CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, MINISTER; R. W. BROCK, DEPUTY MINISTER.

GEOLOGICAL SURVEY

MEMOIR 52

No. 42, GEOLOGICAL SERIES

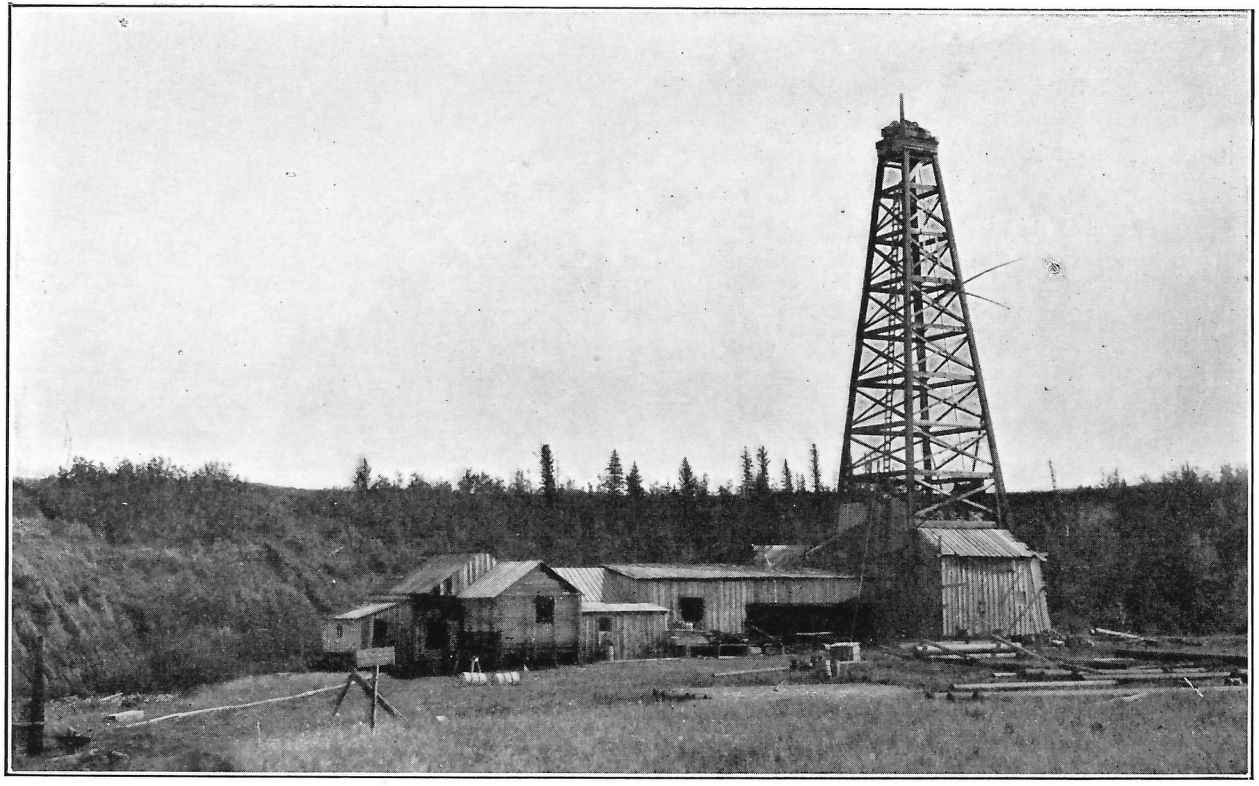
Geological Notes to Accompany Map of Sheep River Gas and Oil Field, Alberta

BY

D. B. Dowling

OTTAWA
GOVERNMENT PRINTING BUREAU
1914

No. 1357.



Calgary Petroleum Products Co's well.

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Geological Notes to Accompany Map of Sheep River Gas and Oil Field, Alberta.

INTRODUCTION.

The western edge of the great syncline which runs north and south through Alberta and crosses obliquely the fifth initial meridian, is for a short distance bent over into anticlinal form. West of this, which is the region commonly called the foot-hill country, the rocks are faulted and folded, and exposures of the lower series of rocks are to be found on many of the streams. Where the above-mentioned anticline crosses Sheep river the rocks exposed by the erosion of the crest of the anticline are Upper Cretaceous shales. These, on the south branch of Sheep river, are well exposed beneath sandstones which appear to belong to the coal bearing Edmonton series of northern Alberta or the St. Mary River beds of southern Alberta. In the centre of the anticline, sandstones and shales of the base of the Bearpaw or top of the Belly River formation appear, and in these, near the south branch of Sheep river, a leakage of strongly smelling gas has been known for years at the apex of the anticline.

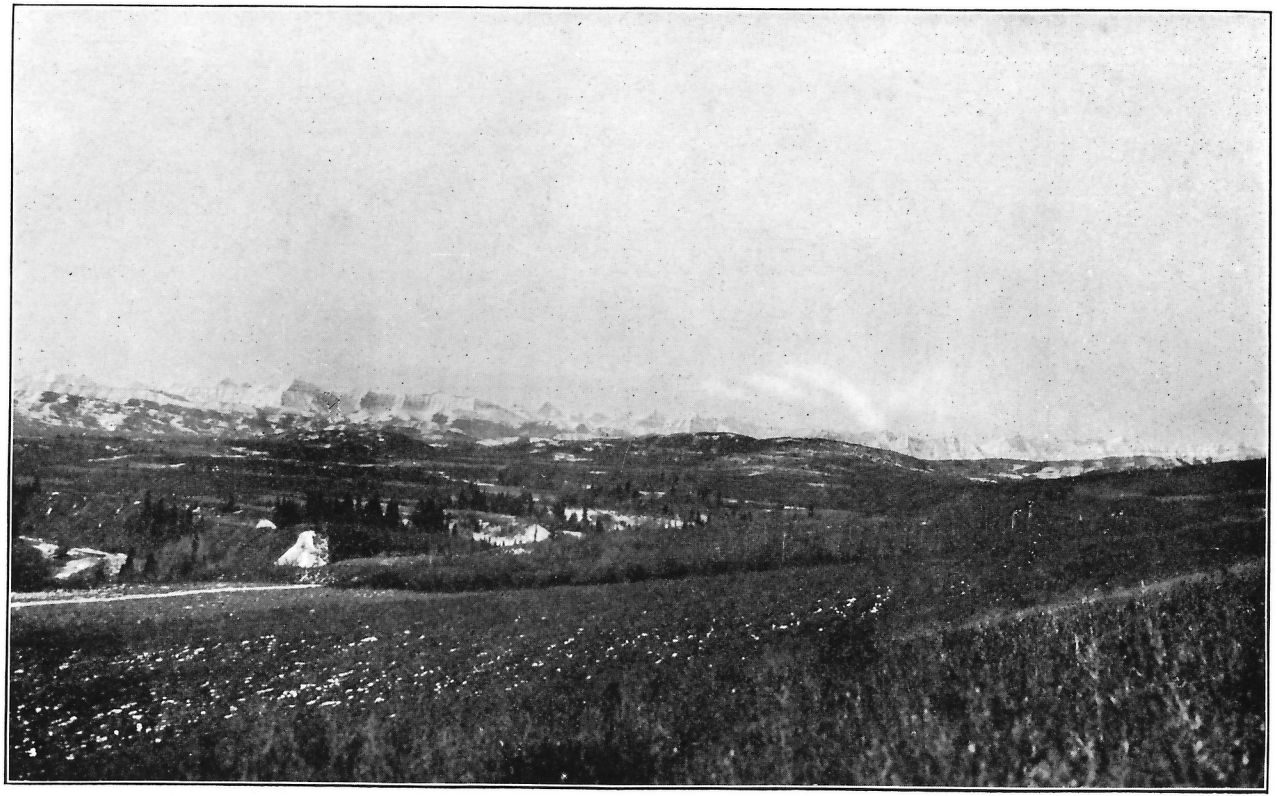
Recent boring operations in this vicinity disclosed the presence of gas in the upper beds of the Belly River formation and, at a depth of a little over 1,550 feet, a small amount of light oil (about 90 per cent gasoline) was found. This stimulated the belief that oil was to be found in commercial quantities in this region and many companies were formed with the object of drilling for oil. Assuming that oil is to be found in the rocks of the Belly River, or those at a lower horizon, it would be essential to success that drilling should be started (1), at a locality where oil and gas might be expected to accumulate and (2), where it could be reached at reasonable depths.

