincident with or above the oil-producing beds, sufficiently thick to store the petroleum; (4) An impervious layer of argillaceous rock to prevent its escape.

It is not to be supposed that petroleum may be found at all points along anticlinals over oil-producing strata, even where the conditions are favorable for sealing it down. In addition to the main anticlinal line, there must be a secondary upheaval, so as to produce a dome or an elevation, at the crown of which the oil may gather and rest. The process by which petroleum is thus concentrated may be compared to a reversal of the drainage of streams of water into a central basin or pond, the attitude of the petroleum basin being inverted, owing to the difference in the specific gravities of the fluids. On the map of a country, therefore, the forms of oil-producing areas are found not to follow long lines, but to occur in isolated areas, or to be "spotty," as this mode of distribution is called by the well-drillers.

The oil wells at present worked in the township of Enniskillen belong to two distinct areas of permanently productive territory. That of Oil Springs is of small extent, and lies between the village of the same name and the south line of the township. The once celebrated "Hendricks Spouting-well" is just across this boundary line, in the township of Dawn, but it is a little outside of the area which has proved to be continuously productive for twenty-seven years. The oil field of Petrolia begins a little to the south-east of the centre of Enniskillen, and extends in a west-north-westerly course, taking in the north-east corner of Moore, nearly to the centre of Sarnia Township, a distance of twelve to thirteen miles, with a breadth of between two and three miles. The central belt of this area, one mile or less in width, is the most productive. A third oil-bearing area has lately been found a little to the north-west of the centre of the township of Euphemia. The first well in this "territory" was put down about July 1st, 1886, and up to November 1st of that year, nearly twenty wells had been sunk, but only four were in operation at the latter date, when about 1,000 barrels of oil had been produced. The petroleum is here found at a depth of 255 feet from the surface, in what is called the "upper show," which will be again referred to. The Euphemia and Oil Springs areas lie in a straight line,

running west-north-west, or parallel to the longer axis of the Petrolia area, but the general bearing of all these together would be north-west and south-east, or in the direction of the Bothwell area already alluded to.

The petroleum of the Enniskillen region was early conceived by Logan and Hunt to occur on the course of the great Cincinnati anticlinal, which was, however, thought to be connected with the anticlinal of the head of Lake Ontario; and, following up this view, maps were published, and much was written by others, tracing the supposed position of the anticlinal, and shewing where oil might be looked for along its course. In the "Geology of Canada" (p. 379) Sir William Logan says: "The general course of the main anticlinal can be readily traced by means of the distribution of the formations. It would appear that the crown of the arch runs in a gentle curve from the western extremity of Lake Ontario by Woodstock, in the neighbourhood of which the base of the Corniferous folds over it. Proceeding thence by the Thames in the general course of the Great Western Railway, it would reach the town of Chatham, and then pass to Pigeon Bay, on Lake Erie. The springs of Enniskillen would appear to lie north of this axis, and they may probably be on a subordinate one, parallel with it; which may be connected with the undulation that has been already mentioned as affecting the outcrop of the Guelph formation at Rockwood." It is stated ("Geology," p. 363), that "a belt of higher Devonian rocks crosses the country from Lake Huron to Lake Erie, and divides the region into two areas. These newer strata occupy a saddle-shaped depression on the great Cincinnati anticlinal, which runs nearly east and west through the peninsula; while the course of this depression or synclinal is nearly north and south from Plympton on Lake Huron to Orford on Lake Erie."

