The Oil-fields of Eastern Canada.— By R. W. Ells, LL.D., F. R. S. C., Geological Survey of Canada, Ottawa.

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The occurrence of petroleum or rock-oil has been known from a very early date in the world's history. It is referred to frequently in Holy Writ under such names as slime or pitch, in connection with the building of the city of Babylon, the construction of the ark, the preparation of the cradle of Moses, etc. It was found in considerable quantity in the valley of the Dead sea, whence it was transported to Egypt and to the ports on the Mediterranean, where it was extensively employed in ship-building, as well as by the Egyptians and other nations in the embalming of the dead. Many references to this substance are also found in the works of profane writers, more especially of Herodotus, Plutarch, and Josephus; while the ancient sect of Guebers or Fire-worshippers of Persia apparently derived the visible symbol of their religion from the oil-springs and accompanying natural gas of the Baku district, now in southern Russia, but till within the last 200 years a part of the Persian empire; or from similar occurrences in other parts of Persia and in India, in both of which countries the presence of this substance has been known for many centuries. In some places also, as in China and Japan, natural gas, which is frequently an accompaniment of petroleum, has been used for a long period for both heating and lighting purposes.

In certain parts of Europe where petroleum occurs in the form of springs it has long been used medicinally, and has been regarded as a valuable remedy for rheumatism and other kindred diseases. So also in the early history of Canada and the northern States, crude petroleum, under such names as Seneca and British oil, was extensively employed for various

ailments and commanded quite a large price, the material being obtained from the natural springs which are found in western Ontario and southern New York or Pennsylvania adjacent to the south.

Petroleum or rock-oil is in fact a substance of almost world-wide occurrence. It has been found in nearly every country in Europe and Asia; in some of the islands of the Pacific and Indian oceans; in New Zealand and Australia, and in North and South America. It is especially abundant in the United States and in Canada, occurring in many places from the Atlantic to the Pacific. It has been asserted by some authority that in its distribution it is only surpassed by water itself, but whether this statement can be maintained or not, it may safely be said that petroleum in some form is one of the most widely known of mineral substances to-day.

Its wide range in distribution over the earth's surface is only equalled by its extended geological occurrence, since in some one of its many forms it has been found in most of the formations or systems from the earliest Laurentian to the latest Tertiary. The result of the study of this material within the last thirty years has been to do away very largely with the old theory that rock-oil was practically confined to rocks of Devonian and Upper Silurian horizons. In face, some of the largest known deposits at the present day are found in the newest rock-formations, while other very large oil-fields have their location in rocks of Trenton age. In so far as the geological horizons are concerned therefore, it would seem in the present state of our knowledge, to be a difficult matter to predicate just where petroleum or some one of its related substances may or may not be found. A safer test as regards deposits capable of economic development would appear to be connected with the geological conditions which prevail in the special field to be exploited.

Petroleum, in the form of crude oil, is doubtless one of the most important of the bituminous compounds. Several other var-

ieties are, however, found, among which may be mentioned anthraxolite, asphalt, ozokerite, albertite, manjak, etc. Petroleum can also be obtained in large quantities from certain rock formations which abound in bitumen, such as the Utica shales of Ontario and Quebec, the Albert shale of New Brunswick, the stellarite of the coal areas in Pictou, and various other formations found in widely diverse portions of the globe. In a number of cases these formations have been extensively utilized as a source of supply for petroleum, as in the case of the bituminous shales of Scotland, France and elsewhere, while in Canada in the early years of the industry, quite extensive plants were erected in Ontario for the distillation of the Utica shale, and in New Brunswick of the Albert shale deposits. Unfortunately for these industries the discovery of the great reservoirs of crude petroleum in the United States and in western Canada (Ontario) speedily reduced the price of the raw material so that its further extraction from the shales became unprofitable, and this industry was long since abandoned.

The mineral anthraxolite, appears to be to all intents merely a hardened or thickened petroleum, and has been found in rocks as low down as the Laurentian and Huronian, where it occurs in vein form in granitic or associated rocks in Ontario; in slates of lower Cambrian or Huronian age west of Sudbury, at Chelmsford; and in the Black river limestone associated with baryte near Kingston. In Quebec it has been found in veins traversing slate and quartzite of lower Cambrian age in Labrador; and in irregular deposits in slates of the Sillery and Lévis formations near the city of Quebec. It is very probable that future examinations may reveal its presence elsewhere in these old rocks. In some places, as near Chelmsford, the quantity is considerable, and, if sufficiently pure, might be worked, but the large percentage of ash in its composition interferes with its utilization as a suitable fuel for domestic or steam purposes. At one time great hopes were

entertained by certain persons that Ontario had at last obtained a fuel supply peculiarly its own, and it is to be regretted that these expectations have not yet been realized. So also at Quebec it was at one time anticipated that workable deposits might be obtained, the mineral found at this place giving fairly satisfactory results as a fuel. It was, however, found, on attempting development, to be confined to mere strings and pockets of no commercial importance.