The Sheep Creek anticline offers, as far as structure goes, an opportunity of piercing these rocks at a moderate depth. To the west in the faulted zone of the foot-hills, these lower rocks are again brought to the surface and there may be areas there where oil may have accumulated, but the broken nature of the country would argue against any very large reservoirs.

A sketch of the geological structure on a line of section across the strike of these beds in the Sheep River area appears on the map accompanying these notes. The most striking feature illustrated by this section is the apparent great depth at which the Cretaceous rocks are buried at points to the east of the Sheep Creek anticline, and, therefore, all drilling in the Tertiary areas must depend for a possible supply of oil or gas on the rocks forming the Tertiary beds. Up to the present a small flow of gas has been obtained at several points, but this has been without much odour and the only oil found in Alberta in beds near this horizon is to the north, near Edmonton, in surface showings which have a possible origin in drift material brought from the Athabaska.

Extended notes on the geology of the foot-hill area southwest of Calgary will be found in a report by Mr. D. D. Cairnes on Moose Mountain region, Geological Survey Publication No. 968. Information of a more general nature on the geology of the northwest provinces is contained in Memoir No. 29 by Wyatt Malcolm, entitled "Oil and Gas Prospects of the Northwest Provinces of Canada." The following notes are intended to supplement the information therein given in regard to the possibilities of oil being found in the Cretaceous rocks. To the description of each formation is added a note regarding its oil-bearing character in the United States, especially in Wyoming and Colorado. The intervening state of Montana so far does not appear to have an oil field.

The field work on which this report and accompanying map are based,was performed during a visit in October, 1913; the map is to be considered merely as a sketch which it is hoped will be of use in the further prospecting of the area. The age of the shales in the section west of the Sheep River anticline requires careful investigation, as the recognition of the several shale horizons is difficult and the position assigned in the sketch section is only provisional.



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The foot-hills and outer Rocky mountains from Lineham, Alta.

SUMMARY AND CONCLUSIONS.

The boring on Sheep river has demonstrated the presence of small quantities of oil in the Belly River rocks, and there is a trace of oil in the weathered face of these sandstones in outcrops on the stream nearer the mountains.

Gas has been obtained at a number of localities in the Belly River formation.

The Cardium sandstone, which seems to represent the top of the Niobrara, is exposed on Sheep river, to the west of the Sheep River anticline, and paraffin and oil have been obtained from hand specimens by treatment with chloroform. This horizon is probably the source of much of the gas in the shallow wells at Medicine Hat.

The Dakota sandstone is in places, especially to the east where it is superposed on the Devonian, impregnated with bitumen and heavy oils.

The above three formations contain many sandstone beds which where porous may serve as reservoirs for the accumulation of oil or gas, but their accumulation in quantity depends partly on the structural form and mainly on the character of the surrounding shales. Traces of oil, it appears, can be found in many of the dark shales of the Cretaceous, and in the oil fields of the western states, such as Wyoming and Colorado, the finding of oil at the several horizons in the Cretaceous depends greatly on the presence of sandy, porous beds in which it can accumulate. The anticlinal form is, in the majority of cases, necessary for the concentration of the oil into pools, but in very dry beds such as in the Florence field, Colorado, the oil acts as the heavier liquids and collects in the bottom of the basins or synclines.

The Sheep River anticline would seem to be a favourable situation for the concentration of any oil or gas in the rocks beneath, and by deep drilling the horizons which present possibilities, namely, the Belly River, the Cardium sandstone, the Dakota, and the Lower Cretaceous sandstones beneath, may be reached. The anticline in the first fault block to the west, namely the one passing near Lineham, affords a chance to reach the Dakota at a comparatively shallow depth.

GENERAL DESCRIPTION OF GEOLOGY.

The Macleod branch of the Canadian Pacific railway skirts the eastern edge of a belt of hilly country which lies to the east of the foot-hills proper. The rocks in these hills are of early Tertiary age and consist of light coloured sandstones and clays that are exposed in the vicinity of Calgary and westward, on the Bow river. In the district under discussion these beds are found in the hills west of Okotoks and are there seen lying almost horizontally. To the west, up Sheep river, there are occasional exposures, and near the forks of the river the dip of the strata is to the east, thus showing the approach to the western edge of the syncline. The rocks beneath the heavy bedded sandstones such as are occasionally seen cropping on the sides of the hills, are apparently varicoloured shales and sandstones dipping eastward and are in evidence on the banks of the stream north of the post-office at Black Diamond. From beneath these comes a thick series of sandstones which a short distance farther west are tilted at higher angles, and as coal seams are found with them, they may be provisionally correlated with the Edmonton beds. As these latter sandstones are of a harder nature than the rocks above and below, their presence is indicated by a line of hills crossing the river valley and through which the two branches of Sheep river have cut channels. This line of hills marks the eastern side of a long fold running parallel to the mountains, and, at a short distance west, a similar ridge seems to be formed by the westerly dipping beds of the same series, thus indicating an anticline. The rocks exposed across this portion between the hills, are dark coloured marine shales representing the Bearpaw or upper portion of the Pierre-Foxhill formations. The intercalated fresh and brackish water member, the Belly River series, comes very near the surface in the centre of the anticline. The presence of a sandstone with markings resembling plants, indicates a change in condition of deposition, but, according to the record of drilling operations on this anticline, shales continued for nearly 300 feet before the sandstone series was reached. Westward of the sandstone rib on the west side of this anticline, a decided break or fault is indicated and lower beds have been brought up. These, both in thickness and composition, resemble