There seems to be no doubt that the occurrence of petroleum in Enniskillen is connected with the Cincinnati anticlinal, but the writer, after having done a considerable amount of geological work in Western Canada at various times since 1859, and having carefully studied the question, has come to the conclusion that this anticlinal, coming up from Ohio, does not run eastward, as Logan supposed, into Lake Ontario, but that it maintains its northward course, and runs into the southern extremity of Lake Huron. This geological axis is not marked by a conspicuously visible fold in the strata, as in narrower and sharper anticlinals, but it nevertheless constitutes a remarkable feature in the geology of North America. Southward of Lake Erie, in the form of a long, wide swell, it is plainly traceable by the geological distribution of the formations through Ohio and Kentucky, and again, in Tennessee and even in Northern Alabama. It separates the Pennsylvania from the Illinois and Michigan coal fields. Northward of Lake Erie, an impartial study of what is actually known of the geographical structure, as well as of the distribution of the formations, indicates that its axis, after crossing the lake, continues on, as we should naturally expect it would, in the same general north-north-eastward bearing through the counties of Essex, Bothwell and Lambton, from about Little's Point on Lake Erie, to about Kettle Point on Lake Huron, from which it probably continues in the same course under the latter lake, and parallel to its eastern shore, to a point opposite Southampton, where, turning a little more to the north-east, it would cross the Indian Peninsula parallel to another anticlinal, that seems to run through Saginaw Bay and the gap between the extremity of this peninsula and Grand Manitoulin Island.

Following the line of axis above indicated, northward from Kentucky, where the

Trenton limestone forms the surface, the different geological formations become successively more and more deeply buried as they fold over this line, one after another, each forming a long curve or "nose" to the north. Judging by the records of the borings, the northern point of the Niagara formation, where it curves round this axis, may touch the north shore of Lake Erie, while the Onondaga formation probably occupies a great part of the county of Essex, and is in turn followed by the Corniferous, Hamilton, and the Portage and Chemung, in Lambton. Northward of Plympton and Bosanquet the axis of the anticlinal gradually rises, and in following it on in the same direction, the order of the reappearance of the formations in succession along it becomes, of course, the reverse of what it had been to the south of that region, and we get the Corniferous in the county of Huron, followed by the Onondaga, Guelph and Niagara in that of Bruce. The south-west course of the Onondaga formation, on the east side of Lake Huron, first pointed out by the writer in 1861, proves the existence of an anticlinal to the west under the lake. Owing to the existence of the synclinal or belt of higher Devonian rocks, which Sir William describes as crossing the country in a nearly north and south course from Lake Huron to Lake Erie, shewing that the strike is really in that direction, it would necessarily follow, from structural considerations, that there must be an accompanying anticlinal to the west of it, and we have just seen that this brings to the surface the older Devonian rocks under the drift in the Enniskillen region, and that it is, in fact, the Cincinnati anticlinal.

Prof. Edward Orton, State Geologist of Ohio, has published a valuable report on the recent discoveries of petroleum and inflammable gas in the north-western part of that State. He thinks the Trenton limestone received its low arched form along the Cincinnati anticlinal in that region before the next formation was deposited upon it, which would indicate extensive movement at a very early geological time. He says: "There is a smaller measure for these shales by 200 feet in the central region than there is immediately to the eastward. In other words, there is an arch in the underlying Trenton, revealed by the drillers, of which no hint whatever could be obtained by the surface exposures" (p. 29). A further upward movement of the anticlinal may have taken place in Ontario after the formation of the Corniferous limestone, and before the deposition of the Hamilton shales upon it, for in certain parts we find the Marcellus shale eastward and westward of the axis, but not directly upon it.

The Onondaga formation is shewn by borings to carry important beds of salt near its base, and to be greatly augmented in volume in Western Ontario along a belt to the east of the anticlinal, and apparently parallel to its axis, all the way from the county of Huron to Essex; and it is possible that the shallow sea or bay in which these deposits took place had the same general drection, and that it was held in position by the arched form of the older strata, the successive beds of salt being formed as slight changes in the sea level took place from time to time. Beds of salt of considerable thickness are found again westward of the axis, along St. Clair River.