The presence of these carbon compounds in rocks of great antiquity would, on the hypothesis that all these substances, including graphite, are of organic origin, carry the life history of the globe to a very remote period. While it is no doubt true that organic remains are found as far back in time as the early Cambrian period, and in some of these older rocks are abundantly displayed, crude petroleum in workable quantity has not yet been found therein. Moreover, the presence of petroleum and its kindred minerals in rocks of igneous origin, such as basalts and various diorites, where there is no indication of sedimentary rocks or traces of organic life opens up another aspect of the question that should receive careful consideration. In this connection it may be stated that petroleum in some of its forms occurs in greenstone and basalt, hornblende rocks, augite, feldspar, etc., at various places both in Europe and America. It is found in the Laurentian, both in Scotland and Canada; in melaphyre at several places; in the granite of Cornwall, England; and in trap rocks both in the province of Quebec at Gaspé, in connection with Devonian slates, and on the west coast of the Queen Charlotte islands in basalts of Tertiary age.

In so far as the petroleum deposits of economic importance occur on this continent it may be said, generally speaking, that in the eastern or Atlantic division these are confined to Silurian, Devonian and Carboniferous rocks, while in the western or Pacific division they belong to formations of Cretaceous and Tertiary age.

The various geological formations in which crude petroleum is found in various parts of the world may be briefly stated. Thus in the Baku district of southern Russia, where probably the largest and most productive wells are situated, the associated rocks are somewhat incoherent sandstones of recent Tertiary age, so incoherent, in fact, that the oil which outflows in immense quantities contains a large percentage of sand which has to be separated after collecting the oil. In India, Burmah, Assam, Beloochistan, Persia, Japan and China, oil is found in workable quantity in rocks of the same general horizon or from some portion of the Tertiary formations, wherever the conditions are favourable to its occurrence. Of these an interesting feature is seen in the oil wells of Beloochistan, where, owing to the disturbed and faulted character of the strata, attempts to obtain the minerals in paying quantities have proved a failure.

In the group of islands comprising Borneo, Java, Sumatra and Timor, as well as in the Phillipines, the oil-bearing rocks are also of Tertiary age, and this is likewise the case with the deposits of New Zealand and of Australia.

In the South American states it occurs in rocks of practically the same horizon, as well as in Mexico and in the islands of Barbados and Trinidad; while along the west coast of United States, from Texas on the south to Alaska on the north, as also in territory bordering the east side of Rocky mountains, in oil-fields of Colorado and in Alberta, the containing formations range from the Cretaceous into the Tertiary. In Canada on the Pacific coast no oil-wells have yet been reported, but traces of oil have recently been found in connection with the Tertiary sandstone and shale of one of the interior coal basins. On the east slope of the mountains, however, borings have been carried on for several years in connection with oil springs which are supposed to issue from Cretaceous rocks, while the great deposits of tar sands which occur along the Athabasca and

upper Peace rivers, in the district north of Edmonton, also belong to the same horizon. The recent flows of natural gas which have been struck at Calgary and at Medicine Hat in the country of the plains, are also from strata of Cretaceous age.

In Europe it is also of interest to note that the oil-wells, in so far as these are at present productive, belong to recent rather than to Palæozic times. Thus in Italy petroleum is found in Tertiary sediments along anticlines which follow generally the trend of the Appennines; in Germany in the Tertiary in part and partly in the underlying Jurassic; while in Great Britain, France, Spain, and Switzerland, in Europe, and in Algeria and Egypt in Africa; it occurs also in rocks pertaining to the Cretaceous and Tertiary formations.

It will be seen, therefore, that in the greatest number of petroleum producing countries the mineral is obtained from formations which are quite recent as regards the geological scale. Coming nearer home, however, we find, as a rule, that petroleum pertains rather to rocks of Palæozoic age. In Canada these have usually been assigned to the Devonian system, since it was long supposed that it was from these formations that the wells derive their flow of oil; but in the United States some of the most productive wells are sunk in formations as far down as the Trenton. On this continent, therefore, there appears to be a marked line of separation as regards the horizon of both coal and petroleum, between the occurrences east of a line defined by the Mississippi river for the United States side of the boundary, and by the eastern edge of the prairie country in Canada which divides the deposits of Palæozoic age on the east from those of Cretaceous and Tertiary age on the west.