the Bearpaw shales; but since at the top, overlain by black or brown shales, there occurs a sandstone member which is not to be found in the exposures of these shales to the east, it is concluded that they represent the Claggett which is below the Belly river. Marine fossils have been collected from this series, but they are not of species definitely characteristic of any horizon. These shales overlie the Niobrara-Benton and the Dakota, but no exposures of either are here found as the lowest beds of the anticline are shales of the same series. The axis of this anticline passes just to the west of Lineham ford. For some distance west, the shales continue with moderate westerly dips, but a broken zone is reached near the eastern boundary of section 33, in which there is considerable folding and the thin sandstones found in this shale series are repeated several times. This sandstone is probably the series called by Mr. Cairnes the Cardium sandstone and it is expected that in places some oil may be obtained from it. The outcrops in places are stained with paraffin which can be detected only by treatment with a solvent such as chloroform, and in this way a trace of a heavy oil can also be obtained. A band of steeply inclined beds of Belly River sandstone is found just above the mouth of Macabee creek, and in these there are two horizons similarly stained with paraffin. One at about the centre is supposed to represent the beds from which some oil was obtained in the well being drilled on section 6, township 20, range 2. The shales to the east of this series of sandstones may possibly be the Claggett, but as their thickness is considerable and the sandstones at the base resemble the top of the Belly River series rather than the Cardium sandstones, they are provisionally called Bearpaw.

DESCRIPTION OF GEOLOGICAL FORMATIONS.

The rocks exposed in the district, including also some of those found in the foot-hills to the west, are discussed in the general order of the following table:—

Table of Formations.

Tertiary.....	Paskapoo series of northern Alberta, or Porcupine Hill beds of southern Alberta.

Cretaceous.....Edmonton series of northern Alberta or St. Mary River beds of southern Alberta.
Bearpaw shales, the equivalent of the Pierre shales described east of the Alberta syncline.
Belly River series.
Claggett shales, the equivalent of the Lower Dark shales of southern Alberta, or the lower part of the Pierre.
Cardium sandstones.
Niobrara-Benton shales.
Dakota sandstones.
Kootenay formation.
Jurassic.....Fernie shales.
Palæozoic

TERTIARY.

Paskapoo Series—The rocks of this series as exposed in northern Alberta are thus described:[1] "The beds consist of more or less hard, light grey or yellowish, brownish-weathering sandstone, usually thick-bedded but often showing false bedding; also of light bluish grey and olive sandy shales, often interstratified with bands of hard, lamellar, ferruginous sandstone, and sometimes with bands of concretionary blue limestone."

The thickness in the outer edge of the foot-hills on Little Red Deer river was determined as being at least 5,700 feet.

In southern Alberta the sandstones are comparatively soft with intercalated greyish and blackish shales, the lower beds (Willow Creek of Dawson) having a pronounced reddish or purplish tint. The series is so far found to be entirely of fresh water origin. A few coal seams in the lower part are found in the country between Calgary and Edmonton. No authentic records of oil having been found in rocks of this division are known, though there are unconfirmed rumors of oil being found in the country west of Red Deer. Small flows of gas have occasionally been found as instanced in the gas well at High river, but there it is not certain that the beds are of purely fresh water origin.

In the valley of Sheep river these sandstones are exposed in horizontal beds in Wilson coulee near Sandstone station, and in the hills bordering the valley west to the forks. Near Black

[1]J. B. Tyrrell, Geol. Surv., Can. Ann. Rep., vol. II, 1886, p. 136 E.

Diamond post-office a heavy bed of sandstone outcrops near the south branch in section 16, and west of this exposures of the variegated shales and sands of the base of the formation are seen with an eastern dip. The thickness of the formation here has not yet been measured but seems to be very great. East of the hill country the beds that are at the surface should be those of the lower and more shaly part.

The late Tertiary rocks of Texas produce in some of the domes both gas and oil. Veins of gilsonite, a hardened bitumen, are found in Tertiary rocks of Middle Park, Colorado, and in the Green River formation in Utah. The great oil fields of California are mainly in late Tertiary rocks. The Tertiary rocks of Wyoming, the lower part of the Wasatch formation in Carbon county, contain sandstones that yield 8 per cent of oil with an asphaltic base

CRETACEOUS.

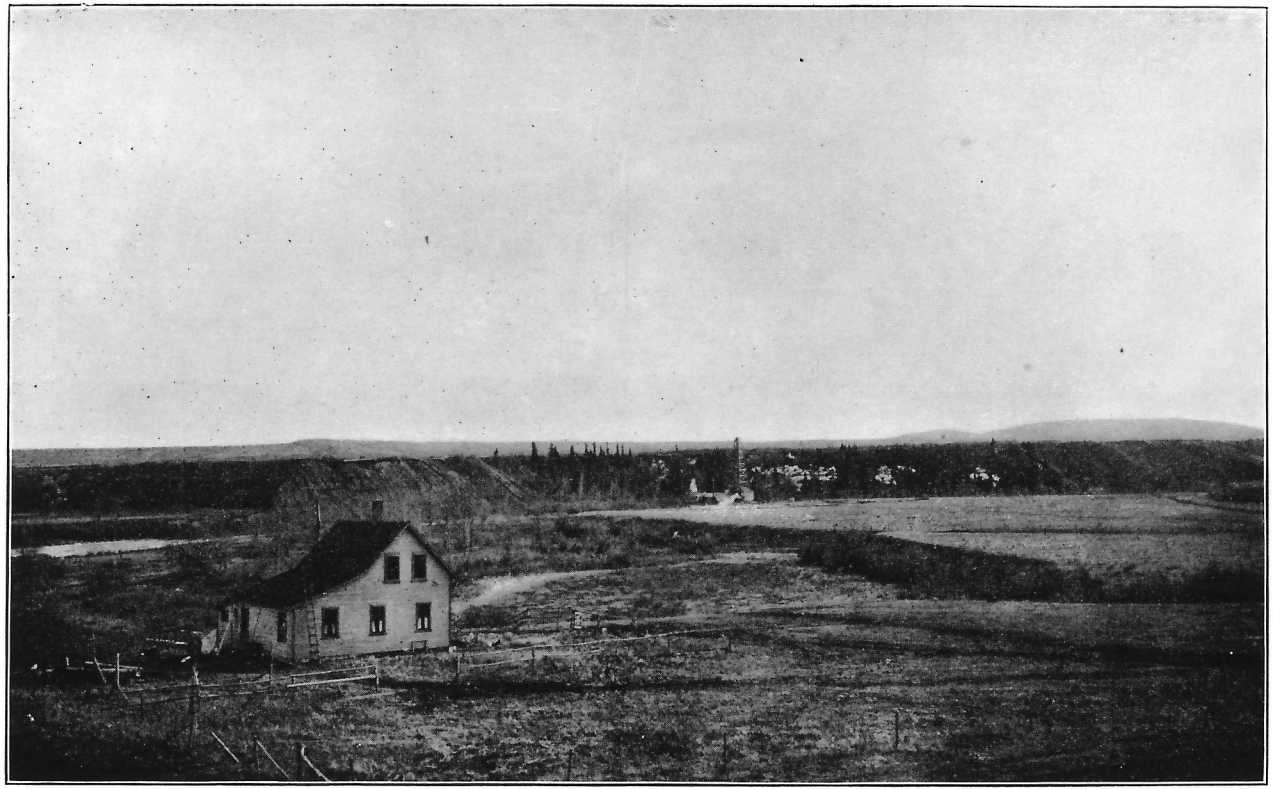
Edmonton Series.—In the vicinity of Sheep river the series of sands and clays which form the base of the Paskapoo, merge into grey clays and sandstones in which one seam of coal is known and these are succeeded by more sandy beds. The base of the formation is distinctly a sandstone which is exposed on each side of the anticline, and being more resistant to erosion is marked in the topography by a series of long, narrow hills. The thickness of the sandstone rib is probably over 1,000 feet. In the foot-hills a second coal horizon is found near the base, though, on Sheep river, none was there noted. The upper coal seam at Black Diamond and south near Tongue creek is repeated on the west side of the anticline in the McDougall mine near Lineham post-office. Coal reported near the surface at the McDougall-Segur well may possibly have been from the lower coal horizon in the Edmonton.