The cause which produced the Cincinnati anticlinal must have begun at a very early geological period, and appears to have been of continental extent. It is worthy of notice in this connection that, if its general course were prolonged northward in the vast regions of the more ancient rocks, it would pass through the central and clearly volcanic portion of the great Huronian trough of the Abittibi region, and further on would follow

the deepest and longest part of the immense physical and geological depression of Hudson Bay and Fox Channel. The line would next pass through an elongated Silurian area in the midst of the Archæan, and thence by Smith Strait, Kennedy and Robeson Channels, or the direct chain of waters followed by explorers to the most northern points which have ever been reached by man. The long chain of volcanic islands in the eastern part of Hudson Bay lies directly along this line, and the existence of immense north and south dykes of trap for a great distance south of James Bay, was pointed out in my report for 1875. Great north and south masses of trap occur on this line around Lake Temagami; and at the mouth of French River which is also on its course, I am informed by Commander Boulton, R.N., that there is a large abnormal deviation of the compass. The line above indicated measures thousands of miles in length, and, as will be observed, it is almost straight. The fact, that the axis of the Cincinnati anticlinal lies in direct continuation of this long chain of geological and geographical features, is probably more than a chance coincidence, as the latter may well be supposed to have constituted a line of weakness which would be effected by any east and west movement or force in the crust of the earth, and slight, but persistent, elevations of the Palæozoic strata south of the Archæan area may have easily taken place along its course, and these disturbances may have occurred at different geological periods, as some of the above mentioned facts would seem to indicate.

Leaving the subject of the cause and general course of the Cincinnati anticlinal, some practical results may be obtained by a study of the peculiarities or details of this great arch. The trend of its crown varies locally, of course, but the geological distribution of the formations at the surface shew that this axis, coming northward from Kentucky an passing under the town of Findlay, would strike the south shore of Lake Erie about midway between Toledo and Port Clinton; but in this vicinity the general wave is divided by a small synclinal into two subordinate anticlinals. Professor Orton has shewn, by the result of borings, that the form of the Trenton area in north-western Ohio, as indicated by a horizontal plane at 500 feet below the sea level, would prove that the axis at that depth points directly towards Toledo. Notwithstanding the difference in the courses of the deeply seated and surface folds, the main axis of the anticlinal will intersect the north shore of Lake Erie in the vicinity of Little's Point, in the county of Essex; then running about north-north-east through Essex, Bothwell and Lambton, it will reach the southern shore of Lake Huron near Kettle Point. Its general bearing from Lake Erie to Lake Huron is about N. 30° E., but it appears to curve gently to the south-east of a straight line and to pass under Petrolia.

South of the edge of the Archæan nucleus, which forms the north shore of Lake Huron and Georgian Bay, the axes of the numerous anticlinals in the Palæozoic strata run south and south-west and their average course corresponds with that of the Cincinnati anticlinal, but as we recede from the outcrop of the ancient rocks, and the newer strata deepen over them, the inequalities in the old foundation become covered up and more and more obliterated, and smaller undulations running in other directions manifest themselves. The Cincinnati anticlinal in south-western Ontario, as elsewhere, is a gentle swell of great breadth, but within its general area, and especially near the summit, are minor anticlinals, sometimes of a sharper form, running both parallel with and transverse to its general course. One of these secondary anticlinals, having the former course, is shewn to

exist in Euphemia, both by the dip and distribution of the rocks. At Smith's Mills, in this township, it interrupts the overlying Portage group, and brings to the surface the limestones of the Hamilton formation, with a north-westward dip of 40 or 45 feet to the mile. (Report of Mr. Alex. Murray for 1850, p. 29). Between this undulation and the main axis in Enniskillen, about 150 feet of the black Marcellus shales have lately been found by borings in a trough between the two anticlinals, in the north-eastern part of Dawn. In the Ontario oil-field, the drillers consider it a bad sign to strike these black shales, as experience has taught them that, in such cases, no oil is to be found in the underlying Corniferous limestone, the reason apparently being that these shales occupy only the synclinals in the oil-bearing formation.