In character also petroleum varies greatly in different districts. It ranges from a highly fluid condition and a light colour in some areas, to a thick and exceedingly dark coloured substance in others; the specific gravity of the mineral, according to observations made by Boverton Redwood, having a

proportionally wide range, extending from 0.771 to 1.020. As a rule, the lighter oils yield a larger percentage of kerosene than the heavier grades. Comparing the oils of western Ontario with those from the celebrated wells found in the United States it is found that the Canadian product has a somewhat greater specific gravity, while tests made on the oils taken from the wells in Gaspé during the borings some years ago, gave sometimes a still higher specific gravity. The oils of western Ontario have also a more offensive odor than many of those to the south, due presumably to the presence of sulphur.

In colour, native oils range from a light yellow to a black or brownish-black, and often with shades of green. In regard to density this is measured by what is known as the Baumé scale, in which the lower the grade on Baumé the higher the specific gravity of the oil; thus, 10 degrees Baumé is equivalent to specific gravity 1.000, while 90 Baumé is the equivalent of an oil with specific gravity 0.6363.

Turning now to the consideration of the conditions under which petroleum in economic quantity is usually obtained, it will be observed that the general arrangement of the rock formation is a very important factor, whether the locality be underlaid by rocks of the older or the newer horizons; and this feature is sometimes lost sight of in search for new oil-fields. For not only must the rocks in which the oil is supposed to occur lie in a nearly horizontal attitude, or in the form of low swelling anticlines but the oil itself must be kept in by an impervious covering of shale or some other rock. If in the case of a rock series, which is supposed to carry oil in greater or less amount, this covering is broken or faulted or the rocks, as a whole, are more or less tilted and disturbed, it is probable that the cementing cover is quite unequal to holding down the underlying oil, which will therefore in some way tend to find an outlet to the surface, and will have been lost in ages long since past. It is, therefore, evidently unwise, to say the least,

to waste much time or capital in an attempt to obtain oil in quantity from an area where the rock formations are much disturbed. In several such cases small quantities of petroleum have indeed been obtained, sufficient for the time to lead the explorer to invest additional sums of money, though the final outcome, as might have been expected, has generally been disastrous.

On the hypothesis now generally accepted, oils have originated from the decomposition of animal or vegetable organisms which have been buried during the process of rock formation precisely as we see going along our sea shore at the present day, where shells, seaweeds, fish, etc., are buried by the accession of sands or other materials which are moved by tidal currents or by wind action.

These decomposed organisms, with their resulting carbon contents, were supposed by Dr. T. S. Hunt to be the actual source from which petroleum was derived, and the resulting oil to form a part of the formation in which they are deposited, preferably in limestone, since their remains were easily recognized and were often observed to be highly charged with oily matter in the several strata encountered. He, therefore, contended that petroleum originated from the primary decomposition of organic matter and pertained to the stratum in which the organisms were first laid down. Another school, however, contended that the original source of the petroleum was in some lower stratum, and that the oil resulting from the decomposition of organic matter, as well as the accompanying gases, rose or percolated through underlying sediments till they encountered a non-pervious layer, being assisted in this upward movement by the action of percolating waters at a greater underlying depth.

On this latter theory the oils of the Petrolia district, which may be taken as an example of the general principle, have originated at some lower horizon than that in which they are

now found by boring, and have ascended gradually till they have met the porous dolomite of Devonian age in which they now seem to occur. They were held in place by the overlying cover of grey shales which succeeds the limestone, and which by the drillers is usually called "soapstone", and by this impervious cover, under great pressure, are hermetically sealed till the overlying rock is pierced, when they make their escape to the surface with tremendous force. The strata throughout the Ontario oil district lie in an almost horizontal position or in gentle anticlines so low that the dip of the beds is scarcely perceptible to ordinary measurements.

To go into elaborate details as to causes and effects would, however, swell the present paper to too great lengths. They can be well studied by reference to the excellent report by Dr. Orton on the "Occurrence of Petroleum, etc., in Kentucky," and in other bulletins of a special nature relating to the subject.

While rock-oil and natural gas are widely distributed throughout the Dominion of Canada, and while attempts to work many of these deposits have been made at a number of places from time to time, it is to be regretted that in many cases such efforts have been usually attended with a lack of fruitful results. Much of this unnecessary expenditure could have been avoided had due attention been given to the geological features of the several areas which have been tested.

In so far as boring investigations for oil are concerned in Canada it must be confessed that up to the present the original field in south-west Ontario has been the only one that has given satisfactory results. It is, however, confidently expected that at some future time portions of the great Cretaceous plain east of the Rocky mountains, in which large supplies of natural gas are now being developed, will be found to be also oil-producing; but this is still matter for future investigation. It may, however, be stated that the Pierre shales, in which the oils of the Florence basin in Colorado occur, have an extensive development in the Canadian north-west.

In the Atlantic provinces of Canada explorations for petroleum have been carried on at intervals for many years, in Nova Scotia, New Brunswick and Quebec as well as in Newfoundland. So far only negative results have been obtained, but a study of the several fields in which operations have been conducted will present some features of general interest.