Bituminous sands covered by boulder clay have been found at several places north of Edmonton. The origin of these sands is doubtful and there is a possibility that in some parts of the series a small amount of oil has been formed which has been collected in sands beneath the somewhat dense boulder clay. The possibility, however, of masses of the tar sands having been transported from the Athabaska county by the Keewatin glacier

is not to be lost sight of. Drilling at these localities has been very expensive and has not proved the supposition that the oil found its way upward from the Dakota beds below. These pools of oil have, moreover, little value except when near enough the surface, so that the containing bed can be removed by excavating. The localities so far reported are: near Egg lake, township 56, range 25, west 4th; section 28, township 56, range 2, west 5th; at Legal in township 57, range 25, west 4th; and north of the Athabaska on Freeman river, 12 miles above its mouth. Other localities whose positions are not definitely known are reported near the east end of Lesser Slave lake.

Bearpaw Shales.—These marine shales occupy a position above the Belly River and are the equivalents of the Pierre-Foxhill of the plains of Alberta. The latter formation, as now understood, embraces also shales below the Belly River formation and hence individual names are required for the two divisions respectively above and below the Belly River.

In the foot-hill country, near the mountains, the thickness is found to be 650 feet. In the Calgary bore-hole, shales amounting to 530 feet are taken as representing this formation. At Kipp, borings show a thickness of 615 feet of shale above the Belly River coal seam. On the Red Deer river, east of Calgary, the thickness is about 750 feet. East of Edmonton it is about 800 feet and on the north slope of the Cypress hills McConnell found its thickness to be 900 feet. On Sheep river, between the limbs of the anticline, there is, east of the apex, two apparently unbroken series of shales with ironstone nodules and thin, hardened streaks of sandy ironstone, separated by a very narrow band of shales with a discordant dip. These series each contain a section of shales, the eastern nearly 1,200 feet and the western 800 feet in thickness. At first view this would give a thickness of 2,000 feet, but as this does not seem warranted by the evident thickness elsewhere the presumption that there is a repetition somewhere in this section is warranted The crumpled beds between the above-mentioned blocks are taken to represent a line of weakness and a possible normal fault is there assumed. Other faults may be present but were not detected and as a preliminary it is assumed that there is a thickness of 1,200 feet of shales as shown in what appears to be one block.



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The centre of the anticline on Sheep river.

In Alberta and, probably, also Montana, these upper shales do not seem to contain oil. In Texas the beds representing the top of the Cretaceous contain oil in the Corsicana field and are supposed to have supplied the oil found in the Tertiary rocks at Beaumont.

Belly River Formation.—This is a brackish and fresh-water formation consisting of sandstones, shales, and a few coal seams. It very closely resembles the Edmonton formation and only by its position below the dark Bearpaw shales is its identity definitely known. According to Mr. Cairnes (Moose Mountain Report, No. 968, p. 27) the maximum thickness in the vicinity of the mountains is 1,025 feet. On Sheep river above the mouth of Macabee creek, where these beds are marked on the Moose Mountain map, there seems to be a greater thickness than the above. In these beds signs of paraffin were detected on the outcrops in two places and these may correspond to the horizons at which oil was found in the well on section 6, township 20, range 2, west of the 5th meridian. Gas has been obtained from this formation in several places in Alberta besides the above-mentioned well.

Claggett Shales.—The shales lying below the Belly River rocks are marine and although very similar to the Benton, contain fossils that would place them higher in the series. They correspond in position to the Lower Dark Shales found by Dr. Dawson on Milk river near Lake Pakowki. These latter are classed by Stanton as being of Pierre age and representing the lower part of the Pierre shales as found in South Dakota. These beds are not found in any very great thickness in the foot-hills (150 to 300 feet), and consist of dark shales with bands of ironstone similar to the shales above and below.

In Canada no reference has been made to the finding of oil or gas in these or in the lower Pierre shales, but in Wyoming some oil has been found in sandstones of the lower part of the Pierre, in the Powder River oil field, and also in the Salt Creek field in Natrona county. In Colorado, oil which is supposed to have come up from the Niobrara and Benton is found in the lower part of the Pierre in the Boulder and Florence fields. This horizon may correspond to the Claggett of Alberta.

Cardium Sandstones.—This division, which seems to represent shore and possibly land deposits formed at about the period represented farther east by the calcareous shales of the Niobrara

formation, consists of coarse sandstones and black shales which have a thickness of about 50 to 100 feet. These are described by Mr. Cairnes and correlated with part of the Eagle sandstone of Montana. They are exposed on Sheep river as a narrow crumpled band at several localities west of Lineham post-office. The interest in this connexion lies in the fact that several samples treated with chloroform imparted a decided brown-yellow colour to this liquid. One sample so treated in the office at Ottawa, on evaporation left dark brown, oily markings on the test tube and a large number of small needle-like particles, suggesting crystals of a white paraffin. This sandstone is a possible receptacle for oil that may come from the Benton shales beneath.