The transverse undulations appear to follow two principal courses, one about east and west, and the other north-westward. The anticlinal of the head of Lake Ontario, and the sharper one of Rockwood and others further north, are examples of the former. In northern Ohio the formations dip northward at very low angles along the line of the Cincinnati anticlinal, but a transverse uplift seems to run east and west through the natural gas field of Lima, for Prof. Orton says (p. 28) that "the surface of the Trenton limestone is approximately at the same level at Van Wert, Lima, and Upper Sandusky, or along an east and west line 60 to 70 miles in length." The great spread of the Corniferous formation in north-eastern Indiana is probably due, in part, to an elevation of the rocks running in this direction from the vicinity of Lima to the south end of Lake Michigan. About latitude 42° the strata strike east and west all the way from the Hudson River to the Mississippi, except where this parallel intersects the Cincinnati anticlinal, and it is somewhat remarkable that west of the Appalachian range the southern boundaries of all the Archæan areas, just above this latitude, lie in an east and west line across the entire continent. These facts are mentioned as having a possible bearing on the formation of east and west anticlinals in the regions under discussion. The course of the oil-producing belt in Enniskillen and Euphemia is probably evidence of the existence of a north-westward undulation in these townships, and the fact that the Bothwell oil-field lies south-east of this region, may be an additional fact pointing in the same direction. An undulation in the Corniferous limestone, running nearly north-west, is to be seen on the 13th lot of the 1st range of Rainham, on the north side of Lake Erie ("Geology of Canada," p. 379). In the vicinity of Milwaukee there are distinct evidences of north-westerly folds in the strata. It may be worthy of note in this connection that if a straight line be drawn at right angles to the centre of the great north-westward curve in the folded strata of the Alleghany Mountains in Pennsylvania, it would have a west-north-west course, and would pass in the vicinity of the Enniskillen oil-field.

From what has been said in regard to the anticlinal theory and the accumulation of petroleum, it follows that the most probable sites for searching for this fluid in the regions just described, are at points where the great anticlinal is intersected by one of the transverse folds whose existence has been indicated. Owing to the depth of the drift and the infrequency of exposure of the underlying rocks, we must depend principally on the "logs" of wells drilled in various parts of the possible oil region for the data to guide us; hence the importance of preserving these records, even if the wells have failed to answer the purposes for which they were originally sunk. These records are also of much value in determining the actual thickness of the Silurian and Devonian formations in western

Ontario, where their increase or decrease goes on at pretty regular rates, so that we are able to predict with tolerable accuracy the depth at which any one of them may be found by boring at a given locality.

Dr. T. Sterry Hunt, in his valuable Report for 1866, has put on record the "logs" of a large number of wells which had been bored up to that time in western Ontario, and which would have been otherwise lost. It is to be regretted that the registers of the still greater numbers of wells which have been sunk since that time, have not been systematically preserved. In regard to general deductions, from information obtained by well-boring, the extensive experience of our neighbors in the analagous regions of Ohio and Michigan, is of great value to us.

The petroleum of the Enniskillen region has hitherto been supposed to have originated in the Corniferous formation, but from circumstances which have lately come to light, it seems possible that it may have its origin, wholly or in part, in the Trenton limestone. Without necessarily adopting this view, the writer may mention the following, among other circumstances which appears to favor it:—

(1). The Trenton limestone along the Cincinnati anticlinal has proved to be eminently an oil-producing formation in north-western Ohio, as well as near Barksville and elsewhere in Cumberland County in Kentucky, where great flowing wells of petroleum were found in boring for brine in 1829. Wells sunk in the same region in later years have yielded large quantities of oil. (Dr. Hunt's Report for 1866, p. 253). This formation is not likely to have lost its oil-producing character within a short distance on passing into Canada. On the contrary, we know that much further to the north it yields petroleum on Manitoulin Island, where the writer has seen wells drilled into it near Wequimakong and at Pike Lake. Petroleum, or pitch resulting from it, are found in this formation in other parts of the Dominion. At one of these localities near Chicoutimi on the Saguenay, where petroleum exudes from the Trenton limestone, gallons of it have been collected, by breaking open the cavities in the rock. Again, to the west, the Lower Silurian limestones in the vicinity of Chicago, are said to hold petroleum.