In contrast with the oil-fields of western Ontario or of the eastern States, in both which areas the oil-bearing rocks lie in nearly horizontal layers, either of sandstone, limestone or shale, the rocks of the eastern areas in Canada are more or less disturbed, being thrown into folds with their accompanying faults and dislocations.

Although the island of Newfoundland is not politically a part of Canada, geologically speaking its oil-fields are related and may be considered in this place. Of these there are at present but two in which operations have been carried on, viz., at Port au Port bay, north of St. George's bay, and on the west coast further north, at Parson's pond.

In the article on petroleum published in the Annual Bulletin of the United States Geological Survey, these occurences are assigned to Cambrian rocks. The reason for this is not very clear, for during a visit to the former locality, several years ago, a brief study was made of the district by the writer which led to very different conclusions.

The two principal geological formations found around the shores of Port au Port bay from the Gravels east and west, are 1st., a series of fossiliferous limestones of the Lévis or Calciferous formation, a part of the old Quebec group of Canada, and 2nd., an unconformably overlying series of fossiliferous shales and limestones of Lower Carboniferous and Upper Devonian age, portions of which are faulted down into the Calciferous division which forms prominent ridges along the shores of the bay. Towards the inner end of the long point, on which the borings are situat-

ed, these Carboniferous rocks occupy the shore for some distance and extend for several miles out to the end of the point itself, though concealed in part by peat deposits, in which distance they also appear to include portions of an underlying series of Devonian shales. On the eastern side of the bay, where borings have also been made, the sales and sandstone are again exposed, and include bands of bituminous shale, which exactly resemble certain bands in the Albert shale series of New Brunswick. The shales on both sides of the bay are much disturbed, with numerous faults and dislocations, and in places contain remains of plants. It is in this series of rocks that the oil-wells of Long point have been sunk, as well as those on the east shore already referred to.

While indications of petroleum are seen at several places along the beach in the form of oozings or small springs, and while it was found in small quantity in several of the bore-holes, the amount thus obtained was in all cases unimportant from the economic standpoint, and the geological conditions were such as to warrant the conclusion that the expenditure of further capital in the locality was not advisable. Similar conditions apparently exist at Parson's pond to the north, where the oil-bearing rocks are apparently of the same horizon, judging from the statements published on the work done in that district, and are affected by a like series of folds and breaks as at Port au Port. The results of the borings at this place are apparently quite similar to those already described, the oil occurring in small quantity, while the geological conditions appear to be equally unfavourable as at Long point. The geological horizon of these deposits, therefore, instead of belonging to the Cambrian is assignable to the Devonian or lowest part of the Carboniferous, probably the former.

Crossing the Gulf of St. Lawrence to the Gaspé peninsula, in the province of Quebec, we reach another oil-field which has been known for half a century, and in the exploitation of which

very large sums of money have been spent in a vain attempt to find petroleum in paying quantity. More than fifty years ago Sir William Logan recognized the existence of oil-springs in this district, and they were described in his earliest reports as situated in places sometimes near the shore and sometimes inland. Attempts were made as far back as 1866 by a boring located near one of these springs to find the source from which the outflow was derived, and the boring reached the depth of nearly 700 feet. Here a small quantity of oil was reported, but owing to the loss of the boring tools the hole was abandoned, the occurrence of oil being apparently insufficient to warrant further expenditure at that time. Subsequently the Petroleum Oil Trust began an extensive series of borings in 1889, which were carried on for nearly fifteen years, and in connection with the Canada Petroleum company, an area extending inland for some thirty miles and with a breadth of six to ten miles, was very thoroughly explored by boring, several of the holes being sunk in close proximity to the original location near the spring already referred to. In all, more than fifty holes were bored, some of which reached a depth of over 3700 feet. The results of all these borings have been collected and were given to the public in a report by the writer to the Geological Survey Department in 1902. An interesting fact was disclosed in the several borings made at the original site, in that, though a depth of over 2400 feet was reached no oil was found beyond mere traces; the rocks are highly inclined at this place, and there is probably a line of fault and an anticline in the vicinity.

The rocks of this district belong to the Devonian system, of which a section aggregating 7000 feet is exposed along the eastern Gaspé shore. Generally speaking, these rocks are inclined at high angles, in some places reaching sixty to eighty degrees. Faults are seen at several places, and intrusive dykes of diabase also occur, one of which of large size at Tar point is remarkable for containing petroleum, sometimes as a solid, but

generally in liquid form, disseminated through the igneous rock in drusy cavities, some of which are lined with chalcedony.

The area is also traversed by well defined anticlines, running generally in an east and west direction; and in several places these are affected by fault lines. It is near these lines of fault that most of the oil-springs are situated.