Niobrara-Benton Shales.—The upper part of this series may contain deposits of the same age as the Niobrara formation, but as these shales possess none of the Niobrara characteristics they are generally considered under the caption of Benton shales. This is also the case in Montana where the formation derives its name. At the town of Fort Benton there is no limestone corresponding to the Niobrara, and as there is no erosion interval or unconformity the Niobrara is probably represented by shales or sandstones; in this particular the Benton shales of Montana and Alberta no doubt embrace more than the formation known by the same name in Nebraska.

In the eastern exposures of the Cretaceous in Manitoba and also at various places along the northern face of the Cretaceous plateau, calcareous shales are found beneath the Pierre, which seem to be of Niobrara age, and at several localities these have a strong odour of petroleum and are often so impregnated that the shales will burn. Petroleum may be obtained from them by distillation.

These bituminous shales are exposed in the valley of the Pembina river south of Manitou in Manitoba, and on the face of the Pasquia hills in eastern Saskatchewan, and, as before remarked, the Cardium sandstones which represent a contemporary deposit in the foot-hills seem to have contained petroleum in some of their exposures.

South of the International Boundary, the oil in the Salt Creek field of Wyoming is supposed to come from the Niobrara, but it is found in sandy beds at the base of the Pierre. In Colorado the oil of the Rangely oil district is procured from the central part of the Mancos shale, and as this formation includes Pierre and Niobrara-Benton, the horizon at which the oil is found may correspond to the Niobrara. In the Niobrara of the Florence field the rocks of the Apishapa and Timpas divisions contain in the pores and small joints much solid bitumen. None is found in the larger joints.

In Canada no mention is made of oil or bitumen as having been found in the Benton shales. In Manitoba they evidently contain much carbonaceous matter, but in the foot-hills the characteristic intense black colour is not so prominent and the shales are more rusty in appearance and may be described as dark grey, rusty shales with many thin bands of ironstone and rusty sandstone.

Oil is found in the Benton in Wyoming and Colorado. In the Wyoming fields of Unita county, oil is obtained in the Aspen formation northeast of Spring Valley, and in the Bear River formation near Spring Valley. Near Bonanza, oil is found in the Wall Creek sandstone near the base of the Benton. The upper part of the Benton in the Douglas field, Converse county, contains a very thick oil, while that from the lower part is much lighter in colour. In the Colorado oil fields, the Carlisle shale in the upper part of the Benton contains oil in the Florence field, while in the Boulder field it is thought that some oil obtained in higher measures has worked upward from the Benton.

Dakota.—The thickness of the Dakota in the foot-hills is from 900 to 1,700 feet. Rocks very similar to those of the Dakota formation and probably of the same age, are found in the foot-hills region and will, probably, be penetrated in some of the deeper borings. In the foot-hill exposures these rocks are sandstones of a general greenish tint. Dark shale beds are found in the lower part of the series and the division between the Dakota and the Kootenay series below is not well marked, and has been here assumed at a heavy conglomerate bed which serves as a horizon marker for the top of the coal-bearing rocks beneath. This series of sandstones is an important gas reservoir in the anticline which passes north through the plains region between Bow Island and Medicine Hat. The great pressure of the gas and its economic value has until lately satisfied the companies drilling, so that the origin of the gas has not been determined. It is well known, however, that where these beds rest on the Devonian rocks of the Athabaska river, they are impregnated with a heavy oil which on weathered outcrops is thickened to a bitumen. The origin has been ascribed to the Devonian beneath, and in this connexion it may be mentioned that these oils and tars are found over a large area in isolated exposures. The tar spring on Tar island, Peace river, and others in the country at the head of the Wabiskaw river, although found in rocks above the Dakota, probably derive their oil from the Dakota. The suggestion that this sand formation acts as a reservoir for oil extracted from Devonian rocks is quite probable, since in the basin drained by the Mackenzie where a wide area of these rocks occurs, many instances of tar springs in the Devonian are known. Thus on Slave river, below Fort Smith, and at several points on

the west shore of Great Slave lake, there are evidences of petroliferous shales and tar springs. Others are to be found on the banks of the Mackenzie near Fort Good Hope and below Fort Wrigley.

The sandstones of the formation discussed under the name Dakota no doubt underlie a great part of the area occupied by the Cretaceous plateau, and the question of its oil or gas bearing qualities depends in great measure on whether the underlying strata are capable of producing oil or not. It is not expected that the Devonian is in immediate contact with the Dakota over the whole area now covered by the Cretaceous, since the contact is one of unconformity and in the exposures of the lower rocks in the mountains a great thickness of Carboniferous limestones and shales, as well as later beds, are there found between the Dakota and the Devonian. It may be that some of these intervening beds are themselves petroliferous or gas-producing, in which case, the Dakota may have enriched zones that would in a general manner be aligned with the mountains and would also follow the structure lines or flexures on the plains.

The nearest of the foreign oil fields developed in this horizon is that of Wyoming. In several of the areas there prospected, the Dakota formation is credited with containing bitumen and heavy oil. In the Powder River field, Natrona county, some oil is found in sandstone doubtfully called Dakota, but which may be of earlier age. Dutton and Rattlesnake fields also credit some oil to the Dakota. In the Oil Mountain field there is one spring on Oil mountain in Benton shales, but the oil probably comes up through a fault from the Dakota. In several fields in Unita county, small amounts of oil are obtained from the lower part of the Benton or Dakota.

In Crook county a heavy lubricating oil is obtained from the Dakota. Some oil has been got from near the outcrop of the top of the Dakota in the Newcastle field of Weston county. In Converse county, oil that is found in the lower part of the Benton or top of the Dakota is lighter than that found in the upper Benton of the Douglas field. A very light oil has been found in the lower part of the Dakota in the Shoshone field of Fremont county.

In Colorado, solid bitumen is found in the Dakota, and in the states to the south, the origin of oil in the Trinity sands (probably of this horizon) is generally ascribed to the underlying Palæozoic limestones and shales.

Kootenay.—This formation, which is generally very rich in coal deposits in the exposures in the Rocky mountains, thins out towards the east, so that its presence beneath the Dakota can only be expected in the western and perhaps southwestern

portion of the Cretaceous area. The rocks are brownish sandstone and shales with abundant plant remains, and coal seams may be expected in the foot-hills area. This formation is found in Montana and thin deposits of about this horizon occur as far east as the Black hills. In the oil fields of Wyoming some oil is credited to sandstones at the base of the Cretaceous, which may be of this age, such as in Fremont county, and certain sandstones in the Douglas field of Converse county.

JURASSIC.

Fernie Shales.—In the foot-hills a thin series of black shales which vary in thickness from 100 to 250 feet is correlated with the Fernie shales of the mountain areas. The formation has thinned so much to the east that very little of it may be expected even in bore-holes in the outer foot-hills. As an oil producing stratum it seems of rather small moment, and oil, although found in rocks credited to this age in the Powder River field, Wyoming, and in the Florence field of Colorado, is found only in small quantities and is very heavy and black.