(2). The Trenton formation is of a more generally bituminous character than the Corniferous, and it is also much thicker. In various parts of the provinces of Quebec and Ontario it ranges from 600 to 750 feet in thickness, including the Black River and Birdseye, but not the Utica; and at Findlay in Ohio, the drill has passed through 550 feet of it. (Prof. Orton's Report, p. 18.)

(3). In the States of New York and Ohio, the Corniferous is not a petroleum-bearing formation. Although oil has been observed in its cavities in some places in the south-western part of Ontario, there is nothing to show that it was originally formed in these rocks. Its thickness in western New York is only ninety feet, but in the townships of Woodhouse and Townsend in Ontario, seventy miles west of Niagara River, it has attained 160 feet. In Ohio, its thickness is from 75 to 175 feet, and at Mackinaw, in the northern part of Michigan, it is 275 feet. In south-western Ontario, well-borings have given the following thickness for limestones believed to represent the Corniferous: Port Lambton, 320 feet; Petrolia, 248 and 378; one mile south-west of Belle River, 209; Leamington, 310; but it is difficult in all cases to draw a line between the limestones of this formation and those of the underlying Lower Helderberg or upper part of the Onondaga (salt) formation. For example, the following thickness of limestones were obtained in

wells starting on the Corniferous : Test Well at Petrolia, 623 feet; artesian well at London, 1,000 feet; at Comber, 520 feet; at St. Mary's, 500 feet; at Tilsonburg, 854 feet; at Clinton 975 feet. In boring salt wells at Goderich, 775 feet, and at Kincardine, 508 feet of limestone of the Onondaga formation alone, were passed through.

(4). The petroleum of Enniskillen has the same pungent or sulphurous character as that derived from the Trenton limestone of Ohio and Manitoulin Island, and its chemical constitution appears to be identical, as it requires the same peculiarities in the process of refining to deodorise it; whereas petroleums known to originate in Devonian rocks, are of a different character in various respects. Dr. Sterry Hunt, from whose valuable report for 1866, some of the above figures are taken, hinted (on p. 254) at the possible Trenton origin of the petroleum of Oil Springs, although elsewhere he always maintained that its probable source was in the Corniferous limestone. If all the formations are present under Enniskillen, with their probable volumes, and if the writer's estimate of their thickness be correct, the top of the Trenton limestone will lie some 2,600 feet, or half-a-mile, below that of the Corniferous formation. Notwithstanding this considerable depth of the intervening strata, it may have been quite possible for petroleum to have come up from the lower formation and stored itself in the cavities and fissures of the upper one; and indeed it may even now be steadily rising through natural channels from great accumulations remaining in the deeper source, and this may, perhaps, account for the large, long-continued and nearly uniform yield which this small territory has kept up and is still maintaining. But if the Cincinnati anticlinal had been formed in the Trenton in this region before the deposition of the overlying strata, as appears to have been the case under Findlay in Ohio, this formation may lie considerably nearer the surface than has been supposed. A careful comparison of the gas and the bitter saline water which accompany the Enniskillen petroleum with those from the Trenton limestone in Ohio and different parts of Canada, might be of service in helping to determine the question of the original source of the petroleum.