As might be anticipated from a close study of these rocks conditions favourable to the occurrence of oil in quantity are absent, owing, in large part, to their usually highly inclined character and to their broken condition. In fact, the area if it ever contained petroleum in quantity, of which, however, there is no particular indication, would have been deprived of its stores long since by escape along these lines of fracture. Be that as it may, it has been clearly demonstrated by the expenditure of large sums of money and by the sinking of numerous wells to great depths, that with but few exceptions, the rocks passed through are now practically barren as regards oil. In some of the wells it would appear that there is a small amount of oil which finds its way into the bore-holes, probably by seepage from the surrounding strata, which can be obtained by pumping, but in most of the holes bored there was evidently no trace of oil whatever, though from a number water is still flowing freely.

The results obtained in this area, as in Newfoundland, tend to strengthen the theory, already well proved in the western oil-fields, that productive wells in eastern Canada must be sought for in rocks which are comparatively undisturbed, and preferably with low anticlinal dips, and while the records of the wells bored in the Gaspé district show in several cases the occurrence of oil, aggregating an output of some hundred of barrels, the general principle laid down is still maintained.

In the province of Quebec no other occurrences of petroleum are as yet recorded, the bituminous matter found at Lévis in the form of anthraxolite, and in Labrador being excepted.

In the flat country lying east of Lake St. Peter, which is an expansion of the St. Lawrence between Montreal and Quebec, boring operations have been carried on for more than twenty years, some of the holes being sunk to depths of more than 1000 feet. The rocks of the district in which the borings have been made belong to the Lorraine and Medina formations, which lie in a comparatively flat basin extending across the St. Lawrence westward. Though natural gas in considerable quantity has been found, this has not yet assumed large commercial importance, but no petroleum has yet been met with.

In Nova Scotia, rocks supposed to be oil-bearing occur at several places. Probably the most important area of these is found in Cape Breton on the shores of Lake Ainslie, where attempts have been made for a number of years to find petroleum in quantity by boring. Here, as in Gaspé, the indications of rock-oil are observed in the form of springs and oozings, which escape from shales along the lake shore.

The rocks consist of shales and sandstone, generally of grey or greenish shades, which contain plant stems and fucoids. They have been classed provisionally as Lower Carboniferous, but as they clearly underlie the lowest known rocks of this formation it would seem more fitting to include them, on stratigraphical evidence, as a part of the Devonian series. They correspond closely in character and position with those rocks which are regarded as of the Devonian age elsewhere in this province and in New Brunswick.

Attempts to obtain oil by boring were commenced on the east side of this lake half a century ago; but though many holes have been put down, some of which reached a depth of 3000 feet, these have as yet been unsuccessful in finding oil in quantity. As in Gaspé and elsewhere, the strata are usually much broken up and inclined at high angles, with a well marked faulted structure in places. This feature is pointed out by Dr. I. C. White, of Virginia, in his report on the probable oc-

currence of oil in this district, where he says "the area of the field is so limited and the dip of the strata so high that there is hardly a chance of its being obtained here in large enough quantity to pay for its development." The area has apparently been fairly well proved in depth, and it would appear that any petroleum that may at one tme have been present in these rocks has long since passed off along the lines of fracture.

On the south side of Minas basin, at Cheverie, and on the Avon river, near Hantsport, borings for oil have been carried on during the last three years. Along the Avon, below Hantsport, a considerable thickness of shale and sandstone, with occasional beds of limestone, outcrops. These are regarded as the equivalent in age of the celebrated Albert shales of New Brunswick, though the percentage of bituminous matter is much less in the Avon, or, as they are usually styled, the "Horton series". Though for many years regarded as a portion of the Lower Carboniferous formations they are now considered as belonging to the Devonian system; since they uncomformably underlie the lowest known Lower Carboniferous rocks in this province.

These shales extend eastward from the Avon to the south side of Cobequid bay, and at Cheverie underlie a considerable thickness of gypsiferous rocks also associated with sandstone and shales. In the borings which have been made at this place the drill passed through these gypsiferous strata and entered a series of shales, etc., which were supposed to be a part of the oil-bearing series. In the underlying rocks indications of petroleum are found in cavities and crevices in the gypsum itself, and the borings were put down on the assumption that when the underlying bituminous shales were struck the source of these oils would be found. These underlying rocks are, however, much disturbed, and no trace of petroleum was encountered when these were reached.

This tilted and faulted character is well seen in the section of these rocks exposed along the lower Avon, and the boring

made near Hantsport in this formation was also devoid of results as regarded the finding of either coal or petroleum. As is Gaspé and elsewhere it may be generally inferred that in such a series of titled and faulted strata the chances of finding oil in economic quantity are by no means good, and the ultimate result of all these attempts, at places so widely separated, will probably be the same.