PALÆOZOIC.

It is quite certain that the floor on which the above described Mesozoic deposits were laid down, consists of a series of limestones of which the western portion is formed of Carboniferous rocks with possibly some Triassic and Permian sediments lying here and there upon them. It is possible that these Triassic and Permian sediments and some of the Upper Carboniferous which is found to be oil-bearing in some of the Wyoming fields, may be oil-bearing in places beneath this mass of Cretaceous, and if so possibly may have enriched overlying beds that can be reached by drilling from the surface. The eastern and northern part of the Cretaceous area is underlain by Devonian limestones, and it is already demonstrated that the Devonian in its northern portion at least is fairly rich in bitumen, and is there the source of the oil found in the Dakota sandstones.

OCCURRENCE OF OIL AND GAS IN GENERAL REGION.

Gas.—In Alberta, small quantities of gas are to be found in the sandstones of the Paskapoo and Edmonton formations. As these formations contain abundant evidence of plant life, both in the form of scattered material and in coal seams, the presence of gas may be expected; but as the beds are generally quite porous and are not capped by closer grained beds than the occasional clay deposits, therefore, the gas is probably to be obtained only in small amounts and at low pressure.

In the Belly River rocks which have a general resemblance to the Edmonton, the accumulation of gas is helped by the cover of close grained Bearpaw shales which overlie them, and although no great accumulations have yet been found in the prairie country, a very fair flow of gas was obtained in drilling on the Sheep River anticline. The gas was strong smelling and was evidently associated with a volatile oil.

Gas has also been obtained from rocks at about the horizon of the Niobrara at Medicine Hat and in southern Manitoba.

The great flows of gas at Bow Island and at Pelican Rapids on the Athabaska, are believed to come from rocks at the horizon of the Dakota.

Oil.—The Devonian rocks of the Mackenzie basin have long been known to contain bituminous shales and they are also supposed to have been the original container of the oil found in the Tar Sand on the Athabaska. Small amounts of oil are known to exist in certain of the beds of the Niobrara as exposed in southern Manitoba and northern Saskatchewan. The percentage is, however, low and the oil could only be obtained by distillation. The value of these beds as sources of gas or oil, depends mainly on the presence of porous material above it, at the base of the Pierre, to act as a retainer. As remarked above, small flows of gas from this formation have been found near Treherne, Man.

In the foot-hills a sandy deposit at about the horizon of the Niobrara has been found in outcrop samples to contain paraffin and some oil, and it is expected that oil may be found at this horizon in the Sheep River borings.

The presence of oil in the Belly River formation at the well on Sheep river is the first intimation that the formation might be a source of oil, but an examination of the outcrops near Macabee creek revealed the presence of small traces of oil in these rocks so that the theory that this oil came up from below through faults or cracks at a recent date is not necessary.

OIL-BEARING HORIZONS IN WYOMING.[1]

FREMONT COUNTY.

The Dallas Field (1).—The oil is found in an anticline in Palæozoic rocks. The lowest rocks exposed on the crest of the anticline are of Triassic age and the source of the oil is supposed to be in Upper Carboniferous rocks. The oil is a heavy, dark brown fuel of asphaltum base with a specific gravity of 0·912.

Shoshone Field (1), (8).—This is a continuation northward of the Dallas field; the whole anticline is sometimes referred to as the Lander oil field. The Cretaceous measures cover the Triassic and other rocks in the centre of the field, and oil from a supposed fault in the anticline gives rise to what is called the Washakie spring. The oil from the centre of the field is high grade illuminating oil of paraffin base, while that from the lower rocks of each extremity of the field is thick and has an asphaltum base. The crude oil from the lower part of the Dakota was very light and when tried in automobiles was found to be a fair substitute for gasoline.

The lower formation yielding heavy oil is Permo-Carboniferous. About half of this is a limestone, but in it there are two sandy shale members that are full of fossils and bituminous matter that comes to the surface in oil seeps. After exposure to the air for some time it slightly thickens.

Plunkett Field (2).—This lies west of the Lander anticline, on which the Shoshone and Dallas fields are located. The oil is supposed to come from the Lower Cretaceous in which the

[1] The reference numbers refer to the individual articles as numbered and enumerated in the accompanying bibliography, page 22.

representative of the Dakota lies. Heavy oil is also found in the Upper Carboniferous. It is dark brown and has an asphalt base. A small coal seam was found 70 feet above the oil horizon.

NATRONA COUNTY.

Salt Creek Oil Field (8), (1), (7).—This field is situated in the northeast corner of Natrona county, in the drainage basin of the Powder river. Wells are drilled in the Salt Creek anticline which consists of two distinct domes: the Salt Creek dome, on which most of the wells are situated, and the Teapot dome. Oil is found in the Shannon sandstone, which outcrops around the Salt Creek dome, and in the Wall Creek sandstone, which is beneath. Doubtful quantities of oil are supposed to be also in the Dakota and Morrison. These horizons are widely separated. The Dakota, a conglomerate sandstone, contains a heavy oil of 0·916 specific gravity; the Wall Creek sandstone, 80 feet thick and near the top of the Benton, is the principal oil sand of the district. It is 1,350 feet above the Dakota and carries a light oil of 0·822 specific gravity. The Shannon sandstone, 1,970 feet above the Wall creek, is in the Pierre, 1,025 feet above the Niobrara, and carries a heavy oil of 0·909 specific gravity.

The oils of the Benton and Pierre are paraffin oils, while the Dakota has an asphaltum base.

JOHNSTON AND NATRONA COUNTIES.

Powder River Oil Field (4), (1), (7).—The only oil found in any amount has been from open wells in the sandstones overlying the Morrison formation. Although called Dakota, these are possibly to be correlated with the Lakota of the Black hills and thus may belong to the Lower Cretaceous. These beds outcrop around the Powder River dome and are underlain unconformably by the Morrison which may be likened in structure and age to the Kootenay. Oil seeps out of these rocks at the sharp fold at the summit of the dome. As the oil is heavy and black with asphaltum base, it is thought that its origin may be from a shale in the Carboniferous.

Oil Mountain Field (1).—There is one spring on Oil mountain in an outcrop of Benton shales, but the origin is ascribed to the Dakota, and a fault supposed to be the channel by which it came up.

Dutton Field (1).—This is a small field in which oil sands of the Dakota furnish some oil. Seepages are reported in the Benton.

Rattlesnake Field (1).—Several seepages of oil supposed to come from the Dakota sandstone. The oil is heavy and has an asphaltum base.

UNITA COUNTY.