In recent years, no wells have been drilled in the Enniskillen oil field beyond the depth known to give the best return in petroleum, but, in 1878, Mr. J. L. Englehart, with commendable enterprise, sunk a well to a depth of 1,505 feet, on the 12th lot of the 11th concession, about seven-eighths of a mile north of the centre of the town of Petrolia. The last 400 feet were said to consist of gypsum and rock-salt and the 500 feet just above these were stated to be light-colored hard limestone with sandy beds. The strata in this field are so nearly horizontal, and so constant in thickness, that, over considerable areas, the drillers count with certainty on striking the same beds at nearly the same depths. The following is the average descending section in the thousands of wells which have been drilled around Petrolia :—

	Feet.
Stiff blue clay, with stones and some boulders	100
Upper limestone, with a little black shale occasionally at the top	50
Bluish grey and drab shale ("soapstone"), with a few hard layers	120
Middle limestone	15
"Soapstone," with two or three hard beds	40
Lower limestone (Corniferous) in which oil is found at 45 ft. ("upper show") and also ("lower show") at	135
Total from the Surface	460

The Corniferous limestone has a thickness in this vicinity of about 300 feet, but it has

been found by experience that it is seldom worth penetrating more than 135 feet into it. In Sarnia township, the drift clay is 145 feet deep, but the oil is met with at 385 feet from the surface, or only 240 feet in the rock, instead of 360, as at Petrolia, shewing that more of the solid strata had been denuded away in Sarnia than at Petrolia before the clay was deposited.

The wells are bored by tubing the drift deposits, so as to shut off the surface water, when the work of boring in the solid rock is begun—the motive power being a small engine. The drilling apparatus is suspended by wooden rods, which constitute the peculiar, and, it is claimed, a superior feature, of the Canadian method, which is now in universal use in this country. The rods, which are of hard wood, measure 18 feet in length, and two of them fastened together, end to end, make what is called a "length." The lengths are joined to each other by a tapering screw at the one end, fitting into a corresponding threaded socket at the end of the next. They last throughout two or three years of constant use, although unscrewed and screwed together again very frequently. The rods are withdrawn from or lowered into the hole by means of a derrick, and latterly by a tall tripod, erected over the well. Boring for oil has developed into an established trade, and about 100 skilled men are employed in it. The process has become so systematised and cheapened that it costs only about $400, and requires but one week, working day and night, to sink an average well at Petrolia. Mr. W. K. Gibson, an oil merchant, of that town, informed me that 2,392 wells had been in operation at Oil Springs, Petrolia, and in Sarnia Township, in 1885, but that 193 of these had been shut down during the year, leaving 2,199 in operation on December 31st. The writer is indebted to Mr. James Kerr, the obliging secretary of the Petrolia Oil Exchange, for most of the following statistics. He states the number of wells which had been pumped in 1886 at nearly 2,600, and the number of new wells sunk during the year at about 200. Some 500 of the above wells are situated around Oil Springs. For the last few years, the proportion of successful wells to the "dry holes," or those not worth pumping, has been 80 per cent. In the early days of the industry a separate engine was used to pump each well, but now, by an ingenious contrivance of rods and cranks, called "jerkers," 20 to 40, and even 50 wells, are pumped by one engine, and this of much smaller power than would be supposed necessary. In one case, Mr. Englehart worked no fewer than 70 wells with a single engine by this means. The rods, which are small, are made of hard wood, spliced together with iron, and, in order to diminish friction, they are hung from a horizontal wooden rail about four feet from the ground, by means of very light iron suspenders, which swing backward and forward with each stroke of the engine. The direction of the force is changed, whenever required, by means of horizontal cranks. With such economy in the cost of pumping, it has become possible to work profitably wells which yield only small quantities of oil. Indeed, in 1886, the average production per well per day in the Petrolia region was only twenty-three imperial gallons, or not much more than half-a-barrel. The ten largest wells in the district furnished an average of twenty barrels each, of thirty-five imperial gallons, per day. In 1886 the total quantity of crude oil produced in the entire region was 576,000 barrels of the above capacity; and of this amount, Oil Springs contributed 180,000 barrels. At the latter place the yield diminished rapidly from 1860, the time of the discovery of the spouting wells, till 1865, when operations ceased, and nothing was done for sixteen years. But, in 1881, some of the old wells were revived by means of torpedoes; new wells were

drilled in 1882, and operations were again active in 1883, when some 45,000 barrels were produced; in 1884, 130,000, in 1885, 145,000, and in 1886, 180,000 barrels, or a total of 500,000 barrels since the revival.