The only other source of petroleum known to us in this province is the band of "Stellarite", found in association with one of the coal seams of the Pictou basin. This mineral is reported to yield more than 100 gallons of crude oil per ton by distillation, equalling in this respect the Albertite of New Brunswick and the Torbanite of Scotland, both of which are now practically exhausted. No attempt has been made in recent years to utilize this mineral for the manufacture of oil.

It would appear that as a rule the shales of the eastern provinces do not, readily yield oil except by distillation although in places containing a large percentage of bituminous matter in composition; and from the results which have attended the borings at a number of points no large deep-seated reservoirs of liquid petroleum are likely to be encountered from which "gushers" may be derived.

The largest and most important body of these bituminous shales occurs in Albert county, New Brunswick, whence the name "Albert shale". Attention was directed to this locality more than half a century ago by the finding of a body of what was at first supposed to be a coal of superior quality. Some persons, however, contended that the substance had more of the nature of hardened pitch or asphalt and was not a true coal, and a legal contest ensued since the ownership of the property depended upon the actual determination of this question. Finally, after hearing a great mass of so-called expert evidence, the finding of the court was to the effect that the mineral in question was a true coal and not an asphalt, only two

of the experts maintaining its asphaltic nature. Subsequent investigation has clearly shewn that this early decision of the court was erroneous, and it has long since been established that Albertite, as the mineral was called, is merely an altered petroleum.

The Albert shales were for many years regarded as a part of the Lower Carboniferous formation, purely on the evidence of certain fossils, chiefly the remains of fishes. The detailed investigations of 1876, however, shewed them to unconformably underlie the lowest known Lower Carboniferous sediments, and they are now generally held to form the upper part of the Devonian system.

The peculiar feature of these Devonian shales is the presence of bituminous matter throughout their whole extent. While the great bulk of these sediments are shales, beds of sandstone and limestone also occur as a part of the series, and both are also highly bituminous. Interstratified beds of a tough, blackish and massive shale also occur, which break with a roughly conchoidal fracture and contain a much higher percentage of bitumen than the shales of the general mass, which are often thin-bedded.

The source of all this bituminous matter is somewhat obscure; for while according to strict orthodoxy the contained bitumen is supposed to be derived from organic matter contained in the mass of the rock itself, and while in certain layers the remains of fossil fishes are fairly abundant and occasionally the traces of plant life are visible, the proportion of fossiliferous strata, as compared with the great body of bituminous shales, is very insignificant.

The bands of rich oil-shale are sometimes styled Cannelite. They are occasionally grey in colour but for the most part are a blackish-brown. They are clearly a portion of the series, occurring as regular beds. At the old Albert mines, which were near the eastern end of the Caledonia mountain, a very

large deposit of Albertite occurred, and was worked extensively some years ago. This was the mineral first discovered in this district and which was pronounced to be bituminous coal by the courts. It occurred in vein form, following a line of fissure not far from the axis of an anticline in the shales. This deposit extended from east to west for about half a mile, with a width ranging from a few inches at either extremity to a thickness of from fifteen to seventeen feet near the middle of the outcrop. In depth the fissure continued for 1500 feet, the lower 250 feet being for the most part filled with a breccia made up of shale fragments cemented with Albertite.

The extent and value of this deposit can be understood from the fact that during the time of working over 200,000 tons of the mineral were marketed at prices varying from $16.00, in the early years of the industry, to $22.00 per ton, for some years before the mine ceased operations. It yielded about 15,000 feet of gas per ton and more than 100 gallons of oil by distillation.

The Albert shales with their associated oil-bands cover a considerable area in the counties of Albert and Westmorland. They extend from east to west for more than sixty miles, and have a thickness of not far from 1,000 feet. They are thrown into a series of folds, often with steep dips, and are broken by faults at a number of points. To the west they again outcrop near the line of the Intercolonial railway to the vicinity of Hampton, in Kings county. They are in places overlaid by Lower Carboniferous shale and conglomerate, with which are associated large deposits of gypsum and thick beds of limestone in parts also bituminous, and in other places are capped directly by the coarse beds of the Millstone grit.

All the shales of the series yield oil by distillation, the bulk of the formation probably from fifteen to thirty gallons per ton of shale, while the rich oil-bands, or cannelite, yield from 50 to 80 gallons. These bands were about forty years ago

worked for the extraction of the contained petroleum at Baltimore, N. B. They range in thickness from four to eighteen feet, the thicker bands being of the grey variety and found near the upper part of Turtle creek in the western portion of the main field. They can be mined after the manner of ordinary coal-beds, and while the amount of ash is large, reaching in parts from 40 to 50 per cent., the shale burns readily, forming an excellent fuel, both for grates and for the generation of steam. As determined by actual experiment it is claimed that their combustion yields a greater heat and calorific power than can be obtained from ordinary bituminous coals, while the large amount of ash is held to possess certain elements which make it valuable as a fertilizer.