Spring Valley Field (5), (7).—The beds in this field are in synclines separated by fractures. The oil beds are dry, but water is found below and above and does not follow the oil when it is pumped out. The oil is, therefore, found in the synclines. The yield is small being probably 5 to 10 barrels per day. The geological section includes the following:—

Niobrara	Hilliard formation.
Benton	Frontier formation.
	Aspen formation; contains oil northeast of Spring Valley.
Bear River	Bear River formation yields oil near Spring Valley.
Dakota and Lower Cretaceous	Beckwith formation.
Jurassic	Twin Creek formation.
Triassic	Nugget formation with red basal member.
Carboniferous.	

In Carter, Evanston, Hilliard, Spring Valley, and Twin Creek fields (1) the oil is high grade and is refined mostly in the vicinity. It comes from the lower Benton or Dakota.

CARBON COUNTY.

Muddy Creek Field (3).—Oil is known in the lower part of the Wasatch formation (lower Tertiary) but seems not to have been struck in any wells. The sandstone at the top of the Fort Union contains about 8 per cent of oil with an asphaltum base.

CONVERSE COUNTY.

Douglas Field (1), (3).—Some showings of oil are found in the top of the Benton that are very dark and thick. The oil that is found in the lower Benton is much lighter in colour and is from 36 to 41 degrees Baume. It is a paraffin oil and has no sulphur. The saturated sandstones at the base of the Cretaceous have not been reached by drilling, and as oil seepages have been observed from the Embar formation (Upper Carboniferous), asphalt oils may also be found.

CROOK COUNTY.

Belle Fourche Field (1).—There are many oil springs in this district, and although several wells are drilled they have been poorly placed and the output is smaller than expected. The oil is a lubricating variety and comes from the Dakota.

WESTON COUNTY.

Newcastle Field (1).—Oil indications are found northwest and southeast of Newcastle. Several wells have been drilled and oil obtained. The oil is heavy and contains little or no gasoline or kerosene. The source of the oil is probably upper Dakota or lower Benton (Graneros shales).

BIGHORN AND PARK COUNTIES. (1)

A number of promising oil fields are known. Near Grey Bull, several wells are producing a fine illuminating oil and a large flow of gas.

OIL-BEARING HORIZONS IN COLORADO.

Florence Oil Field (9).—The section given for the measures in this field commences with the Trinidad sandstone which overlies the Pierre.

Pierre shale	4,000	feet, marine shales; several oil horizons.
Niobrara	450	feet, Apishapa shales, light coloured, calcareous.
	100	feet, Timpas limestone. Both divisions of the Niobrara contain solid bitumen in pores and small joints.
Benton	200	feet, Carlisle shale; black shale; small quantities of oil present.
	30	feet, Greenhorn limestone, dark grey shale.
	300	feet, Graneros shale; black with thin limestone.
Dakota	200	feet, sandstone with clay partings near Canyon City; solid black bitumen has been found in it.
Jurassic	400	feet, Morrison, sands, shales, and limestones. Several oil springs known which give a heavy black viscous oil of 15 degrees Baume.

In the Pierre there are several horizons from which oil has been obtained. The highest is from 750 to 1,000 feet below the surface. The oil lies in joints and fissures as there are no sand lenses to act as reservoirs.

A great number of wells have been drilled and a small per cent are producers. The field is in synclinal form, and lies between Front and Wet ranges on the west and a fold in the Cretaceous and older strata on the east.

Boulder Field (10), (11).—In this area the Pierre which is the oil-bearing formation has several lenses of sandy material that are reservoirs for the oil, so that the oil occurs as pockets at various

horizons. The productive wells are more or less within a narrow belt which runs parallel to the mountains. The formations are upturned on the west and probably form an anticline. The wells are on the easterly dipping member. It is thought that possibly the oil may have come up through crevices from the Niobrara and Benton (12), which elsewhere is more bituminous than the Pierre. The oil is of a light amber colour, and has a paraffin base; specific gravity, 42 to 44·6 degrees Baume, and the oil flashes below 60 degrees F. The specific gravity of the oil increases away from the top of the anticline (9). The paraffin base crystallizes in the wells and pipe lines and clogs both wells and pipes.

Rangely Oil District (13).—This is in the western border of the state and the oil basin, although in a valley, is on an anticline in the Cretaceous. The surrounding rocks are the Mancos shale which represents all the formations from about the top of the Pierre to the bottom of the Benton. Foxhill fossils are found in the upper part and Benton in the lower. The formation is about 5,000 feet thick, and oil is found in the central part. The Dakota is represented by sandy beds below, and these rest on supposed Jurassic sandstones and variegated shales. Above this great shale series are rocks somewhat like the Edmonton series of Alberta, that is, they are sandstones and light shales with coal seams in the lower part. These are called the Mesaverde and, practically, are at the top of the Cretaceous, being capped in places by Tertiary. The oil is found in certain sandy layers about 3,000 feet above the Dakota, and is of a clear, light red colour with strong green fluorescence. It has the odour of kerosene and is a light oil of about 44 degrees Baume, with a paraffin base.

OIL-BEARING HORIZONS IN UTAH (6), (4)

Although some veins in the Green River formation, which is of Tertiary age, are filled with bituminous material, the supply of oil comes mainly from the San Juan oil field, and is found in the Goodridge formation, of Upper Carboniferous age. The oil field is a syncline and it is possible that the oil is confined to a strip on each side of the basin, as it is suspected that the lower part may be flooded by water.

BITUMEN IN NEVADA AND ARKANSAS.

In Nevada (14) some hardened bitumen has been found in cracks and crevices of the Carboniferous south of Palisade.

The asphalt deposits of Pike county, Arkansas (15), are found in the Trinity sandstone group which is the lowest Cretaceous found in the Gulf province. Drilling for oil has met with little success.

OIL-BEARING HORIZONS IN OKLAHOMA.

This state produces a very large amount of oil and although many of the wells are in Palæozoic rocks from which practically all the oil comes, the lowest Cretaceous has here, as on the Athabaska river, acted as a container and several of the wells are in the Cretaceous beds.

Maxill Pool (9).—The Trinity sands at the base of the Cretaceous were deposited on the gently undulating surface of granite and the hard and soft rocks of Palæozoic age. It is approximately 400 feet thick, and the porous sands at the base, about 25 or 30 feet in thickness, serve as a receptacle for the oil which is probably derived from the Carboniferous beds beneath. The capping rock is the Goodland limestone. The oil is dark olive in colour; its specific gravity 0·7887 or 45·5 degrees Baume; this is 13 degrees higher than the average mid-continent oil. The crude petroleum gave 6 per cent of lighter oil and 7 per cent paraffin. The lighter oils were 22 per cent gasoline and 30 per cent kerosene.

Muscogee Oil Field (16).—The oil sands are interstratified with Lower Carboniferous limestones and the oil is of paraffin base. Other oils of the vicinity are generally of asphaltum base. The oil is dark green in colour, but cherry red when viewed by transmitted light, and is of higher grade than the oils from the Upper Carboniferous from which much of the Kansas oil is obtained.