The drift clay of Petrolia is so impervious that tanks excavated in it and lined with wood are found to be capable of holding the oil, and large quantities of it are stored in this way. These receptacles are circular in plan, and the largest are forty feet in diameter by fifty and sixty in depth, but those of the average size are thirty feet in width by thirty-five feet in depth. They have a total capacity of 600,000 barrels. The largest of them are owned by tanking companies. On November 1st, 1886, ten of them were full, and Mr. W. K. Gibson informed the writer that the aggregate of oil which they then contained was 415,000 barrels. The same gentleman gave me the following as the stocks of oil on hand on December 31st, 1885: in tanks at the wells, 36,000 barrels; in the tanking company's tanks, 373,504 barrels; crude oil and its equivalent at the several refineries, 38,372 barrels, or a total of 447,876 barrels. At 85½ cents per barrel in the tanks, which was the actual mean rate at which crude oil was sold during 1885, this would represent $382,934. The average selling price of the illuminating oil in 1886 was 14½ cents per gallon. Formerly the crude oil was sent to London (Ontario), Sarnia, Montreal, and elsewhere, to be refined, but now the whole of it, except about 5 per cent., is treated at Petrolia, in nine distilleries and refineries. The stills are great elongated cylinders, the largest of them capable of holding from 275 to 300 barrels of petroleum. The six stills at the Producers' Works, when in operation, contain 1,600 barrels, or 266 each. These are arranged side by side, to the number of six to twelve or more, on a brick "bench," so that the fire can reach their whole length beneath. The fuel consists of water and the refuse tar, strongly injected together from a nozzle. Mr. James Kerr, who is thoroughly versed in the chemistry of petroleum, and acts as inspector for the refiners, gave me the average commercial constitutents, per cent., of the crude oil of Petrolia, as follows :—

Naptha	7.72
Burning oil of the Government standard	49.50
Gas oil	14.74
Lubricating or paraffin oil	9.65
Intermediate oil	4.00
Paraffin wax	1.41
Hard coke	3.75
Soft coke and waste	9.23
TOTAL	100.00

During 1886, the average number of pumping engines at work in the district was 75, or one to every 35 wells. They had an average of 18, and a total of 1,350 horse-power. About 30 engines, with an average of 15, or a total of 450 horse-power, were employed in drilling. In addition to these, the refineries, shops, lumber-mills, etc., connected with the oil industry, employed about 50 more engines, with an average of 40 and a total of 2,000 horse power, to say nothing of the locomotive power required on the railways, etc., to transport the products. Large numbers of horses are used in hauling the crude and refined oil, the machinery, lumber, and supplies of all kinds required in the business. The total number of men and boys employed in connection with the oil industry of Enniskillen is about 2,000, and these would represent a population of about 10,000 depen-

dent upon it. The town of Petrolia and its suburbs contain about 6,000 inhabitants. Besides the above, about 200 more men and boys are employed in connection with the refining, etc., of the crude petroleum sent elsewhere; and in a less direct manner, the products of the Ontario oil-field help to swell the general volume of the carrying and other trades of the country. It would be difficult to give a correct estimate of the capital employed in the business, but it must amount to several millions of dollars. The wages of experienced well-borers and distillers are $1.50 to $2.00 per day, while laboring men receive from $1 25 to $1.50. All the operations are carried on by native Canadians, who have, by their own ingenuity, developed each branch of the business to its present perfection, by carefully studying the necessities of the case. This has afforded an excellent mechanical education to a large number of intelligent men, whose services are now sought for in every oil-producing country in the world. We hear of them directing the boring, pumping, storing, and other operations connected with the petroleum business in Galicia, Russia, Afghanistan, Belochistan, India, Burma, California, Australia, etc., where their skill and knowledge are highly appreciated.