Although these shales contain so large a percentage of bituminous matter they do not readily part with this in the form of free petroleum either by shafting or boring. In support of this statement, it may be said that during the entire period of mining operations at the Albert mines where one would naturally suppose conditions were most favourable for the free escape of the contained oils, according to the statement of the late manager, but slight indications of crude petroleum were observed in any part of the workings, except at one point near the west end of the mine, where there was a slight dripping from the end of the mine, where there was a slight dripping from the sides of the drift. On the Petitcodiac river, near Dover, and at several points in the vicinity, several oil-springs occur, and have usually been regarded as indicating the presence of underlying reservoirs of this material. As at Gaspé and elsewhere, however, in such disturbed rocks these are more probably escapes of petroleum along lines of fracture, and can scarcely be held to indicate the occurrence of oil in quantity in the underlying rocks.

Boring operations have been carried on in this district for more than fifty years. Apparently the first holes were sunk in

the area near Dover and Memramcook, between 1850 and 1860, the exact date being somewhat uncertain, as records of these borings are not now available. It was, however, reported at the time, that small quantities of a thick oil were obtained. Subsequent borings were made at intervals for some years with apparently no better results, but within the present century a systematic search has been carried on in the area between Memramcook and Petitcodiac rivers, in which over sixty holes have been bored, some of which reached depths of more than 3000 feet. While small quantities of oil were struck in some of these holes, as was also the case in Gaspé and in Newfoundland, in rocks of practically the same horizon, in so far as can be learned no outflows have as yet been found in quantities sufficient to warrant the erection of an extensive refining plant, and at present operations have been suspended for some months.

The nearest geological formation to which these Albert shales can be compared from the economic standpoint, are the bituminous shales found in Scotland, and to some extent, in England and Wales. They also occur and have been utilized for the production of oil by distillation in some parts of Australia, in New Zealand, in France, in Germany and in several other countries. In none of these places, however, have they been regarded as producers of crude petroleum in any other way than by destructive distillation.

Their economic importance is evident from the fact that in Scotland and elsewhere millions of pounds have been invested in the erection of large plants for the distillation of the contained bituminous matter, and a brief comparison of some of these Scotch shales with those of New Brunswick may possess some points of interest.

In Scotland, since it is not necessary to discuss the shale-oil industry of other countries, the distillation of oil, first from bituminous coal and then from bituminous shale, was begun by Dr. James Young, of Renfrewshire, about the middle of the

last century. The first experiments were made with the bituminous coals, but the discovery of a mineral, very rich in bitumen, which was known as Bog-head coal or Torbane hill mineral or Torbanite, soon furnished a new supply of the raw material. This Torbanite yielded as much as 130 gallons of crude oil to the ton, as compared with a yield of from 70 to 90 gallons from the coal. After the exhaustion of the Torbane hill mineral attention was directed to the bituminous shales of the coal-measures which were first worked in 1862.

The growth of the shale-oil industry in Scotland may be seen from the fact that the output of this material in 1874 was only 361,970 tons, while in 1891 this has risen to 2,337,932 tons for Scotland alone, yielding 47,63,458 gallons of crude shale oil, the amount of capital invested being for that year no less than £2,664,431, the yield of oil being much greater than the output of crude petroleum in the whole of Canada for the year 1904.

The shale series in Scotland is estimated to have a thickness of about 3000 feet, and in this eight principal bands of oil-shale occur, varying in thickness from two to eighteen feet, and are thus not very different in quantity from those found in the Albert shales of New Brunswick.

Of the Scotch shale bands which most nearly resemble those of Albert county, though none appear to contain as high a percentage of bitumen, the richest, known as the Fell shale, yields from 36 to 40 gallons of crude oil to the ton, and from 25 to 33 pounds of ammonium sulphate; the Broxburn band is probably next in importance with a yield of 28 to 33 gallons crude oil, and from 26 to 32 pounds ammonium sulphate; the Dunnet shales yield from 15 to 30 gallons, and the Curley shales yield about 19 gallons of crude oil and from 50 to 60 pounds ammonium sulphate. In geological position these Scotch shales correspond almost exactly with those of New Brunswick, being situated between the Lower Carboniferous limestone and the Old Red sandstone of the Devonian.

These several oil bands are mined after the fashion of bituminous coals, and are delivered at the distillation works at a cost of four to six shillings per ton. There is also a royalty of from three to tenpence per ton of shale, and the cost of the finished illuminating oil, after crediting the value of the ammonium sulphate, is two and a half pence per gallon. Much of this detail is taken from the valuable work of Boverton Redwood, in whose book on "Petroleum and its products" a very full description of the industry in all its stages is given.