OIL-BEARING HORIZONS IN TEXAS.

In Texas (15), (17) small quantities of oil are obtained from the lower part of the Coal Measures, but the gulf coast oil pools are in late Tertiary. These rocks are lying quite flat with a slight dip to the gulf. Small swells on the surface indicate corresponding domes in the rocks beneath, and in these oil and gas are found. Occasionally the salt and sulphur deposits of the gulf coast occur in similar domes, but where oil is found it forms intermittent gushers from the presence of gas with the oil.

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NOTES ON ORIGIN OF OIL AND GAS, by C. W. HAYES AND W. KENNEDY.

(From Bulletin 212, U. S. G. S.)

CLASSIFICATION OF THEORIES.

The origin of petroleum is one of the most obscure problems by which geologists are confronted. Numerous widely different theories have been advanced and advocated by geologists and chemists during the last fifty years, but as yet there is none which can be regarded as generally accepted and of universal applicability. In the present connexion any full discussion of these theories is manifestly out of place, and only a bare outline of the more important ones will be given It should be stated, however, that numerous facts have come to light in the development of the Coastal Plain field [Mexican gulf] which have a very direct bearing upon the theories of the origin of the oil.

The theories may be divided into three main groups: (1) those which attempt to explain the origin of the oil by inorganic agencies; (2) those which ascribe it to an organic origin; and (3) those which involve both inorganic and organic agencies.

THEORIES OF INORGANIC ORIGIN.

In 1866 Berthelot suggested that water containing carbonic acid or an earthy carbonate, coming in contact with metallic sodium or potassium at a high temperature might produce both liquid and gaseous hydrocarbons such as are found in various oil fields.

In 1877, Mendeljeff published his theory which remains the most plausible of all the inorganic theories thus far proposed. Stated briefly, it is that water percolating downward through fissures in the earth's crust comes in contact, under conditions of high temperature and great pressure, with metallic carbides; that a chemical reaction takes place, with the formation of

metallic oxides and saturated hydrocarbons, and that the latter ascend and impregnate the porous beds of sedimentary rocks in which they are now found.

Various modifications of the theories of Berthelot and Mendeljeff have been suggested by other chemists, but these contain the essentials of all the purely inorganic theories which merit consideration.

The fact is unquestioned that hydrocarbon similar to or identical with some of the constituents of natural petroleum may be produced in the laboratory by the action of inorganic substances, but no geologic or other evidence that these reactions actually take place in the earth's crust has been discovered. The conclusion must, therefore, be that while the inorganic theory is attractive it is not proved.

THEORIES OF ORGANIC ORIGIN.

These theories may be again divided into two groups: (*a*) that petroleum is indigenous to the rocks in which it is found; and (*b*) that it is the product of natural distillation.

The first of these was advocated by Sterry Hunt, who asserted that all petroleum was formed in limestone by the decomposition of the animal remains which it originally contained. It was also advocated by Lesley and Whitney. The theory was further amplified by Orton, who extended it to the petroleum found in the shale and sandstone in the Appalachian field as well as that found in limestone. According to Orton,[1] petroleum results from the primary decomposition of organic matter, and was formed when the rocks containing it were themselves formed.

A modification of this theory has recently been advanced, namely, that the oil, instead of being the product of decomposition of organic matter, is produced by living organisms of a low order, such as diatoms, and, therefore, exists as such, as an original constituent of the rock in which it is found. The presence of oil associated with diatoms in the mud at Sabine Pass [Texas coast] is regarded by Dr. Phillips as furnishing some degree of support to this theory.

[1] Ann. Rep. Geol. Surv., Ohio, 1890, p. 85.

The majority of geologists have held to the second theory, namely, that petroleum is derived from the organic matter disseminated through great masses of carbonaceous shales by the process of slow natural distillation at relatively low temperatures and that it has subsequently migrated through the strata to the reservoirs in which it is found. In proof it is pointed out that these carbonaceous shales yield by artificial distillation a large quantity of hydrocarbons, both gaseous and liquid, which are indistinguishable from those found in nature; but the possibility of natural distillation at a temperature sufficiently low to leave the enclosing rocks entirely unchanged has not been proved, nor have the residues of carbon which would result from such distillation been found in the rocks.

Again, there is much diversity of opinion among those who hold to the organic origin of petroleum as to whether its source is in animal or vegetable remains. Peckham believes that petroleum may be derived from both animal and vegetable matter, but that the source of the organic matter determines the character of the oil, that with a paraffin base (e.g., Pennsylvania) being derived from plant remains and that with an asphalt base (e.g., California) being derived from animal remains.

THEORIES OF COMBINED ORGANIC AND INORGANIC ORIGIN.

Among the theories which fall in the third group may be mentioned that proposed by O. C. D. Ross[1] in 1891. It is that petroleum is produced by the action of volcanic or solfataric gases containing sulphurous acid and hydrogen sulphide upon limestone, with the formation of gypsum and free sulphur. The reactions given undoubtedly take place in the laboratory, and they may also take place in certain localities in nature. On the other hand, Hopkins[2] proposed a theory, which has been elaborated and modified somewhat by other chemists, according to which the gypsum is the original material and the limestone is secondary.

The essential features of this theory are that gypsum, (calcium sulphate), in the presence of decomposing matter which

[1] Chemical news, vol. lxiv, 1891.
[2] Report on the geology of Louisiana, 1869.

gives off carbonic acid, is reduced, with the formation of limestone, calcium carbonate, free sulphur, and hydrocarbons.

This reaction has not been exactly reproduced in the laboratory, but neither can the conditions which must prevail at great depths in the earth be exactly reproduced.

It will be observed that the theories of this group are intermediate between those of the first two classes. The original materials are in part organic (limestone and vegetable or animal matter) and in part inorganic (volcanic gases and gypsum).

CONCLUSION.

This great diversity of views regarding the origin of petroleum is equalled by the diversity in character of the petroleum itself and in the geologic conditions under which it is found. In fact, it is probable that the final theory will include most of those outlined above, and will recognize the fact that this substance which is so widely distributed in nature may be the product of widely different processes acting upon a great diversity of materials. Thus the hydrocarbons which have been observed in certain volcanic rocks and in gases given off from volcanic vents may be entirely inorganic, resulting from the reaction between water and heated metallic carbides. The oil of the Appalachian field may be derived from the slow distillation of plant remains disseminated through the underlying shales, and that of the Trenton limestone of the Lima field from animal remains originally contained in the rocks in which it is now found.

Finally, the oil of the Gulf Coastal Plain is probably derived, in part at least, from the action of decomposing organic matter, both animal and vegetable, but chiefly the latter upon gypsum.

CLASSIFIED LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account.

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A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

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MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley Mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3. Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

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MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

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MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

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MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

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