Comparing then the small size of the Scotch seams and the comparatively low percentage of the bituminous contents with the generally thicker beds of Albert county and the much higher percentage of bitumen, the economic importance of these deposits, as a possible source of supply for crude petroleum becomes at once apparent; and in the present strenuous search for new oil-fields and the rising price of the finished product, it would seem perfectly feasible under proper management to operate these New Brunswick areas with a fair margin of profit; more especially in view of the now well established fact that these shales, whenever they are found, do not readily yield up their bitumen contents except by distillation. The further consideration of this question is, however, a matter for the careful consideration of the best expert engineering skill, and careful management is required in all its stages.

Considered from the standpoint of fuel under steam generating boilers, it has already been hinted that some of these heavy bands of oil-shale possibly could be utilized as a source of heat and power. Of these there are two kinds, the black being especially well developed at the old Albert mines and at Baltimore in Albert county, as well as in parts of the district between the Petitcodiac and Memramcook rivers, having been shipped quite extensively from the latter area for distillation in 1860-65. The grey shales are better developed in the area west of Baltimore on the head waters of Turtle Creek;

the analysis of these shales is of interest and may be here given. They are from the laboratory of Ricketts and Banks, of New York, and are as follows:—

Black oil-shale.

Moisture	0.36	0.64
Volatile	39.50	45.52
Fixed carbon	3.00	5.05
Ash	56.10	48.79
Sulphur	1.04	.....
	100.00	100.00

Grey oil-shale.

Moisture	1.10	1.54
Volatile	45.32	51.22
Fixed carbon	1.29	3.03
Ash	50.69	44.21
Sulphur	1.70	.....
	100.00	100.00

As already stated the origin of the immense amount of bituminous matter contained in this body of shale and sandstone has never been satisfactorily explained, and is a very interesting problem. On no hypothesis yet suggested can it be accounted for either as arising from the decomposition of organic matter *in situ* or as derived from underlying fossiliferous sediments, since the underlying rocks being of pre-Cambrian age are entirely devoid of all trace of organisms. Similar difficulties are also met in the attempt to explain the origin of the great deposits of bitumen found in the island of Trinidad, where the associated rocks are shales of Tertiary age. While the consideration of the several theories put forward from time to time to account for the bituminous deposits throughout the world would be of considerable interest, and while the inorganic origin of bitumen and its compounds has quite a number of supporters at the present day, such discus-

sion is beyond the scope of this paper, and if indulged in would probably leave the final determination of the problem in its present unsatisfactory position.

We may, however, glance for a moment at the enormous output of crude Petroleum which has been obtained from certain parts of the well known oil-fields of the eastern and western hemispheres. Without considering the amounts derived from the smaller areas it will suffice to note that from the official returns of the Geological Survey of the United States, the number of barrels of crude petroleum of 42 gallons capacity, taken from the oil-fields of that country since the commencement of the industry forty-five years ago, amounts to 1,382,815,000, or nearly sixty billions of gallons, by far the greater part of which has been obtained from what is known as the Appalachian district, comprising the states f New York, Pennsylvania, West Virginia, south-east Ohio and Kentucky, only comparatively small portions of which are oil-bearing. These oils are all obtained from the Palæozoic formations. The recent discovery of the immense stores of petroleum in Texas, California and from other areas on the Pacific slope is to some extent already revolutionizing the industries of that portion of the republic by the substitution of oil for fuel on railways and steamships. These oils are from the much more recent horizon of the Cretaceous and Tertiary formations, and some of the areas are already rivalling in productiveness the original seat of the industry in the Appalachian district. The value of the oils for the time mentioned for the entire output to the end of 1904 is given as $1,362,781,879.

The value of the petroleum produced in Canada from the commencement of the industry cannot be correctly stated owing to the fact that for some years the returns were loosely kept. For the period extending from 1881 to 1903, both inclusive, the production of crude petroleum in this country was not far from 530,000,000 gallons, the output being practically all from the

small area in south-western Ontario. The actual value of the output cannot be stated.

In southern Russia a most wonderful revelation as to the amount of crude petroleum which can be obtained from a limited area is presented. Thus from the oil-fields of the Baku district at the southern end of the Caspian sea, in an area of about eight square miles only, and in a period extending only from 1880 to 1904, the output of petroleum amounted to, in round numbers, 950,000,000 barrels of some 40,000,000,000 gallons. The average depth of the wells bored in this district in 1894 was only 1260 feet, the depth having gradually increased year by year. Of the 239 wells sunk in that year the average yield was 384 barrels per day. Such a yield must truly be characterized as enormous, and while some of the wells become exhausted, others are bored from which the same tremendous outflow occurs as when the field was first tapped. If we could take into account the enormous amount of bituminous matter which has passed off in the form of natural gas in all these years in this district, the figures of output would reach such amazing proportions as to be scarcely comprehended, and make the solving of the problem as to the source of such wonderful deposits of bituminous matter, in so limited an area, still more perplexing.